

Review Article

The 50 most-cited publications in reverse total shoulder arthroplasty for proximal humerus fractures

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Keywords: reverse total shoulder arthroplasty, proximal humerus fracture, bibliometric analysis

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In order to provide individualized care to each patient, he begins by listening to their unique problems and goals. He aims to help patients understand their orthopedic conditions and work with them to choose the best treatment to help them return to their activities. He is passionate about helping people of all ages and backgrounds regain their quality of life and return to the activities they love.

Working at The Ohio State University Wexner Medical Center allows him to provide cutting-edge clinical care to patients. He takes pride in collaborating with a team of sports medicine experts and participating in clinical research that improves treatments for our patients. He also enjoys serving as a team physician for high school, collegiate and professional athletes, including the Columbus Clippers (AAA affiliate of Cleveland Indians).

When he's not at work, he enjoys spending time with my family, as well as running, skiing, baseball, and hiking.

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He developed a focus on patient care, research and education while training at the world-renowned Hospital for Special Surgery in New York City. However, as someone who was born and raised in Columbus, The Ohio State University Wexner Medical Center has always been a special place to him. The team-based approach and willingness to address any problem, no matter how complex, set Ohio State apart for providing the best care possible to patients and made it the ideal place to continue his career. He's served as a team physician and taken care of athletes at all levels of competition, including providing care as an assistant team physician with the New York Giants. He also enjoys taking care of the athletes at Ohio State.

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Introduction

Citation analysis is a useful tool to understand the contributions publications make within their fields. As the use of reverse total shoulder arthroplasty (RTSA) for proximal humerus fracture rapidly increases, it is vital to highlight influential literature that may inform readers of innovations and current trends within RTSA research. The purpose of this study was to identify and analyze the 50 most-cited publications related to RTSA for proximal humerus fracture.

Methods

The Clarivate Analytics Web of Science Database was searched using various Boolean searches. Author name, journal, study type, publication year, number of citations, level of evidence, and geographical origin were recorded for each publication.

Results

Included publications accumulated 4702 total citations with the most-cited article achieving 627 citations. Most studies were of level IV (28) and level III (17) evidence. Case series (29) and cohort studies (15) dominated this list. Authors from the United States (16) produced the most publications, followed by France (11) and Germany (8).

Discussion

Case series and cohort studies composed much of this analysis. As RTSA for fracture continues to evolve, studies of higher evidence may replace the publications reviewed in this analysis.

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His research interests include enhancing our understanding of shoulder instability and available treatment options as well as patient expectations and clinical outcomes for shoulder replacements and rotator cuff repairs. When not at work, he enjoys spending time with his family as well as playing tennis and hiking.

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INTRODUCTION

Originally developed in Europe for the treatment of rotator cuff arthropathy, reverse total shoulder arthroplasty (RTSA) has been shown to be effective in reducing pain and improving shoulder function in patients with deficient rotator cuff function. (Baulot et al.; Boileau et al.) Since the approval of the RTSA by the FDA in 2003, the incidence of total shoulder arthroplasty in the United States has increased significantly. (Best et al.; Kim et al.; Schairer et al.) This can be partly attributed to an aging population, advancements in surgical techniques and implant design, the rapid implementation of RTSA nationwide, and a robust expansion of the surgical indications for RTSA to include a variety of cuff-deficient shoulder pathologies including proximal humerus fracture and fracture sequelae. (Best et al.; Dillon et al.; Kim et al.; Schairer et al.)

Proximal humerus fractures are among the most common fractures in persons aged older than 65 years. (Acevedo et al.) Within the aging population within this age group, it is expected that the incidence in this type of fracture will significantly increase over the next few decades. (Acevedo et al.; Jost et al.) Due to their advanced age, fracture patients in this demographic have been noted to exhibit poor bone quality, predisposing them to comminuted, complex 3- or 4-part fractures requiring surgical intervention. (Acevedo et al.) Historically, surgical options for the management of these fractures include open reduction and internal fixation (ORIF), hemiarthroplasty, and RTSA. In a systematic review in which the results of 34 trials encompassing 2165 proximal humerus fracture patients who underwent RTSA, ORIF hemiarthroplasty, intramedullary nailing, and non-operative treatment, the authors found that RTSA was associated with the highest Constant score, highest reduction in complication incidence, and the lowest number of reoperations, thus demonstrating the potentially greater effectiveness of RTSA over other historically employed strategies for proximal humerus fracture management. (Chen et al.)

The impact of the approval of RTSA on the landscape of shoulder arthroplasty has been immense and given that the usage of this procedure is expected to continue, it is crucial to identify substantially influential literature in this area to provide historical context and highlight the contributions that researchers and their publications have made in the advancement of this surgical technique. (Dillon et al.; Palsis et al.) Citation analysis is an effective tool to quantify the impact of publications in any field. Many past studies in orthopedic literature have quantified citation frequency in effort to identify the most influential articles within various subspecialties and their procedures. (Baldwin et al.; Ding et al.; Elshohna et al.; Gross et al.; Malik et al.) To date, there is an absence of bibliographic analysis specifically dedicated to RTSA for fracture. One bibliometric review evaluated the 50 most-cited articles in reverse total shoulder arthroplasty research, however only 10 papers in this study included specifically RTSA for proximal humerus fracture. (Gross et al.) Another citation analysis presented the 50 most-cited articles in RTSA and yielded interest-

ing information regarding the level of evidence, publication year, and overall trends in the number of citations of the articles they examined, however this article featured only 11 of 50 studies that specifically evaluated RTSA for fracture. (Gross et al.)

The purpose of this study is to identify the 50 most frequently cited articles related to RTSA for proximal humerus fracture and determine their implications on this field. The journal of publication, trends in publication year, and authorship of the top-50 cited articles will also be examined. Identifying and quantifying these highly cited articles will serve as a useful resource for orthopedic surgeons and researchers to stay up to date in the rapidly changing field of RTSA. We hypothesize that year of publication will have a significant impact on the total number of citations achieved by an article.

METHODS

Institutional review board approval was not required due to the availability of this data to the public. The Clarivate Analytics Web of Science database was used to perform this analysis using methods similar to those utilized in previous orthopedic bibliometric analyses. (Barbera et al.; Gross et al.; Moore et al.; Namdari et al.) On 19 February 2023, several queries using different Boolean combinations were used to determine the broadest search that returned the greatest number of publications regarding RTSA for fracture within the Web of Science database. The following search was successful in obtaining the article and citation data used in this study: (TOPIC: (reverse OR reverse total OR inverted OR inverted total)) AND (TOPIC: (shoulder arthroplasty OR shoulder replacement)) AND (TOPIC: (fracture)). There were no restrictions placed on resulting publications regarding language, journal, publication date, or country of origin, and no additional filters were utilized to complete this search.

The publications were then sorted by the number of citations from most-cited to least-cited. Titles and abstracts were reviewed to identify articles that were unrelated to RTSA for the treatment of proximal humerus fracture and these studies were excluded. If a publication was a systematic review, a cadaveric study, only briefly mentioned RTSA for fracture, only included a small number or percentage of patients being treated for proximal humerus fracture, or if RTSA for fracture was not the primary focus of the article, then the article was excluded from the study. For example, a study discussing locking plate fixation for proximal humerus fracture that only briefly mentioned the use of RTSA was excluded from the study. (Jost et al.) Similar to inclusion criteria in previously conducted analyses, articles that presented information on indication for surgery, procedural descriptions, techniques, as well as outcomes of RTSA for fracture were included. (Barbera et al.; Gross et al.; Moore et al.; Namdari et al.) If there remained uncertainty with a specific publication after the initial screening process, the full article was reviewed by an additional author to determine whether it met the inclusion criteria used in this study.

The top 50 most-cited publications were reviewed by three authors to obtain the author's name, the total number of citations, publication year, country of origin, journal name, article type (case series, cohort study, expert opinion, case-control study, randomized controlled trial, non-randomized control trial), and the level of evidence for clinical studies determined using the *Journal of Bone and Joint Surgery* guidelines. (Wright et al.) Citation density (the total number of citations divided by years since publication) was calculated similarly to previous bibliographic analyses. (Gross et al.) Due to the relatively recent emergence of RTSA in the treatment of proximal humerus fracture, all bibliometric metrics were recorded per year. The level of evidence and article type were independently determined by three authors. If uncertainty remained regarding a classification, an additional author was called upon to make a final determination.

RESULTS

The final search yielded 1360 publications. Of the resulting articles, the top 238 in terms of total number of citations were reviewed to identify the top 50 articles that met our inclusion criteria. The resulting list of 50 publications can be considered the Top 50 publications pertaining to RTSA used for treatment of proximal humeral fractures ([Table 1](#)). Each of the top 50 articles were published between the years 2006 and 2020, with the most publications occurring in the years 2014 and 2016 (6). Only 8 of the listed articles were published prior to 2010, and 27 of the top 50 articles were published since 2014. However, these articles amassed 1706 total citations, approximately 40.55% of the cumulative number of citations across the top 50 publications. The year with the most total citations amassed across the top 50 articles was 2020 with 495, followed closely by 2019 and 2021 with 488 citations and 477 citations respectively. There was a significant rise observed in the number of citations collected per year between 2006 and 2019, followed by a period characterized by small fluctuations in the total number of citations per year between the years 2020 and 2022 ([Figure 1](#)).

At the time of data collection, the total number of citations amassed by the top 50 articles was calculated to be 4207 with an average of 247.47 total citations per year and an average of 84.14 citations per publication. The most highly cited article was cited a total of 627 times (Boileau et al.), followed by publications with 308 (Bufquin et al.) and 216 (Levy et al.) citations respectively. The least cited articles (Savin et al.; Lopiz et al.) each garnered a total of 27 citations since their publications in 2016, exactly 600 fewer citations than the article with the highest number of citations (Boileau et al.).

The top 50 articles were also analyzed based on citation density, or the number of citations per the number of years since publication ([Table 1](#)). The study by Boileau et al. was the most prolific in terms of both total citations (627) and citation density (36.9 citations per year), and is notably the earliest-published study included in this list. The study conducted by Sebastia-Forcada et al. ranked second in

terms of citation density with 19.9 citations per year, followed by the study by Bufquin et al. with 19.3 citations per year. In terms of citation density, the articles published before 2010 averaged a citation density of 13.4 citations per year and articles published since 2010 showed an average citation density of 7.31 citations per year.

The top 50 publications were evaluated based on study design. It was observed that case series were the most prevalent among the included articles, comprising 28 of the top 50 publications, followed by cohort studies, randomized controlled trials, and case control studies, which represented 17, 3, and 2 of the top 50 publications respectively ([Table 2](#)). It was noted that all randomized controlled trials in this analysis were published during or after the year 2014, and all 8 of the articles published before 2010 were among the case series group. The level of evidence of each of the top 50 publications was also recorded ([Figure 2](#)). Studies of Level IV evidence composed more than half of the top 50 publications, occupying 28 spots on this list. Following closely behind were Level III studies (17) and a small number of both Level I (3) and Level II studies (2). The Level I studies achieved the highest average citation density with an average of 15.9 citations per year per study, followed by the Level II studies (10.7 citations per year per study), Level IV studies (8.1 citations per year per study), and finally Level III studies (7.0 citations per year per study).

The top 50 articles were published in a total of 19 unique journals ([Table 3](#)), with the *Journal of Shoulder and Elbow Surgery* being the most prolific in terms of total publications included on this list, publishing 20 of the top 50 cited articles. *The Journal of Bone & Joint Surgery* (both the British and American volumes) published the second highest number of these articles with 7. Further, these 50 articles originated from 10 different countries ([Table 4](#)), with authors from the United States contributing the highest number of publications (16), followed by France (11), Germany (8), and Spain (5). Only 1 of the articles originating from the United States was published before the year 2010 (Levy et al.), with most of these articles (9) being published since 2014. Interestingly, 7 of the 8 articles published before 2010 originated from European authors from France and Germany while authors from these countries only produced 6 of the articles published since 2014.

DISCUSSION

The reverse total shoulder arthroplasty has been shown to be effective in reducing pain and improving shoulder function in a variety of cuff-deficient shoulder pathologies and proximal humerus fractures and fracture sequelae. (Baulot et al.; Boileau et al.; Kozak et al.) Current indications for RTSA in fracture care include displaced three- and four-part proximal humerus fractures, as well as fracture malunion, nonunion, post-traumatic arthritis, avascular necrosis, and chronic locked dislocations. (Kozak et al.) In a recent review conducted by Kozak et al., the authors reviewed recent literature assessing the effectiveness of RTSA in many different shoulder pathologies including proximal humerus fracture and fracture sequelae. (Kozak et al.) In their review,

Table 1. The top 50 most-cited articles in reverse total shoulder arthroplasty for fracture.

Rank	Article	Number of citations	Citation density
1	Neer Award 2005: The Grammont reverse shoulder prosthesis: Results in cuff tear arthritis, fracture sequelae, and revision arthroplasty (Boileau et al. 2006)	627	36.9
2	Reverse shoulder arthroplasty for the treatment of three- and four-part fractures of the proximal humerus in the elderly – A prospective review of 43 cases with a short-term follow-up (Bufquin et al. 2007)	308	19.3
3	The use of the reverse shoulder prosthesis for the treatment of failed hemiarthroplasty for proximal humeral fracture (Levy and Badman 2011)	216	13.5
4	Three or four parts complex proximal humerus fractures: Hemiarthroplasty versus reverse prosthesis: A comparative study of 40 cases (Gallinet et al. 2009)	213	15.2
5	Reverse shoulder arthroplasty versus hemiarthroplasty for acute proximal humeral fractures. A blinded, randomized, controlled, prospective study (Sebastiá-Forcada et al. 2014)	179	19.9
6	Comparison of Hemiarthroplasty and Reverse Shoulder Arthroplasty for the Treatment of Proximal Humeral Fractures in Elderly Patients (Cuff and Pupello 2013)	177	17.7
7	The reverse shoulder prosthesis in the treatment of fractures of the proximal humerus in the elderly (Cazeneuve and Cristofari 2010)	149	11.5
8	Treatment of Comminuted Fractures of the Proximal Humerus in Elderly Patients With the Delta III Reverse Shoulder Prosthesis (Klein et al. 2008)	148	9.9
9	Functional outcomes of reverse shoulder arthroplasty compared with hemiarthroplasty for acute proximal humeral fractures (Boyle et al. 2013)	132	13.2
10	Is Reverse Shoulder Arthroplasty Appropriate for the Treatment of Fractures in the Older Patient?: Early Observations (Lenarz et al. 2011)	114	9.5
11	Hemiarthroplasty Versus Reverse Total Shoulder Arthroplasty for Acute Proximal Humerus Fractures in Elderly Patients (Garrigues et al. 2012)	109	9.9
12	Reverse total shoulder arthroplasty for acute proximal humeral fracture: comparison to open reduction-internal fixation and hemiarthroplasty (Chalmers et al. 2014)	108	12.0
13	Improvement in shoulder rotation in complex shoulder fractures treated by reverse shoulder arthroplasty (Gallinet et al. 2013)	88	8.8
14	Grammont reversed prosthesis for acute complex fracture of the proximal humerus in an elderly population with 5 to 12 years follow-up (Cazeneuve and Cristofari 2014)	80	4.7
15	Comparison of functional outcomes of reverse shoulder arthroplasty versus hemiarthroplasty in the primary treatment of acute proximal humerus fracture (Young et al. 2010)	73	5.6
16	Reverse total shoulder arthroplasty for acute head-splitting, 3-and 4-part fractures of the proximal humerus in the elderly (Grubhofer et al. 2016)	66	9.4
17	Delta III reverse shoulder arthroplasty: Radiological outcome for acute complex fractures of the proximal humerus in elderly patients (Cazeneuve and Cristofari 2009)	64	4.6
18	Reverse Shoulder Arthroplasty for the Treatment of Nonunions of the Surgical Neck of the Proximal Part of the Humerus (Type-3 Fracture Sequelae) (Raiss et al. 2014)	59	6.6
19	Reverse Shoulder Prosthesis for Acute Four-Part Fracture: Tuberosity Fixation Using a Horseshoe Graft (Levy and Badman 2011)	59	4.9
20	Proximal humeral malunion treated with reverse shoulder arthroplasty (Willis et al. 2012)	55	5.0
21	Reversed shoulder arthroplasty in cuff tear arthritis, fracture sequelae, and revision arthroplasty Outcome in 59 patients followed for 2-7 years (Stechel et al. 2010)	55	4.2
22	Reverse total shoulder arthroplasty for failed open reduction and internal fixation of fractures of the proximal humerus (Grubhofer et al. 2017)	54	9.0
23	Reverse shoulder arthroplasty for the treatment of three-part and four-part proximal humeral fractures in the elderly (Ross et al. 2015)	53	6.6
24	Reverse shoulder arthroplasty versus nonoperative treatment for 3- or 4-part proximal humeral fractures in elderly patients: a prospective randomized controlled trial (Lopez et al. 2019)	52	13.0
25	Revision of failed fracture hemiarthroplasties to reverse total shoulder prosthesis through the transhumeral approach: incorporating a pectoralis-major-pedicled bone window. (Gohlke and Rolf 2007)	50	3.1

26	Reverse shoulder arthroplasty for four-part proximal humerus fracture in elderly patients: can a healed tuberosity improve the functional outcomes? (Chun et al. 2017)	46	7.7
27	Hemiarthroplasty versus reverse shoulder arthroplasty: comparative study of functional and radiological outcomes in the treatment of acute proximal humerus fracture. (Baudi et al. 2014)	45	5.0
28	The use of the Lima reverse shoulder arthroplasty for the treatment of fracture sequelae of the proximal humerus (Martinez et al. 2012)	45	4.1
29	Reverse Shoulder Arthroplasty Is Superior to Plate Fixation at 2 Years for Displaced Proximal Humeral Fractures in the Elderly: A Multicenter Randomized Controlled Trial (Fraser et al. 2020)	44	14.7
30	Reverse shoulder arthroplasty for acute fractures in the elderly: is it worth reattaching the tuberosities? (Boileau et al. 2019)	43	10.8
31	Mid-term outcome of reverse shoulder prostheses in complex proximal humeral fractures (Valenti et al. 2012)	43	3.9
32	Hemiarthroplasty versus reverse shoulder arthroplasty in 4-part displaced fractures of the proximal humerus: Multicenter retrospective study (Bonnevialle et al. 2016)	42	6.0
33	Reverse shoulder arthroplasty versus hemiarthroplasty for treatment of proximal humerus fractures (Schairer et al. 2015)	41	5.1
34	Short and midterm results of reverse shoulder arthroplasty according to the preoperative etiology (Wellmann et al. 2013)	41	4.1
35	Reverse shoulder arthroplasty as treatment for comminuted proximal humeral fractures in elderly patients. (Reitman and Kerzhner 2011)	41	3.4
36	Reverse shoulder arthroplasty for proximal humerus fracture using a dedicated stem: radiological outcomes at a minimum 2 years of follow-up-case series (Garofalo et al. 2015)	40	5.0
37	Reverse shoulder arthroplasty for proximal humeral fractures: outcomes comparing primary reverse arthroplasty for fracture versus reverse arthroplasty after failed osteosynthesis (Shannon et al. 2016)	39	5.6
38	Tuberosity healing after reverse shoulder arthroplasty for acute proximal humerus fractures: the black and tan" technique (Formaini et al. 2015)	39	4.9
39	Reverse Shoulder Arthroplasty for Malunions of the Proximal Part of the Humerus (Type-4 Fracture Sequelae) (Raiss et al. 2016)	36	5.1
40	Reverse shoulder arthroplasty as a salvage procedure after failed internal fixation of fractures of the proximal humerus: outcomes and complications (Hussey, Hussey, and Mighell 2015)	36	4.5
41	Treatment of fracture sequelae of the proximal humerus: comparison of hemiarthroplasty and reverse total shoulder arthroplasty (Alentorn-Geli et al. 2014)	34	3.8
42	Reverse shoulder arthroplasty compared with hemiarthroplasty in the treatment of acute proximal humeral fractures (van der Merwe et al. 2017)	33	5.5
43	Complications after surgical treatment of proximal humerus fractures in the elderly-an analysis of complication patterns and risk factors for reverse shoulder arthroplasty and angular-stable plating (Klug et al. 2019)	30	7.5
44	How the greater tuberosity affects clinical outcomes after reverse shoulder arthroplasty for proximal humeral fractures (Ohl et al. 2018)	30	6.0
45	Nonoperative management versus reverse shoulder arthroplasty for treatment of 3-and 4-part proximal humeral fractures in older adults (Roberson et al. 2017)	30	4.29
46	Acute surgical management of proximal humerus fractures: ORIF vs hemiarthroplasty vs. reverse shoulder arthroplasty (Yahuaca et al. 2020)	29	7.25
47	Hospital Readmissions After Surgical Treatment of Proximal Humerus Fractures: Is Arthroplasty Safer Than Open Reduction Internal Fixation? (Zhang, Schairer, and Feeley 2014)	29	2.9
48	Anatomic and reverse shoulder prostheses in fracture sequelae of the humeral head (Kılıç et al. 2010)	29	2.07
49	Survey study suggests that reverse total shoulder arthroplasty is becoming the treatment of choice for four-part fractures of the humeral head in the elderly (Savin et al. 2016)	27	3.38
50	Reverse shoulder arthroplasty for acute proximal humeral fractures in the geriatric patient: results, health-related quality of life and complication rates (Lopez et al. 2016)	27	3.38

Kozak et al. noted that RTSA for three- and four-part proximal humerus fractures in elderly patients has been sug-

gested to result in superior outcomes when compared to the historically employed hemiarthroplasty, resulting in im-

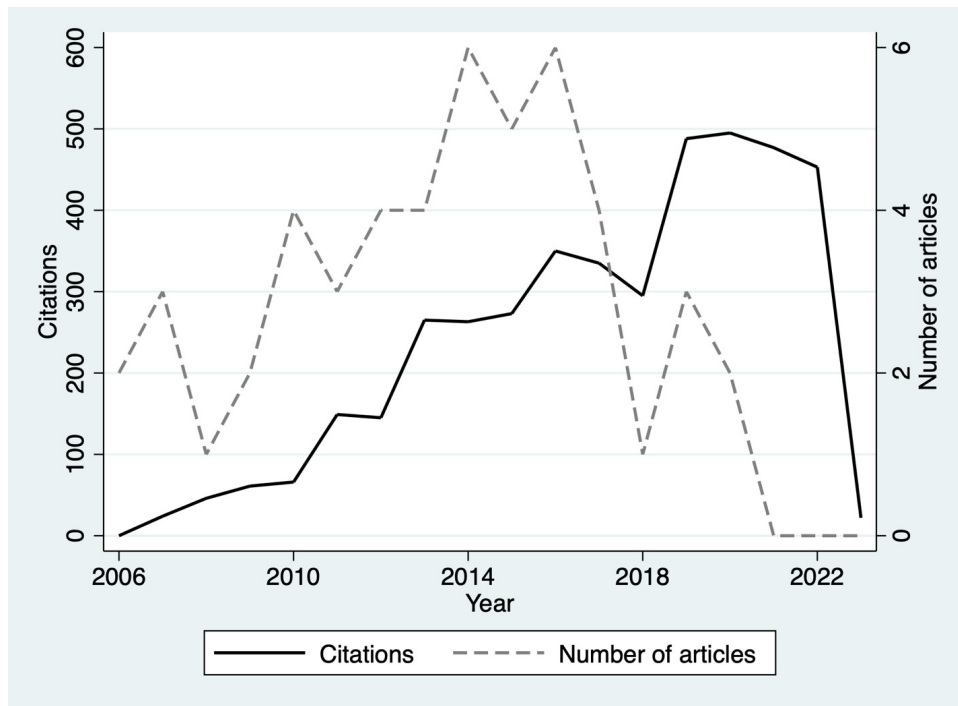


Figure 1. Number of total citations and publications per year.

Table 2. Number of publications by study type.

Study Type	Number of articles
Case Series	28
Cohort Study	17
Randomized controlled trial	3
Case Control	2

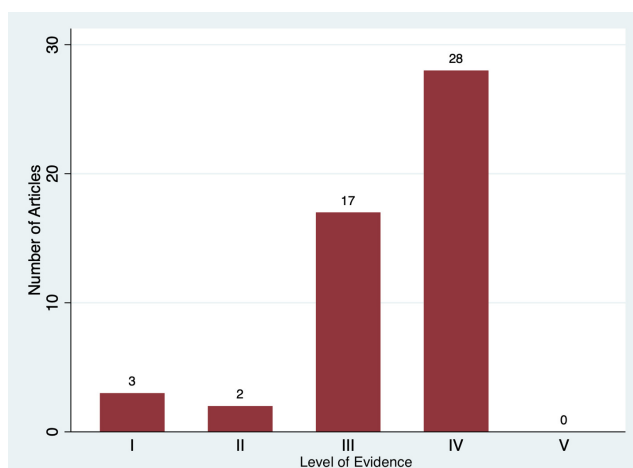


Figure 2. Number of publications by Level of Evidence.

provements in clinical outcomes, forward flexion, abduction, and tuberosity healing. (Kozak et al.) Furthermore, for fracture nonunion, malunion, post-traumatic arthritis, avascular necrosis, and chronic locked dislocations, previous literature indicates that improved function and adequate patient satisfaction is achievable despite elevated

rates of postoperative prosthetic dislocation, as high as 34% in some studies. (Boileau et al.; Kozak et al.; Martinez et al.; Raiss et al.) Thus, due to the increasing prevalence and demonstrated effectiveness of RTSA in the management of proximal humerus fracture and fracture sequelae in elderly patients, this study serves to highlight influential literature in this field and orient readers to the history, clinical impact, and areas of improvement within this widely used surgical procedure.

This study revealed patterns consistent with previously conducted bibliography analyses demonstrating that the year of publication significantly impacts the number of citations that a publication receives. (Chalmers et al.; Gross et al.) Of the identified articles, 5 of the top 8 most cited articles were published between 2006 and 2009 with the top 3 most cited articles obtaining 627 (Boileau et al.), 308 (Bufquin et al.), and 216 (Levy et al.), citations and being published in 2006, 2007, and 2007, respectively. There could be a variety of reasons for this finding. One possibility is that since these articles were published during the early years of RTSA being applied for fracture care, these articles likely served as the basis from which this body of literature could be expanded, resulting in many citations for these studies. Thus, these articles became immensely influential

Table 3. Number of publications based on journal of publication.

Journal	Number of articles
Journal of Shoulder and Elbow Surgery	20
The Journal of Bone & Joint Surgery	
<i>American Volume</i>	5
<i>British Volume</i>	2
Orthopaedics & Traumatology—Surgery & Research	3
Archives of Orthopaedic and Trauma Surgery	2
Clinical Orthopaedics and Related Research	2
International Orthopedics	2
Journal of Orthopaedic Trauma	2
Acta Orthopaedica	1
Acta Orthopædica Belgica	1
Acta Orthopaedica Et Traumatologica Turcica	1
Orthopedics	1
Bone & Joint Journal	1
Revue de Chirurgie Orthopedique et Reparatrice de l Appareil Moteur	1
ANZ Journal of Surgery	1
Operative Orthopädie und Traumatologie	1
Musculoskeletal surgery	1
Journal of Orthopaedic Science	1
American Journal of Orthopedics	1
Journal of Orthopaedic Surgery and Research	1

Table 4. Number of publications based on country of origin.

Country	Number of Articles
United States	16
France	11
Germany	8
Spain	5
New Zealand	3
Italy	2
Switzerland	2
Australia	1
Korea	1
Norway	1

in the first few years after the approval of RTSA within the United States, indicating the profound impact that these early articles had on the advancement of RTSA and potentially their role in guiding the knowledge and training of orthopedic surgeons.

It was observed that this list was largely dominated by case studies of Level IV evidence, including the top 4 most-cited articles. While the evidence level of these articles may be low, this should not detract from the influence these publications had on the field of orthopedic shoulder surgery. The use of RTSA in the care of fracture patients

is still in its infancy, and thus, the early work in this field is expected to be focused on small numbers of cases with lower levels of evidence. However, it is from the observations and evidence demonstrating the success of RTSA in this specific patient population that the foundation of support for the use of RTSA for humeral fractures is built. Thus, these publications became very influential in the field and garnered many citations throughout the years despite their lower levels of evidence. Among the newer publications that emerged in 2014 and beyond, randomized control trials with significantly high citation densities began to emerge,

introducing higher levels of evidence. As RTSA continues to evolve, more studies will draw upon the evidence presented by the older publications presented here to produce novel, higher level of evidence research that will likely expand the scope of RTSA through innovative developments that are likely to be referred to by clinicians and researchers around the world. Thus, future studies with higher levels of evidence will likely gain many citations and there is a strong possibility that the top 50 most-frequently cited articles on this list will see significant change as the use of this procedure continues to grow.

The number of citations an article achieves can further be influenced by the journal of publication and the country from which the article originates. Articles published by authors in the United States contributed the largest number of papers, followed by France, Germany, and Spain. With respect to date of publication, many of the older articles presented here originate from European authors, particularly from France and Germany, while many of the more recent articles were published by authors from the United States. Interestingly, this geographical and chronological distribution indicates that the maturation of research investigating RTSA for fracture was more prominent in European countries early on, yet US-based authors published the largest number of studies included on this list with many of them emerging after 2014. While the definitive cause for the prominence of recent US authorship among these publications remains unclear, it has become evident that the use of RTSA in fracture care is prevalent worldwide due to the contributions seen from publications originating from countries such as New Zealand, Spain, Korea, Italy, and Australia. The diversity in authors representing these studies demonstrates the potential for international collaboration to bolster innovation and potentially alter the standards of care for proximal humerus fracture patients moving forward.

There have been significant changes in the use of RTSA as a primary procedure for the treatment of proximal humeral fractures as demonstrated by these publications. Nearly half of the studies published before 2010 had a particular focus on the use of RTSA as salvage procedures for revising failed hemiarthroplasties or open reduction internal fixation of proximal humerus fractures. (Boileau.; Gohlke et al.; Levy et al.) Furthermore, many of these early articles focused on specific prosthesis designs and approaches to performing RTSA in these complicated patients. (Boileau et al.; Klein et al.; Cazeneuve et al.; Levy et al.) It is likely that these early studies investigating novel prosthesis designs and procedures to mitigate the complications of previously failed fracture repairs subsequently influenced the adoption of RTSA as a primary procedure for use in the setting proximal humerus fractures and contributed to their high number of citations early in the evolution of the RTSA procedure. Thus, the more recently published articles have built upon their predecessors by further describing the results of RTSA as a primary procedure for fracture care, resulting in more studies of Level I and Level II evidence that we are witnessing rising to prominence among the other publications on this list. As the RTSA pro-

cedure continues to grow, more articles evaluating its use as a primary intervention will likely join the top 50 most frequently cited articles about RTSA, thereby inciting advancements to clinical standards of practice.

This study does not come without its limitations, as citation analyses in general are associated with limitations. Most importantly, even though the inclusion and exclusion criteria were explicitly defined for all reviewers and were established based on previous orthopedic bibliometric analyses, there remained some variability in the selection of articles between authors. To combat this, multiple authors served as reviewers for each article. If discrepancies between reviewers arose, an additional author was consulted to aid in the final decision to minimize inconsistencies within the selection process. Furthermore, the use of 50 articles in this analysis was arbitrary, as there were several articles within a small number of total citations from the least-cited articles included in this list. It is very possible that there may have been publications that were omitted that may be currently rising to prominence within the field, and thus the ranks on this list may soon become outdated. Lastly, previous bibliographic analyses have described limitations in which the number of citations of certain articles may become elevated due to authors citing them on the basis of higher citation count rather than content and quality of evidence. (Amhad et al.; Gross et al.; Lefavre et al.; Namdari et al.) Thus, the number of citations for articles listed here may not adequately reflect their relative contributions to the field of orthopedics.

CONCLUSION

Quantifying the top 50 most-cited articles in RTSA for proximal humerus fracture can provide insight into the origins and evolution of the RTSA for fracture care as its clinical utility continues to be explored. Many of the current most-cited publications within this body of literature are case series and cohort studies that present low levels of evidence. A majority of the older, most highly cited included in this analysis were published between 2006 and 2009 by European authors, likely due to the recent adoption of RTSA for use in the treatment of humeral fracture in the United States following FDA approval in 2003. As the use of RTSA continues to expand over time, more randomized controlled studies are expected to rise to prominence as the clinical utility of RTSA for proximal humerus fracture care is further investigated and the body of literature in this field matures. This may result in these studies of higher levels-of evidence eventually gaining enough citations to surpass the articles included in this analysis.

CONFLICTING INTERESTS

The Author(s) declare(s) that there is no conflict of interest.

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RCR

CONTRIBUTORSHIP

JSB, LWB, and GD performed searches and reviewed publications. AVP reviewed publications in which there was uncertainty among the three primary reviewers. JSB, LWB, and AK wrote the first draft of the manuscript. All authors reviewed and edited the manuscript, as well as approved the final version of the manuscript.

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