



Top fifty cited articles on humeral fractures

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Background: Humeral fractures (HF) are common orthopedic pathologies. Reviewing the content and quality of influential literature over time is important to advance scientific research regarding a specific topic. This study aims to explore and appraise the fifty most cited HF studies that had been published in orthopedic literature.

Methods: The Web of Science database was used to conduct a systematic search for articles pertaining to HF. Articles were sorted out in descending order of citations and were included based on their relevance to HF. Data and metrics of the included studies were recorded. The methodological quality of the studies was assessed using the Modified Coleman Methodology Score (MCMS) and the Methodological Index for Non-randomized Studies criteria. Statistical analysis was conducted to explore any significant relationships between the date of publication and other relevant variables.

Results: Included articles (N = 50) were published between 1959 and 2015, with a total of 14,864 accumulated citations. Europe and North America contributed to all but one of the included studies. The *Journal of Bone and Joint Surgery* contributed to the highest number of included articles with 27 articles (54%). The proximal humerus was the most commonly explored HF location in our study (72%). The average MCMS and Methodological Index for Non-randomized Studies scores were reported to be 64.6 and 10.4, respectively, and the majority of articles (52%) were considered level four case series. Year of publication was found to have a positive correlation with increasing level of evidence ($r = -0.301$, $P = .044$), citation density ($r = 0.734$, $P < .001$), and MCMS score ($r = 0.41$, $P = .01$).

Conclusion: The level of evidence, MCMS scores, and citation density of influential HF literature has been increasing with time, reflecting the increasing effort and work being put in that field. While the findings seem encouraging, additional high-quality research is needed to help achieve better treatment strategies and outcomes.

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Humeral fractures (HF) are common orthopedic pathologies that result due to traumatic injuries.¹⁹ They present around 1%–5% of all reported fractures and are most common among young men—due to high energy trauma, and old women—due to low energy trauma.^{14,58,65,72} These injuries often require minute attention, as associated injuries can be debilitating and deleterious.¹⁹ Diagnosis and management of HF have evolved considerably over the years, with both surgical and conservative treatments offering viable options according to the presenting patient.¹⁹ While conservative options offer acceptable union rates and functional outcomes in many cases, surgical options can still remain necessary, especially among older patients.¹⁹ As such, treatment of HF

has been developing and evolving, evident by the establishment of different guidelines and the emergence of different surgical techniques.⁸

As with different medical ailments in general and orthopedic pathologies in specific, it is of pivotal importance to review the content and progression of existing literature in order to continue advancing treatment strategies and modalities. The evaluation of influential articles relating to different topics in orthopedics has been reported in numerous publications in the literature.^{11,26,41,69} Assessment of publication influence can often be measured by calculating the mean number of citations attributed to that publication.²¹ In addition, study characteristics and assessment of quality of evidence is often necessary to elucidate the influence and impact of these publications in the literature.⁹ As such, a fundamental set of highly influential literature can be collected when retrieving the highest cited publications on a topic, taking into account study characteristics and quality of evidence. Even though

Institutional review board approval was not required for this systematic review.

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several recent studies emerged exploring highly cited articles in different orthopedic pathologies, no such study has been published exploring HF.^{11,26,41,69}

Accordingly, the purpose of this study is to identify the 50 most cited studies addressing HF in orthopedic literature using a systematic analysis of current bibliography, appraise them according to validated quality scores, and determine whether any significant correlation existed between year of publication one hand, and level of evidence, methodological quality, and citation density on the other.

Methods

Retrieving publications

In accordance with similar studies in the literature targeting orthopedic topics, the Web of Science (all databases) was used to perform our online search.^{2,27} This database allows the search of independent terms and reports the number of citations for each article. Our search strategy depended on these terms and Boolean operators: for humerus, we used “humerus” OR “humeral” in order to maximize search results possible. For fracture, we used the terms “fracture” OR “broken”. We combined the terms for both the humerus and fracture using the Boolean operator AND. On September 4, 2022, we conducted the search, and all extracted articles were subject to primary screening. The top 150 cited articles were extracted and assessed for eligibility and relevance to the topic at hand. Studies were only included if they pertained to a major focus on HF. Studies targeting additional types of injuries were only included if the data analysis of humeral fracture patients was conducted separately. The resultant top 50 cited articles were included in our final database.

Data collection

Our dataset included the average number of citations attributed to each article, the digital object identifier, year of publication, title, list of authors, name of journal, country of origin, type of study, category of study, location of humerus (proximal humerus, humeral shaft fracture, or distal humerus fracture), and level of evidence. The level of evidence was recorded as reported in published articles. When the level of evidence was not apparent in the published articles, it was determined according to the guidelines of the *Journal of Bone and Joint Surgery*.³⁷ Level of evidence was not scored for biomechanical/cadaveric studies, technique papers, or current concepts/reviews. The Modified Coleman Methodology Score (MCMS) and the Methodological Index for Non-randomized Studies (MINORS) were used to assess and analyze methodological quality.^{12,28,63} MCMS was only used to score studies evaluating treatment and interventions, and MINORS was not used to assess randomized trials.

Data analysis

Descriptive statistics were used to collect and present the data. We used the Spearman correlation coefficient to evaluate the relationship between year of publication on one side, and level of evidence, citation density, and methodological quality on the other. We also used this coefficient to evaluate the relationship between the level of evidence and methodological quality. The strength of the correlation was considered to be weak if $r < 0.4$, moderate if $0.4 < r < 0.7$, and strong if $r > 0.7$. Finally, one-way analysis of variance was used to explore any differences in citation density between articles of different levels of evidence.

Results

The top 50 most cited articles relating to HF were published between 1959 and 2015, with the majority of publications ($n = 35/50$; 70%) published after 2000 (Table 1).^{1,3-7,10,13,15-18,20,22-24,29-32,34-36,38,39,42-51,54-57,59-62,64,66-68,70,73,74} The decade 2000-2010 witnessed the highest number of included articles ($n = 30$; 60%), with the year 2009 being the most prolific in our study, contributing to nine articles (18%) (Fig. 1). The total number of citations in our study was calculated to be 14,864, with a mean \pm standard deviation (SD) number of citations of 297.3 ± 176.9 (range, 197-1352) (Table 1). The top two most commonly cited articles on our list were by Dr. Charles Neer, cited 1352, and 652 times at the time the search was performed.^{42,43} With regard to citation density, the number of citations divided by the number of years since publication, the mean \pm SD citation density was 14.9 ± 6.74 citations/year (range, 5.39-35.6 citations/year). The top three articles were authored by Rangan et al (35.6 citations/year), Sudkamp et al (29.2 citations/year), and Gardner (27.5 citations/year).^{20,50,68}

The United States was the country that contributed to the largest number of articles in our study, with 19 studies (38%), followed by the United Kingdom with 6 articles (12%) and Switzerland with 5 articles (10%) ($n = 27/50$; 54%) (Fig. 2). Only one article (2%) was published from a country outside North America and Europe (Fig. 2). The affiliated journals of the *Journal of Bone and Joint Surgery* (American and British volumes) published more than half of the articles in our study, with 27 articles (54%), and the *Journal of Orthopaedic Trauma* and the *Journal of Shoulder and Elbow Surgery* followed with 5 articles (10%) each (Fig. 3). The majority of included articles in our study involved the proximal humerus, with 36 total studies (72%). Ten articles explored distal fractures of the humerus (20%), and three articles involved humeral mid-shaft fractures (8%) (Fig. 4). The top cited articles for each anatomic site of the humerus can be seen in (Fig. 5).

Out of the 50 included studies in our manuscript, 26 (52%) were considered to have a level of evidence of 4 ($n = 25$, 50%), eight (16%) were considered to have a level of 2, seven (14%) were considered to have a level of 1 (14%), and four (8%) were considered to have a level of evidence of 3 (Fig. 6). Five articles (10%) did not qualify for assessment of quality of evidence (Fig. 6). Twenty-four articles (48%) were classified as case series, making it the most common study design in our study (Table 1). A total of 33 studies were assessed for methodological quality using both the MCMS and MINORS criteria, while 5 were evaluated only using the MCMS criteria (Table 1). The 12 studies (24%) not evaluated for methodological quality included five descriptive epidemiology papers (10%), four case series/cohort studies (8%), two review articles (4%), and one biomechanics/cadaveric analysis (2%) (Table 1). The mean \pm SD MCMS score was 64.6 ± 17.8 (range, 27-95), and the mean \pm SD MINORS score was 10.4 ± 2.4 (range, 3-14) (Table 1).

The Spearman correlation coefficient was used to evaluate the relationship of level of evidence and year of publication, citation density and year of publication, and citation density and level of evidence. Of the studies that were not literature review articles ($n = 45$, 90%), there was a significant positive correlation between year of publication and increasing level of evidence ($r = -0.301$, $P = .044$), increasing citation density ($r = 0.734$, $P < .001$), and increasing MCMS score ($r = 0.41$, $P = .01$). There was not a significant correlation between citation density and level of evidence ($r = -0.121$, $P = .429$).

Discussion

The top fifty cited articles on HF were published between 1959 and 2015 and collectively accumulated over 14,864 citations. The

Table 1
 Characteristics and quality scores of the top fifty cited articles on humeral fractures.

Rank	Lead author (year)	Country	Study design	Type of fracture	Number of citations	Citation density (/year)	Level of evidence	Average MCMS	Average MINORS
1	Neer (1970) ⁴²	USA	Case Series	Proximal humerus fracture	1352	26	4	N/A	N/A
2	Neer (1970) ⁴³	USA	Case Series	Proximal humerus fracture	652	12.5	4	63.5	11
3	Court-Brown et al (2001) ¹³	UK	Epidemiology	Proximal humerus fracture	456	21.7	2	N/A	N/A
4	Flynn et al (1974) ¹⁶	USA	Technique	Distal humerus fracture	449	9.4	N/A	69	10
5	Gardner et al (2007) ²⁰	USA	Retrospective Cohort	Proximal humerus fracture	413	27.5	3	65	14
6	Gartland et al (1959) ²²	USA	Current Concepts/ Review	Distal humerus fracture	410	6.5	N/A	N/A	N/A
7	Boileau et al (2002) ⁵	France	Case Series	Proximal humerus fracture	407	20.4	4	90	13
8	Hertel et al (2004) ²⁴	Switzerland	Case Series	Proximal humerus fracture	403	22.4	4	57	10
9	Sudkamp et al (2009) ⁶⁸	Germany	Prospective Case Series	Proximal humerus fracture	380	29.2	4	87	12
10	Kelsey et al (1992) ³⁰	USA	Cohort Study	Proximal humerus fracture	361	12.0	2	63	13
11	Palvanen et al (2006) ⁴⁸	Finland	Epidemiology	Proximal humerus fracture	359	22.4	4	N/A	N/A
12	Owsley et al (2008) ⁴⁷	USA	Case Series	Proximal humerus fracture	331	23.6	4	80	12
13	Bufquin et al (2007) ⁷	France	Case Series	Proximal humerus fracture	301	20.1	4	82	12
14	Brunner et al (2009) ⁶	Switzerland	Prospective Case Series	Proximal humerus fracture	288	22.2	4	82	12
15	Sidor et al (1993) ⁶⁰	USA	Case Series	Proximal fumerus fracture	288	9.9	4	N/A	N/A
16	Omid et al (2008) ⁴⁶	USA	Current Concepts/ Review	Distal humerus fracture	277	19.8	N/A	N/A	N/A
17	Pirone et al (1988) ⁴⁹	CANADA	Retrospective Cohort	Distal humerus fracture	274	8.1	3	41	7
18	Siebenrock et al (1993) ⁶¹	Switzerland	Case Series	Proximal humerus fracture	263	9.1	4	N/A	N/A
19	Sproul et al (2011) ⁶⁶	USA	Systematic Review	Proximal humerus fracture	262	23.8	1	68	10
20	Robinson et al (2003) ⁵⁵	UK	Cohort Study	Proximal humerus fracture	259	13.6	2	83	11
21	Sarmiento et al (1977) ⁵⁶	USA	Case Series	Midshaft humerus fracture	253	5.6	4	49	6
22	Rangan (2015) ⁵⁰	UK	Clinical Trial	Proximal humerus fracture	249	35.6	1	95	N/A
23	Thanasas et al (2009) ⁷⁰	Greece	Systematic Review	Proximal humerus fracture	246	18.9	1	62	10
24	Fankhauser et al (2005) ¹⁵	Austria	Prospective Cohort	Proximal humerus fracture	245	14.4	2	86	12
25	Agudelo et al (2007) ¹	USA	Case Series	Proximal humerus fracture	244	16.3	4	66	11
26	Resch et al (1997) ⁵¹	Austria	Technique	Proximal humerus fracture	244	9.8	N/A	75	11
27	Jupiter et al (1985) ²⁹	Switzerland	Case Series	Distal humerus fracture	238	6.4	4	34	10
28	Mckee et al (2009) ³⁹	Canada	Clinical Trial	Distal humerus fracture	237	18.2	1	80	N/A
29	Cobb and Morrey (1997) ¹⁰	USA	Case Series	Distal humerus fracture	237	9.5	4	47	12
30	Zyto et al (1997) ⁷⁴	Sweden	Clinical Trial	Proximal humerus fracture	237	9.5	1	89	N/A
31	Sarmiento et al (2000) ⁵⁷	USA	Case Series	Midshaft humerus fracture	235	10.7	4	38	3
32	Skaggs et al (2001) ⁶²	USA	Case Series	Distal humerus fracture	233	11.1	4	27	10
33	Robinson et al (2003) ⁵⁴	UK	Epidemiology	Distal humerus fracture	226	11.9	2	N/A	N/A
34	Krappinger et al (2011) ³²	Austria	Case Series	Proximal humerus fracture	223	20.3	4	70	10
35	Shao et al (2005) ⁵⁹	UK	Systematic Review	Midshaft humerus fracture	222	13.1	1	48	6
36	Lind et al (1989) ³⁶	Denmark	Epidemiology	Proximal humerus fracture	220	6.7	4	N/A	N/A

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Table I (continued)

Rank	Lead author (year)	Country	Study design	Type of fracture	Number of citations	Citation density (/year)	Level of evidence	Average MCMS	Average MINORS
37	Bell et al (2011) ³	USA	Cohort Study	Proximal humerus fracture	218	19.8	2	N/A	N/A
38	Wijgman et al (2002) ⁷³	Netherlands	Case Series	Proximal humerus fracture	218	10.9	4	64	11
39	Bjorkenheim et al (2004) ⁴	Finland	Case Series	Proximal humerus fracture	217	12.1	4	59	8
40	Levy et al (2007) ³⁴	USA	Case Series	Proximal humerus fracture	216	14.4	4	75	9
41	Solberg et al (2009) ⁶⁴	USA	Cohort Study	Proximal humerus fracture	207	15.9	3	57	10
42	Kralinger et al (2004) ³¹	Austria	Case Series	Proximal humerus fracture	207	11.5	4	60	11
43	Stableforth (1984) ⁶⁷	UK	Case Series	Proximal humerus fracture	205	5.4	4	54	8
44	Gallinet et al (2009) ¹⁸	France	Case Series	Proximal humerus fracture	204	15.7	4	36	11
45	Olerud et al (2011) ⁴⁵	Sweden	Clinical Trial	Proximal humerus fracture	202	18.4	1	87	N/A
46	Lill et al (2003) ³⁵	Germany	Biomechanical/Cadaveric	Proximal humerus fracture	202	10.6	N/A	N/A	N/A
47	Gerber et al (2004) ²³	Switzerland	Case Series	Proximal humerus fracture	200	11.1	4	72	14
48	Nguyen et al (2001) ⁴⁴	Australia	Epidemiology	Proximal humerus fracture	200	9.5	2	N/A	N/A
49	Frankle et al (2003) ¹⁷	USA	Cohort Study	Distal humerus fracture	197	10.4	3	39	13
50	McCormack et al (2000) ³⁸	Canada	Cohort Study	Midshaft humerus fracture	197	9.0	2	54	N/A

MCMS, modified coleman methodology score; MINORS, methodological index for non-randomized studies.

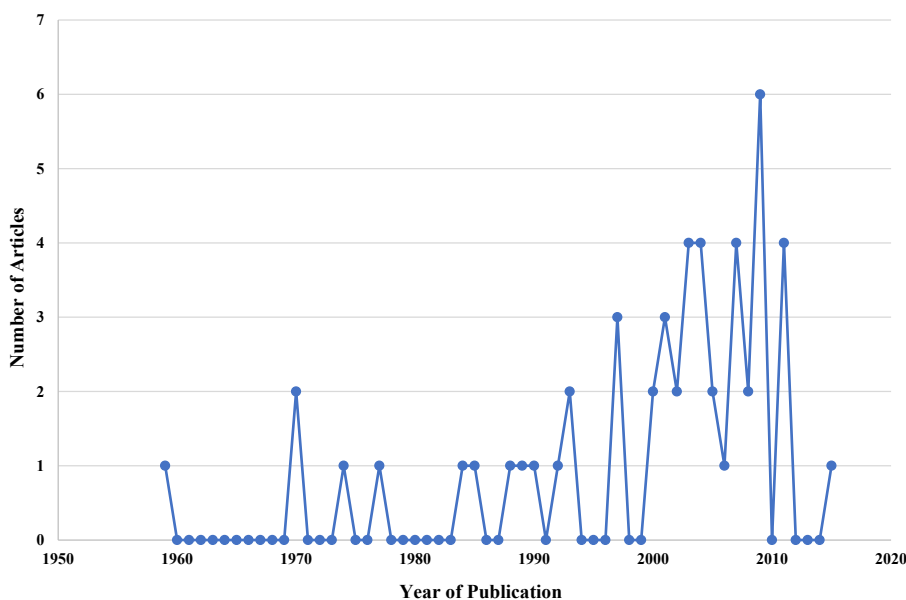


Figure 1 Timeline of publication of the fifty most cited articles on humeral fractures.

vast majority of the included articles were attributed to countries from Europe and North America. The *Journal of Bone and Joint Surgery* was the journal with the highest number of top cited articles, and the proximal humerus was the anatomic location most commonly explored in the included studies. The majority of articles had a level of evidence equivalent to four, and the mean MCMS and MINORS scores were 64.6 and 10.4, respectively. A positive correlation was found between the year of publication and level of evidence, citation density, and MCMS score.

All but one article in our study were attributed to countries from Europe and North America.⁴⁴ The United States, in specific, had the highest number of articles, and this falls in accordance with other similar orthopedic studies in the literature.^{2,25,33} Countries of North America and Europe often have high expenditures in health care fields, and as such, it is expected that these countries invest more in medical research and scientific investigation.⁷¹ It is also then founded that American surgeon Dr. Charles Neer, who pioneered modern shoulder and elbow surgery, be attributed with the two

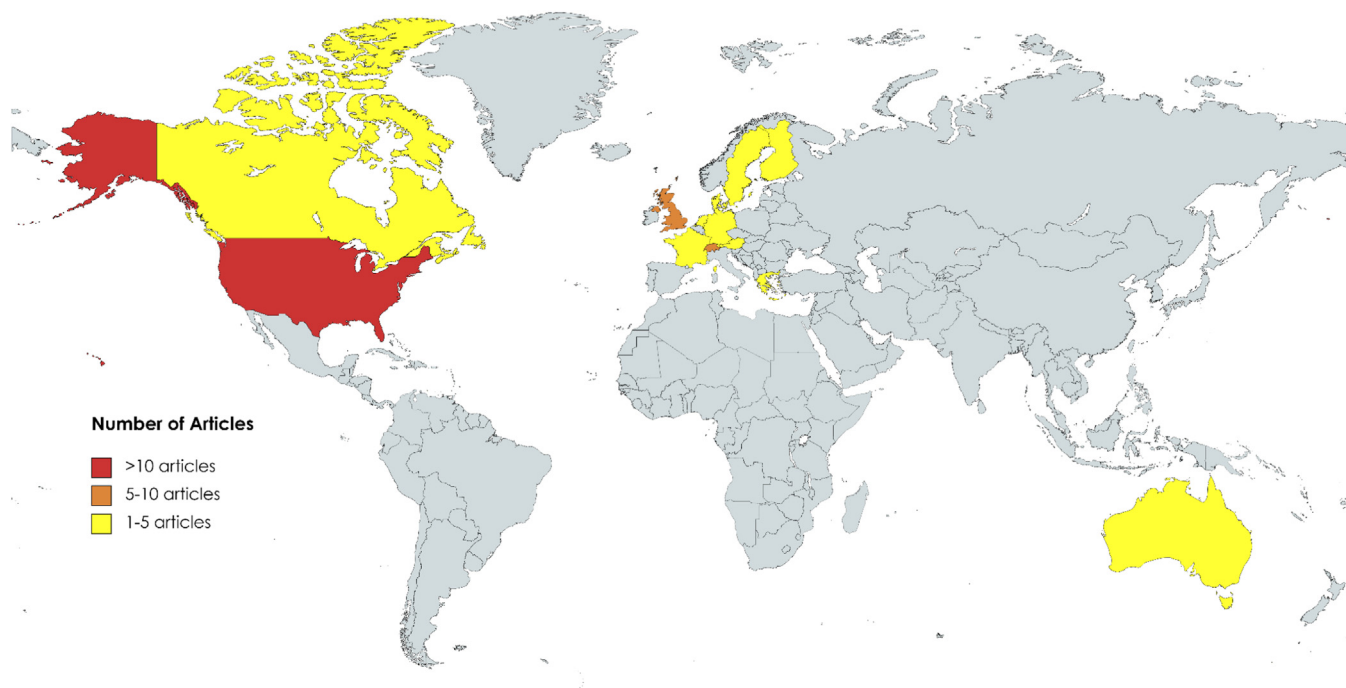


Figure 2 World map showing countries of origin contributing to most cited articles on humeral fractures.

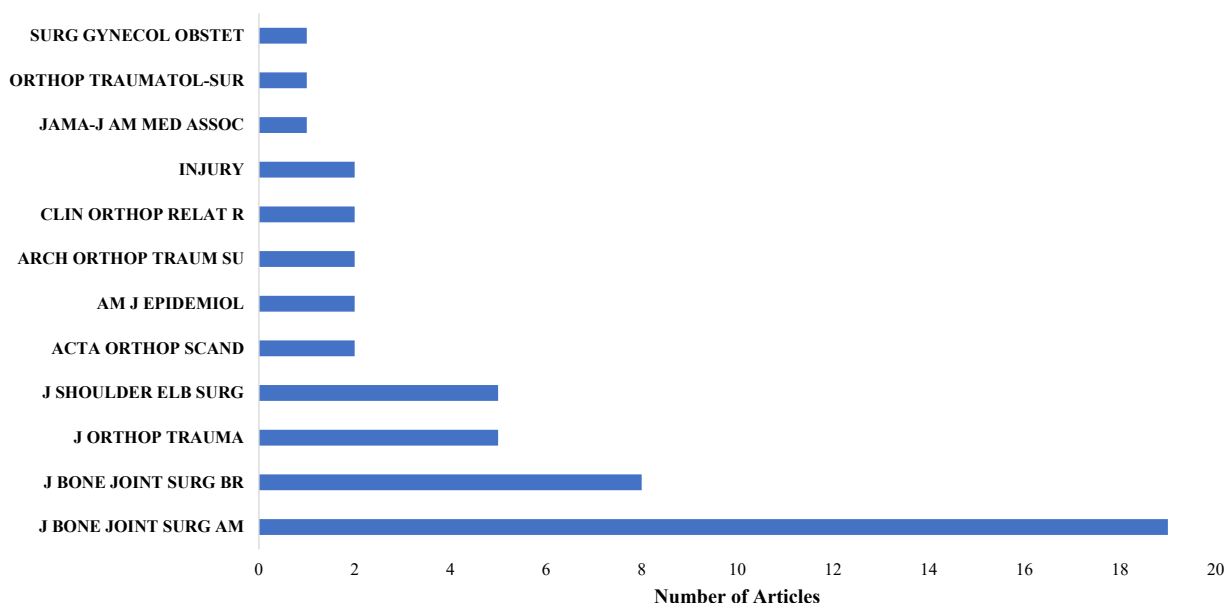


Figure 3 Journals contributing to the most cited articles on humeral fractures.

most cited articles on humerus fractures in our study, tackling the classification, evaluation, and treatment of proximal humerus fractures.^{42,43} It has also been implicated in previous literature that articles published in English may have an advantage with regard to citation potential.⁴⁰ This is corroborated by our study, where all the included articles were published in English, and English-speaking countries contributed to a larger number of included articles. This also explains why the *Journal of Bone and Joint Surgery* (both British and American volumes) contributed to the publication of the largest number of articles in this study.

The majority of the articles in our study revolved around the introduction and comparison of different treatment methods for

humerus fractures. Moreover, the proximal humerus, in particular, was the most commonly involved anatomic location in our study. Fractures involving the proximal humerus are more common and are often more challenging to treat, especially in complex presentations.^{19,48,52} These fractures carry a high risk of complications like humeral head ischemia and are more likely to cause nonunion than other fracture sites in the humerus.^{19,53} As such, research targeting proximal humerus fractures has been more frequent and more prominent with regard to readership and citations. As a matter of fact, the study with the highest citation density in our study was published in 2015 and discussed surgical vs. nonsurgical treatment of displaced proximal HF in adults.⁵⁰ Studies involving

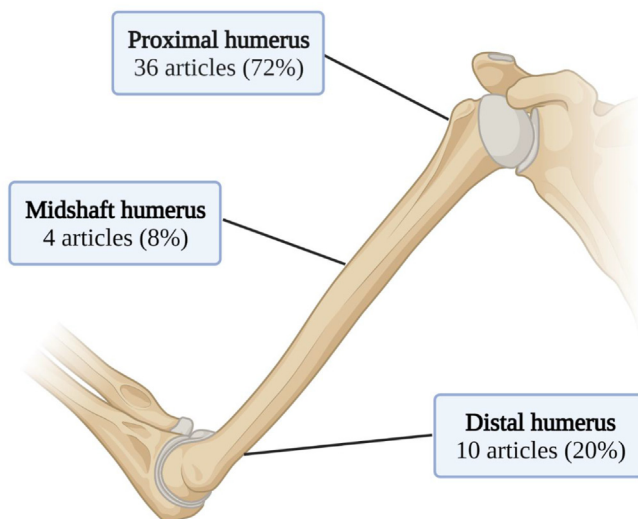


Figure 4 Distribution of the most highly cited humeral fracture articles by anatomic location.

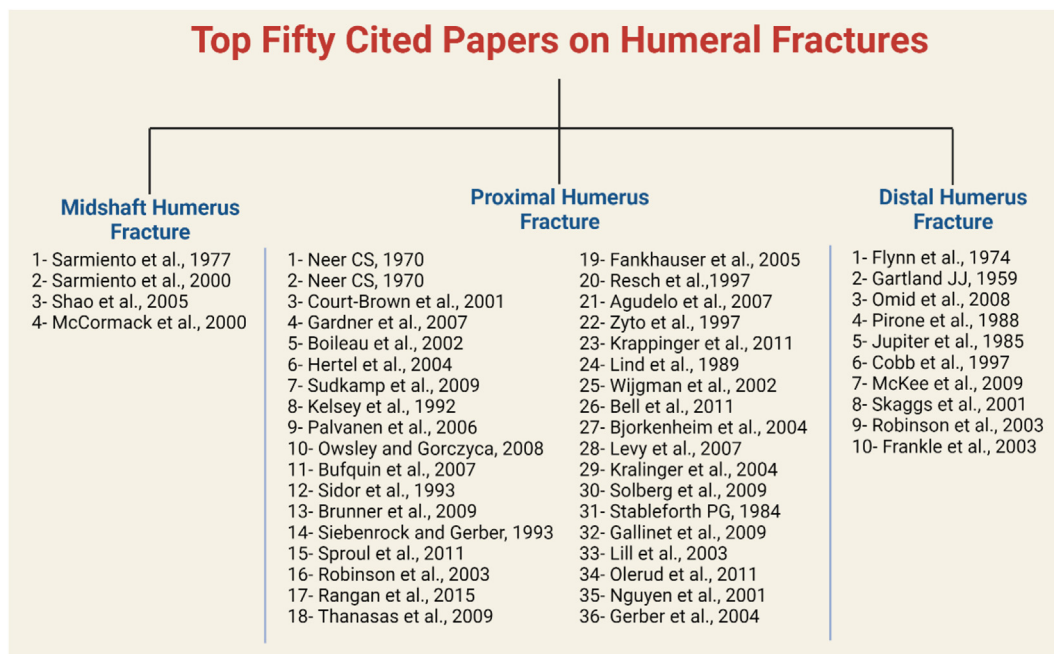


Figure 5 The top cited humeral fracture articles according to each anatomic site on the humerus.

distal HF mainly involved the treatment of supracondylar fractures in children and intra-articular distal HF in older adults.^{16,22,46,49,62} As for studies involving midshaft HF, those included two studies exploring the use of functional bracing, one systematic review discussing fracture-associated radial nerve palsy, and one study discussing operative fixation of the midshaft fracture.^{38,56,57,59}

Articles in our study had mean MCMS and MINORS scores of 64.6 and 10.4, respectively. While the MCMS score in our study is considered relatively higher when compared to other similar studies, both scores demonstrate substantial areas for improvement in the field of humerus fractures.^{2,27} In addition, around half of the included articles in our study were level 4 evidence, while 16% were level 2, 14% were level 1 (14%), 8% were level 3, and 10% were not assigned a level of evidence. These numbers are similar to

similar studies discussing other orthopedic topics.^{27,40} Nevertheless, our study showed that with time, the level of evidence, MCMS scores, and ability to garner citations increased. This demonstrates the increasing effort and work being put in the field of humerus fractures during the recent decades. While the correlational findings in our study seem encouraging, additional high-quality research is required in this field, as higher quality scores can be achieved, and better treatment options and strategies can be targeted.

Our study is the first to explore the top fifty cited articles exploring humerus fractures. Nevertheless, several limitations exist. Partial subjectivity was present in choosing the relevant articles exploring humerus fractures. However, the selection criteria for including these articles were well defined in our methods

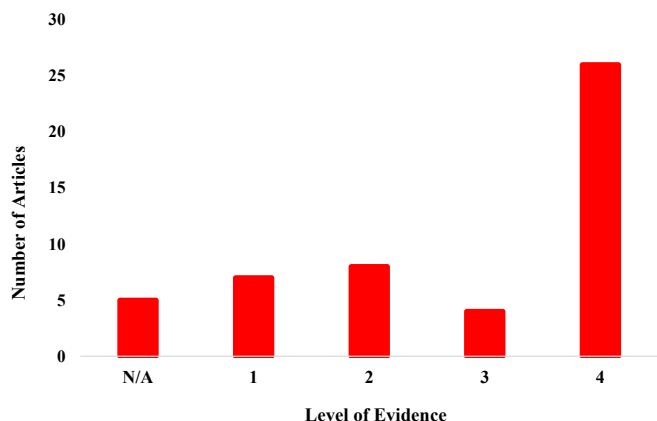


Figure 6 Level of evidence of most cited articles on humeral fractures.

sections to maintain transparency. In addition, the Web of Science (all databases) was explored in our study. While this database is comprehensive and holistic, it remains possible that important studies were excluded by our search strategy or citation categorization.

Conclusion

Fractures involving the humerus have garnered prominent interest in orthopedic literature for several decades, with particular interest after 2000. Our study showed that the top fifty cited articles were published between 1959 and 2015, with the majority being published after 2000. The majority of these contributions came from European and North American countries, which is a reflection of the high interest and investment in medical research in these countries. The included articles explored humeral midshaft fractures and supracondylar fractures, but treatment of proximal humerus fractures was the most commonly explored topic in our study.

The majority of the included articles were level four case series. Our study showed that level of evidence, citation density, and MCMS scores were positively correlated with year of publication, indicating progressive improvement in the quality of research exploring humerus fractures as time passes. These promising findings indicate the need for additional high-quality research in the field of humerus fractures, with the aim of optimizing treatment outcomes and improving patient experience.

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