Orthopaedics & Traumatology: Surgery & Research 103 (2017) 801–807

Available online at
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Review article

Gunshot induced injuries in orthopaedic trauma research. A bibliometric analysis of the most influential literature

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ARTICLE INFO

Article history:
Received 24 February 2017
Accepted 4 May 2017

Keywords:
Gunshot
Bibliometric analysis
Top cited articles

ABSTRACT

A growing burden of gunshot injuries demands evidence-based ballistic trauma management. No comprehensive systematic overview of the current knowledge is available to date. This study aims to identify and analyze the most influential publications in the field of orthopedic ballistic trauma research. All databases available in the Thomson Reuters Web of Knowledge were searched to conduct this bibliometrical study. The most cited orthopedic ballistic trauma articles published between 1950 and 2015 were identified by use of a multi-step approach. Publications with ten citations and more were analyzed for citations, journal, authorship, geographic origin, area of research, anatomical site, study type, study category, and level of evidence. Citations of the 128 included studies ranged from 113 to 10. These were published in fifty different journals between 1953 and 2011. Most publications ($n = 106$; 83%) originated from the USA, were retrospective ($n = 85$; 66.4%), level IV studies ($n = 90$; 70.3%), reported on spinal gunshot injuries ($n = 49$; 38.33%) and were published between 1980 and 2000 ($n = 111$; 86.7%). This bibliometric study provides the first comprehensive overview of influential publications in the field of orthopedic ballistic trauma research. More prospective studies and high-quality systematic reviews are needed. Centres with a high burden of gunshot injuries from the developing world need to share their experience in form of international publications, to provide a more comprehensive picture of the global gun-related orthopedic injury burden. Type of study: bibliometric analysis: level III.

1. Introduction

Gun-related violence kills over 1000 people and injures millions of others worldwide every day. [1–3]. This growing burden of gunshot injuries demands evidence-based ballistic trauma management. Musculoskeletal ballistic injuries constitute a unique group in terms of demographics, injury patterns, management, surgical techniques and clinical outcomes [4–8]. Although thousands of articles have been published on orthopedic ballistic trauma, no comprehensive systematic overview of the current knowledge is available to date.

Bibliometric analysis was originally designed to measure and compare the impact of scientific journals and is now recognized as a valid technique to analyze the scientific value and impact of articles by means of a quantitative appraisal of citations, articles and journals [9–12]. This study aims to identify and analyze the most influential publications in the field of orthopedic ballistic trauma research over the past 65 years by means of a bibliometric literature analysis. We hypothesize that there might be a research gap in field ob gunshot injury treatment.

2. Methods

We identified and analyzed articles on orthopedic ballistic trauma with the highest impact published between 1950 and 2015 in all databases and journals in "Thomson Reuters' Web of Knowledge". This database was chosen because the citation rate of scientific publications has been measured for decades using the citation indexes of the former Institute for Scientific Information. Moreover, the journals Thomson and Reuters "impact factor" are based on this specific database.

2.1. Inclusion criteria

All articles with the primary focus on orthopedic injuries caused by gunshots were included. Orthopedic injuries were defined as damage to bones, joints and soft tissue such as muscles, tendons and

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http://dx.doi.org/10.1016/j.otsr.2017.05.002
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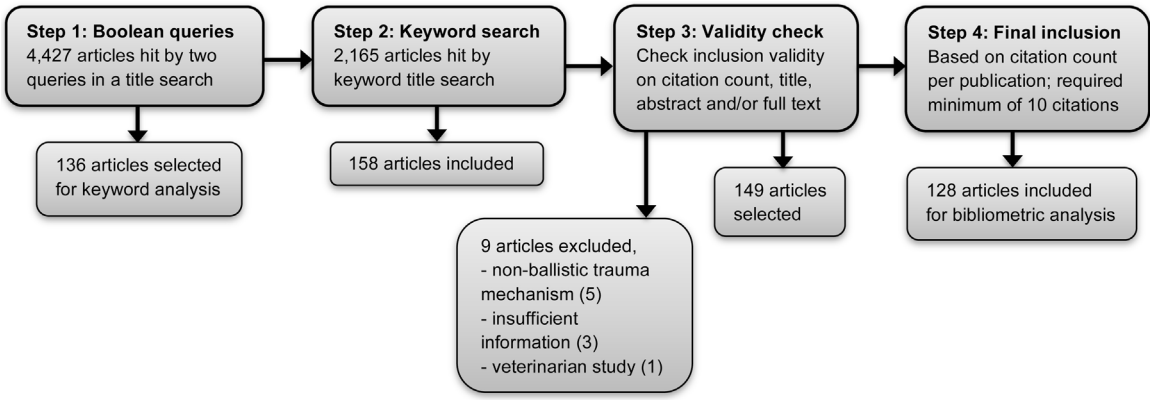

Fig. 1. Flowchart of multi-step approach in article selection process.

ligaments. All injuries to the axial skeleton and extremities were included. Studies on head and neck injuries were only included if their main focus was the involvement of the cervical spine. Gunshot injuries caused by civilian violence as well as injuries from military conflicts and war were included. There was no age restriction for the patients evaluated in the studies nor was there a language restriction of the publications.

2.2. Exclusion criteria

Studies on non-penetrating trauma caused by bullets, such as injuries due to rubber bullets, were excluded. Studies that focused on non-ballistic injuries or non-musculoskeletal anatomic structures in the same as or in a higher degree than orthopedic ballistic injuries were excluded. For example, we excluded one article that assessed open tibial fractures among 62 combat casualties with only 2 cases of gunshot injuries and 60 cases of blast injuries.

2.3. Selection process

The following Boolean queries with the asterisk extending the search to every possible ending of the words were applied: (gunshot* AND fracture*) and ([gunshot*] AND [orthopedic* OR orthopaedic* OR bon* OR musculoskeletal* OR injur*]). A multi-step approach was used to identify the most cited articles (Fig. 1).

2.4. Analysis

For every study included, the following information was extracted: year of publication, title, total citations, citations in 2014, citation density, journal, first author, senior author, institution, geographic origin, type of conflict (civilian or military/war) and age group (adults or children).

All selected publications were then systematically analyzed for the area of research, the anatomical body part studied, the study category, the study type and the level of evidence. The criteria established by *J Bone Joint Surg Am* were used for the classification of both study type and level of evidence [13]. Clinical studies were first categorized into one of the four groups (therapeutic, prognostic, diagnostic and economic) and then given a number corresponding with the level of evidence (highest ranked: I, lowest ranked: V). Other study types, such as experimental research or descriptive epidemiological research, were classified as a basic study without a level of evidence.

In case an article was written by a single author, he or she was regarded both first and senior author. Every article was further classified in a single area of research and study type according to the major focus of the study to prevent faults in the bibliometric analysis.

All studies were first listed with respect to the number of times cited, from highest to lowest. Studies sharing the same number of total citations were then ranked on citations in 2014 and citation density respectively. The maps were made using "Tableau" software (Seattle, USA).

Table 1
Characteristics of top 10 publications.

	Top 10 publications
Top country	USA (n = 8)
Top journal	JBJS Am (n = 2)
Top author	Bartlett, C.S. (n = 2)
Top anatomy	General (n = 8)
Top LoE	Basic (n = 4)
Top study type	Retrospective (n = 4)
Top study category	Therapeutic (n = 5)
Avg citations	68.9 (113–54)
Avg citations 2014	5.1 (10–0)
Avg publication age (years)	21.4 (44–9)
Avg citation density	4.0 (9.4–1.5)

Avg: average; LoE: level of evidence.

3. Results

The total number of citations per publication of the 128 selected articles ranged from 113 to 10. They were published in fifty different journals between 1953 and 2011 (Annex).

Of the top ten most influential articles, 80% (n = 8) were from the USA and the *J Bone Joint Surg Am* was the most published journal with three articles (30%).

The top ten publications were published on average 21.4 years ago (95% CI 44–9), achieved an average citation density of 4.0 (95% CI 9.4–1.5) with an average citation count of 68.9 (95% CI 113–54). Peleg et al. from Israel published the most cited article in 2004, with 113 total citations and the highest citation density (9,42). Eight out of ten publications did not focus on specific anatomical area (80.0%); the other two addressed the spine (20.0%). The highest level of evidence in the top ten articles was level III (n = 3; 30.0%). Prospective studies and randomized control trials were not found in the top ten (Table 1).

Of all included articles, the top journals in terms of total number of publications were the *Journal of Trauma-Injury Infection and Critical Care* (n = 27), the *Journal of Trauma* (n = 10), the *Journal of Bone and Joint Surgery American Volume* (n = 9) and *Clinical Orthopedics and Related Research* (n = 9). Together, these four journals accounted for fifty-five of the 128 articles (43%).

Table 2
Geographic origin of publications.

Country	Publications (*n*)
USA	106
South Africa	3
England	3
Israel	2
Germany	2
Turkey	2
Australia	1
Belgium	1
Canada	1
Finland	1
Ireland	1
Panama	1
Scotland	1
Serbia	1
Switzerland	1
Vietnam	1

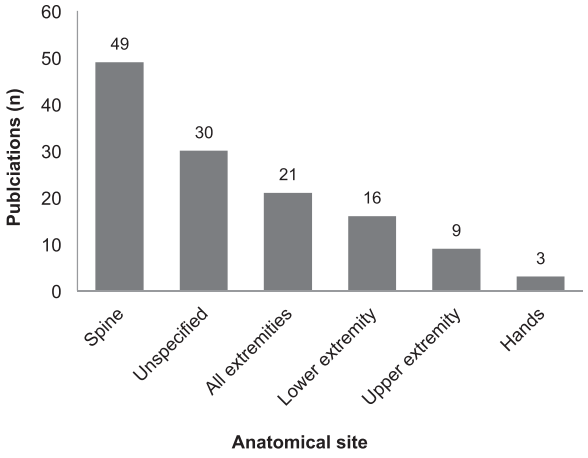

Fig. 2. Number of articles on a specific anatomical structure.

Similar to the top ten, most of the 128 studies (*n* = 106; 83%) were published by American researchers, leading the list of sixteen different countries of authorship (Table 2). Three studies (2.3%) were from the continent of African and no Central American, South American or Asian publications met the inclusion criteria.

Most of the studies were on spinal gunshot injuries (*n* = 49; 38.3%, Fig. 2). Civilian injuries were discussed in eighty-nine articles (69.5%), thirteen studies (10.2%) focused on war-related injuries and twenty-six studies did not specify the type of conflict (20.3%). Pediatric ballistic trauma was the focus of six studies (4.7%) and most studies did not mention the age group of the patient cohort (*n* = 71; 55.5%; Fig. 3).

Most publications discussed injury management (*n* = 36; 28.1%), surgical technique (*n* = 19; 14.8%), epidemiology (*n* = 14; 10.9%) and complications (*n* = 13; 10.2%). Five articles focused on the questions whether or not to remove the bullet and only one article (0.8%) reported on treatment costs (Table 3).

Complications of civilian gunshot injuries were further subdivided in general, neurological, vascular and visceral complications. Two studies focused on general complications of gunshots to the head and spinal cord, including infections, C-spine injury, pneumothorax, cerebrospinal fluid leak and retroperitoneal hematoma. Four case reports concerned neurological complications after gunshots to the spine, including complete paraplegia, bilateral upper extremity paralysis, cauda-equina syndrome and locked-in syndrome. Publications of vascular complications included a report of an arteriovenous fistula of the vertebral artery and one case series that found a predominance of minor injuries in a group of vascular

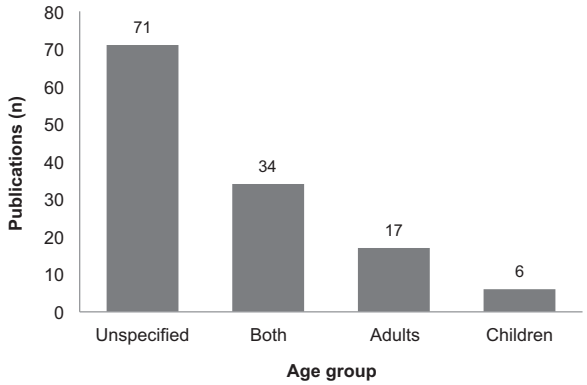

Fig. 3. Age group or patients reported on in the selected articles.

Table 3
Area of research.

Area	Publications (*n*)
Injury management	36
Surgical technique	19
Epidemiology	14
Complications	13
Clinical outcome	9
Injury pattern	8
Overview	6
Antibiotics	5
Ballistics	5
Retained bullets	5
Imaging	7
Treatment costs	1

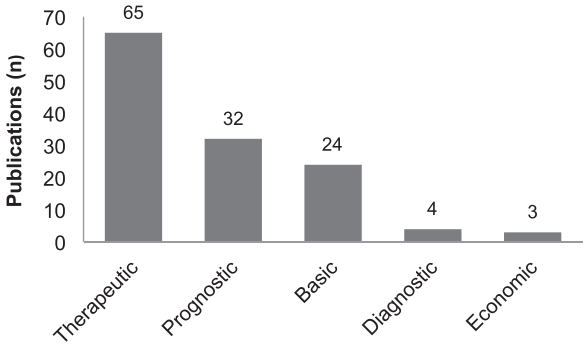

Fig. 4. Study category.

complications after gunshots to the long bones. Visceral complications mainly included perforations of the colon, small bowel and stomach and other transperitoneal injuries after gunshots to the spine. Almost all patients underwent explorative laparotomies, the spinal area was not debrided, the bullet was not removed and the majority of cases were treated with intravenous antibiotics for 5 to 7 days at least. Three studies found a low incidence of vertebral infections was low and that colonic perforation was associated with a high risk of intra-abdominal abscesses and peritonitis.

With respect to study category, the majority of included publications were therapeutic (*n* = 65; 50.8%), a quarter were prognostic (*n* = 32; 25.0%) and four studies reported on diagnostics (3.1%; Fig. 4).

The majority of studies (*n* = 90; 70.3%) provided level IV evidence. Only two studies were randomized control trials with level I evidence (1.6%; Fig. 5). Eighty-five publications were

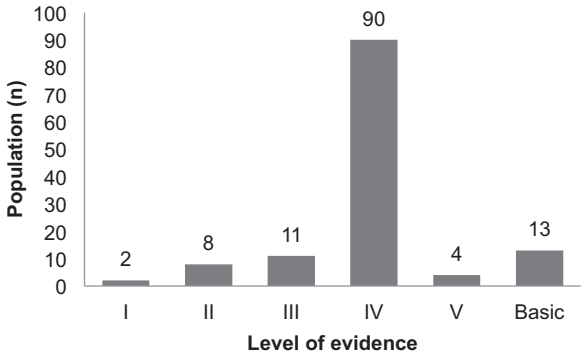

Fig. 5. Level of evidence of selected articles.

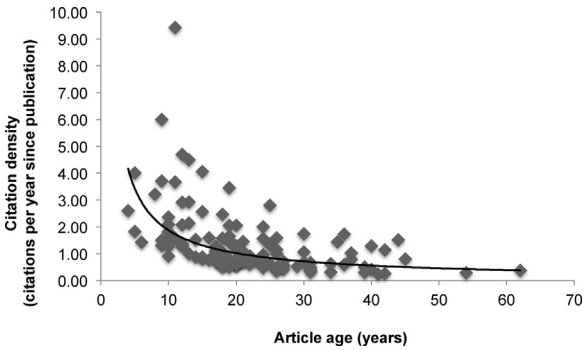

Fig. 7. Citation density and article age.

Table 4
Study type.

Study type	Publications (*n*)
Retrospective study	85
Non-systematic review	17
Systematic review	7
Prospective study	6
Expert opinion	4
Postmortem study	4
Experimental study	3
Randomized controlled trial	2

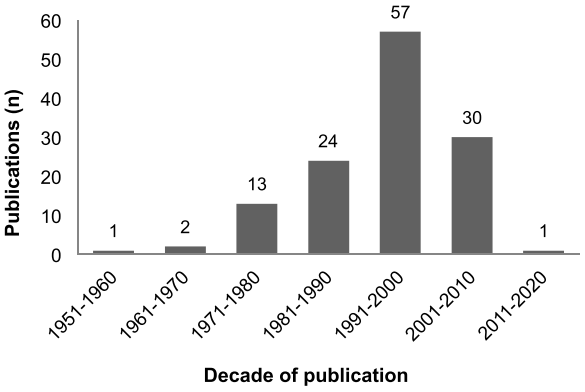

Fig. 6. Number of publications per decade.

Table 5
Authorship.

Name	Total publications (*n*)	First author (*n*)	Senior author (*n*)
Waters RL	6	5	2
Cotler JM	4	0	4
Demetriades D	4	1	3
Lindsey RW	3	0	3
Sie I	3	0	3
Atesalp AS	2	2	0
Bartlett CS	2	2	1
Gur E	2	0	2
Isiklar ZU	2	2	0
McQuirter JL	2	2	0
Omer GE	2	0	2
Pearse LA	2	0	2
Todd AC	2	0	2

retrospective studies (66.5%); twenty-four (18.8%) studies were literature reviews of which only 7 were systematic (Table 4).

The years of publication and a list of top authors and institutions are shown in Fig. 6 and Table 5, respectively.

4. Discussion

This is the first systematic overview of the most cited publications in orthopaedic ballistic trauma. Most articles focused on spinal trauma, were retrospective, level IV studies and originated from the USA.

In accordance with our hypothesis, there seems to be a research gap in the literature addressing gunshot related orthopaedic injuries.

With respect to the citations in 2014, the paper from Peleg et al. from Israel was only cited seven times in 2014. This implies that it received most citations shortly after publication and has gradually lost its momentum. The second most cited article written by Hollerman et al. had nine citations in 2014, followed by an article from Fackler et al. with five citations in that year. The most cited article in 2014 was a postmortem study on imaging in autopsy, published by Levy et al. in 2006. It was cited ten times in 2014 and fifty-nine times in total with a citation density of 6.00 citations per year since publication. Since this article has the second highest citation density while being a relatively recent study, it has potential to improve its current rank in this list in the near future.

With respect to all included publications, most studies were published in the period between 1981 and 2010 with the most active decade being the nineties. On the one hand, the reason for the lack of publications from older decades might be their integration into more recent articles, a phenomenon termed obliteration by incorporation [9]. The older the article, the lower the number of citations per year since publication generally is (Fig. 7). In fact, age was not found to correlate with the total number of citations: the first ranked publication achieved 113 citations in eleven years, while the six papers on the bottom of the list were cited 10 times each in a period ranging from six to forty-one years.

4.1. Geographic origin

On a global scale, almost half of all homicides are caused by firearms [3]. Central America, the Caribbean, South America and Southern Africa remain the epicenter of the intentional gun-related violence burden [2,3] (Fig. 8). The rates of fatal firearm injuries per country were estimated at 10.2 per 100,000 in South Africa (33% of total intentional homicides) and 23.7 in Colombia (77% of total homicides) compared to just 2.8 in the USA (60% of total homicides) [2]. Venezuela led the list of countries with high interpersonal firearm-related violence with an intentional homicide rate of 53.7 per 100,000 population followed by Brazil (25.2 per 100,000) [2]. Despite this obvious trauma burden, only 3 publications could be identified from these are as while USA-based authors published more than 80% of the most influential literature in orthopedic ballistic trauma (Fig. 9). Although the USA is a first world country with

Fig. 8. World map burden of disease.

Fig. 9. World map geographic distribution of publications.

a high burden of gunshot injuries, sufficient academic resources are available to surgeons to publish their experience, which may not be the case for trauma centres in South America and Southern Africa [1,2,14]. Most evidence for orthopedic gunshot injuries is thus obtained in a first world setup, whereas the true trauma burden lies in the developing world. Although it is a common fact that most medical scientific literature originates from Northern America, this research gap in the geographic distribution of injury

burden and publications needs to be addressed by future studies in high-burden countries.

Each of the top five journals published more than five articles and together these journals account for almost half of the publications. A similar pattern was reported before in bibliometric analysis on other orthopedic areas, probably reflecting the degree of specialization and literature dominance among scientific journals [10–12].

Even though most of the ballistic trauma occurs in low-income counties, only one study primarily focused on treatments costs, which is certainly one of the priority areas in need of further research. The spine was the most frequently studied anatomic site, most probably reflecting the high impact of spine journals since gunshots to the spine are not the most frequently seen injuries. Over twenty percent of the included publications did not specify which anatomic part was studied or focused on multiple anatomical structures. The lower extremity was studied almost twice as often as the upper extremity.

4.2. Quality

Although some studies reported on large patient cohorts, most publications were retrospective level IV studies that were conducted over a few decades with limited to reasonable follow-up data. Less than five percent of the studies were randomized controlled trials or other prospective studies. On the one hand, this demonstrates that articles with relatively simple study designs may contribute significantly to the current literature, a finding that is particularly encouraging for centres with limited resources to run prospective or randomized control trials. On the other hand, this illustrates the need for improved design and conduct of future research. Moreover, the quality of writing up or reporting on methods and results could also be improved. Frequently cited publications emphasized that the injury pattern significantly differs between adults and children, as well as military and civilian injuries, but more than half of the included publications did not specify these characteristics. The ballistic mechanism and therapeutic ambiance are significantly different in those two groups and future systematic reviews are thus required to differentiate between civilian and war-related gunshot trauma. Most probably, war related literature will be cited more often in the future and so far underrepresented topics like “damage control” will come into focus.

Even though many literature reviews on orthoballistic trauma exist, no meta-analysis, bibliometric analysis or critical appraisal has been published so far. In this analysis, twenty-four literature reviews were included of which more than two-third was non-systematic. All systematic literature reviews described level III studies or lower and therefore were marked as level III evidence. The majority of these were therapeutic and covered different anatomic structures and areas of research. It is therefore possible that, in the field of orthopedic ballistic trauma research, the level of evidence is not a criterion for publication impact and success.

4.3. Limitations

Citation analysis is a useful strategy in the assessment of scientific impact of publications and the multi-step approach guaranteed a broad coverage in the search for the most influential evidence [15]. Nevertheless, a bibliometric analysis has inevitable limitations related to the dynamics in the field: the articles are selected at a single point in time and new studies are published every day. It is plausible that recent publications in the field of research are as or even more influential, however, they were not eligible for inclusion in this bibliometric analysis, for example due to young age or number of citations.

The average total number of citations in the complete list was 25.4 per publication. With respect to the top ten studies, this average was 68.9 with a range of 59 (54 to 113). In comparison, the range of citations in the bottom ten studies of the top hundred in this selection was only two (13 to 15 total citations) and the difference in total citations between rank 50 and 128 is only thirteen citations (10 to 23). A limitation of this study is therefore that a single citation may change the bottom of this list of most cited articles.

Bibliometric analysis results should be carefully interpreted. The question as to whether this method best reflects the most influential literature remains controversial. The list provides a good overview of the knowledge available, however, a systematic content review may be more applicable when aiming to provide a comprehensive review of the clinical evidence available. This study could be used as a stepping-stone by suggesting directions into which future research should be pointed.

5. Conclusion

This bibliometric study provides the first comprehensive overview of the most influential publications in the field of orthopedic ballistic trauma research. Most articles were retrospective level IV studies, focused on spinal trauma, were published between 1980 and 2000 and originated from the USA. In order to address the identified knowledge gaps, future research should be directed towards prospective studies and high-quality systematic content reviews. Furthermore, trauma centres in Central and South America and Southern Africa need to share their experience to provide useful evidence for areas with limited resources and to establish a more comprehensive picture of the global gun-related orthopedic injury burden.

Disclosure of interest

The authors declare that they have no competing interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.otsr.2017.05.002

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