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ARTICLE

Ophthalmic trauma: the top 100 cited articles in *Ophthalmology* journals

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OBJECTIVES: To analyze the top 100 cited papers on ophthalmic trauma.
METHODS: A literature search of *Ophthalmology* journals within the ISI Web of Science database for the most cited papers related to ophthalmic trauma.
RESULTS: The most cited articles were published between 1943 and 2013, the greatest number being published in 2000. *Ophthalmology* (45), *Archives of Ophthalmology* (17), and the *American Journal of Ophthalmology* (15) published most of the articles. The institutions with the highest number of publications were Wilmer Eye Institute (10) and Massachusetts Eye and Ear Infirmary (7). Sixty-seven percent of the articles originated from the USA. The most common type of trauma studied was non-open-globe injuries and the most frequent topic studied were pathological conditions secondary to trauma (34), particularly endophthalmitis (8), and optic neuropathy (6). Articles presenting a standardized classification system for eye injury received the highest average of citations per publication. Types of research most frequently cited were observational clinical studies (62) and epidemiological studies (30); the least frequent were clinical trials (2).
CONCLUSION: This bibliographic study provides a historical perspective of the literature and identifies trends within the most highly influential papers on ophthalmic trauma. Many of these articles emerged within the past three decades and came from *Ophthalmology* journals that remain high impact to this day. Clinical trials have been difficult to conduct and are lacking, reflecting a critical need in ophthalmic trauma research, as most of our understanding of ophthalmic trauma comes from observational and epidemiological studies.

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INTRODUCTION

The global incidence of eye injuries is estimated to be over 55 million each year with approximately 35% resulting in blindness or low vision [1]. In the USA, the rate of blindness or low vision resulting from serious eye injuries is at least 27% [2]. Interestingly, eye injuries have been shown to vary considerably across countries, demographics, socioeconomic status, gender, and age [3–6]. Significant social and economic burdens such as family care, lifestyle changes, lost time from school or work, workers' compensation, and costly medical expenses from hospitalizations, clinic visits, treatment, and rehabilitation, may stem from ocular injuries [7, 8]. Hence, ophthalmic trauma is a significant part of ophthalmological patient care, and analyzing the most impactful studies within the literature may reveal the scientific progress that has been made in the field and what remains to be improved.

Bibliometric analysis is a statistical method of reviewing the literature to identify patterns. The first bibliometric analysis, by Eugene Garfield in 1987, characterized the top 100 (T100) articles in the *Journal of the American Medical Association* (*JAMA*) [9]. Since then, there have been numerous bibliometric studies within ophthalmology. They have identified trends in research funding [10], contributions by specific countries [11], demographics [12], the impact of different journals [13], and various subspecialty research topics [14, 15]. The purpose of this study is to identify the T100 cited clinical papers related to ophthalmic trauma to provide a historical perspective on ophthalmic trauma research and to identify avenues for future contributions in ophthalmic trauma research.

MATERIALS AND METHODS

The ISI Web of Science (WoS), maintained by Clarivate Analytics, was used to search for the T100 cited papers related to ophthalmic trauma. With coverage from the beginning of the 20th century, the WoS provides

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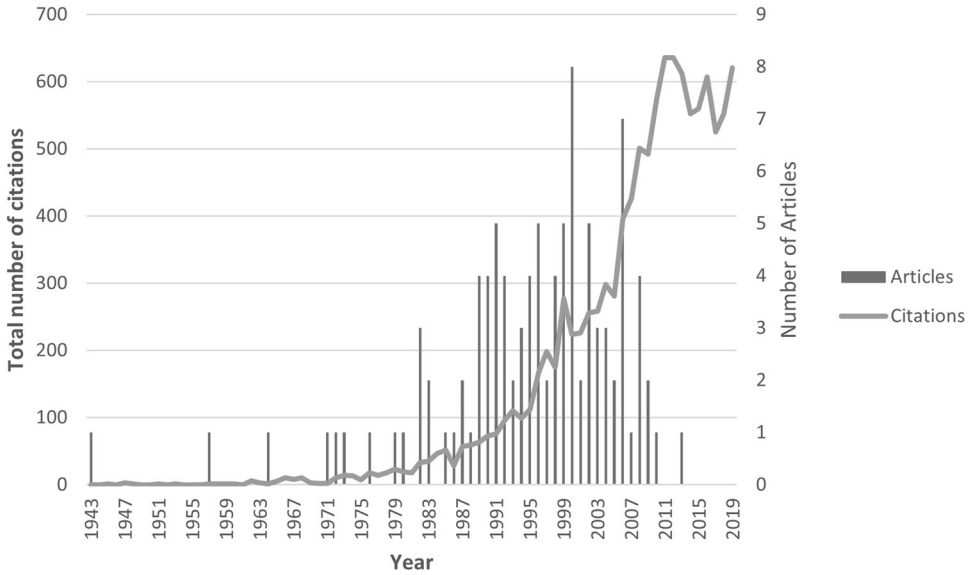

Fig. 1 Yearly citations and articles published from the top 100 most cited articles on ophthalmic trauma. Left y-axis: Line plot of total citations from T100 articles by year (orange). Right y-axis: Histogram of number of T100 articles published by year (blue).

multidisciplinary content in the English language of over 21,000 peer-reviewed journals worldwide and continues to be one of the most trusted, widely-used citation indices for bibliometric analyses [16–18].

Our search included general search terms for eye trauma related to both open- and non-open-globe injuries, although we acknowledge that not every term is mutually exclusive. Our open-globe injury search terms were: open globe, corneal laceration, scleral laceration, intraocular foreign body, rupture, penetrating, perforating, firework, globe laceration, globe rupture, globe perforation, globe penetration, globe trauma, and globe injury. Our non-open-globe injury search terms were: burn, chemical burn, alkali burn, acid burn, thermal burn, abrasion, foreign body (peribulbar, corneal, orbital, conjunctival, lid, lacrimal), hyphema, microhyphema, iridodialysis, cyclodialysis, angle recession, laceration (eyelid, eyebrow, canalicular, nasolacrimal), orbit fracture, retrobulbar hemorrhage, retrobulbar hematoma, commotio, choroidal rupture, sclopetaria, traumatic optic neuropathy, shaken baby syndrome, abusive head trauma, traumatic cataract, and globe contusion.

Only one search was performed, and it was done within the WoS category "ophthalmology," which contained 59 journals at the time of search in August 2020. No limitations were set for the date of publication of the manuscripts in the search. The search was performed utilizing the Boolean search operators "OR" and truncation marks (ie: "trauma*", "injur*"), which is facilitated by the WoS search engine. The search was refined by publication type to include case series and original reports and excluding editorials, reviews, letters, meeting abstracts, and proceedings papers). The results were organized in descending order by times cited. Each paper was then reviewed by three authors (ATP, TDW, and GAJ) and excluded if it did not involve ophthalmic trauma, examples being articles about keratoconus or penetrating keratoplasty.

Our primary outcomes were to define the T100 most cited papers in ophthalmology with the corresponding variables: title, total citations, year published, citations per year, type of trauma (open-globe vs. non-open-globe injury), topic, and type of study. After examining the T100 papers, each article was grouped based on the following topics: classification system, epidemiology of mechanical eye injuries, treatment or management of mechanical injuries, traumatic sequelae (pathological conditions secondary to trauma), iatrogenic globe injury, pediatric trauma, prognostic tools/models, combat injuries, and simulation modeling. The type of study was determined by examining each paper and classifying them into the following categories: clinical experience (observational), randomized clinical trial (interventional), epidemiological, review, and other. Clinical experiences were further grouped into descriptive studies (case reports/case series) and analytic studies (retrospective cohort, prospective cohort, cross-sectional, and case–control). Case series and cohort studies were distinguished according to the definitions described by Dekkers et al. [19]. Basic science papers were excluded. Secondary outcomes were then: journal name, number of authors, first author, last author, and the institutions and countries of the first and last authors.

Statistical analysis was performed using Microsoft Excel (Redmond, WA). Pearson correlation coefficients were calculated to determine relationships between continuous variables. The correlation coefficients were then used to determine the *t*-statistic and *p* value. Alpha was set at 0.05 for all analyses.

RESULTS

The T100 most cited articles on ophthalmic trauma were identified (Supplementary Tables 1 and 2). The mean and median number of citations per article were 100 and 108, respectively, with a range of 67–322 citations. There were 11,571 cumulative citations, with a noticeable skew in article distribution due to 25% of citations coming from the top 13 of the T100 most cited articles. Figure 1 displays the yearly total citation count and the number of T100 articles that were published in that calendar year. The articles identified in this study were cited the most in 2011 and 2012, receiving 636 total citations that year. The earliest article was published in 1943, while the most recent article was published in 2013. The year containing the most articles in this study was 2000 with eight articles identified. There was no correlation between total citations and years since publication ($p = 0.57$).

Of the T100 articles, open-globe injury, non-open-globe injury, and both open- and non-open-globe injuries were studied in 26, 26, and 27 papers, respectively. The remaining papers did not provide the type of globe trauma. Table 1 lists the number of articles that covered specific topics, the total citations that these topics received, as well as the average citations per article on that topic. "Traumatic sequelae" was the most common topic that was investigated in the articles (34). Of these conditions, the most frequently studied were endophthalmitis and optic neuropathy. Articles on traumatic sequelae received the highest number of total citations (4210). However, "Classification System/Terminology" had the highest average number of citations *per* article, with an average of 233 citations per article despite only having three papers on this topic. Figure 2 displays the percentage of articles that fall into different research types. The majority (62%) of articles were observational clinical experiences; 25 papers were descriptive case reports/case series and 37 papers being mainly analytical cohort studies. The least frequent type of study were interventional randomized clinical trials (2%).

The articles were published in 14 journals (Table 2). Table 2 lists the number of articles and the total citations for each journal. The *American Journal of Ophthalmology* published the most cited

Table 1. Topics of the top 100 most cited articles on ophthalmic trauma.

Topic	Number of articles	Total citations	Citations per article	Article rank
Traumatic sequelae	34	4210	124	2, 3, 4, 6, 8, 9, 10, 11, 15, 17, 22, 24, 31, 38, 46, 53, 54, 55, 57, 58, 64, 65, 71, 73, 76, 78, 79, 81, 82, 83, 84, 87, 92, 93, 98
Endophthalmitis	8	859	107	11, 17, 31, 55, 65, 82, 87, 98
Optic neuropathy	6	836	139	2, 4, 71, 73, 78, 83
Keratitis	5	965	193	3, 6, 8, 9, 22
Enophthalmos	4	457	114	15, 38, 58, 64
Hyphema	3	247	82	53, 84, 93
Proliferative vitreoretinopathy	2	212	106	9, 22
Retinal detachment	2	187	94	46, 76
Corneal ulcer	2	271	136	10, 57
Cyclodialysis	1	79	79	81
Macular hole	1	97	97	54
Treatment or management of mechanical eye injury	18	1966	109	12, 14, 18, 21, 26, 28, 29, 39, 47, 48, 60, 66, 67, 74, 94, 96, 97, 99
Epidemiology of mechanical eye injury	16	1487	93	23, 35, 36, 44, 52, 61, 62, 63, 69, 70, 77, 80, 86, 88, 89, 100
Pediatric trauma	12	1198	100	20, 33, 37, 41, 42, 50, 68, 72, 75, 85, 90, 95
Prognostic factors/tools/models	7	837	120	16, 27, 30, 34, 43, 49, 56
Iatrogenic ocular trauma	6	732	122	7, 13, 45, 51, 59, 91
Classification System/Terminology	3	698	233	1, 5, 19
Combat injuries	3	312	104	32, 40, 92
Simulation modeling	1	131	131	25

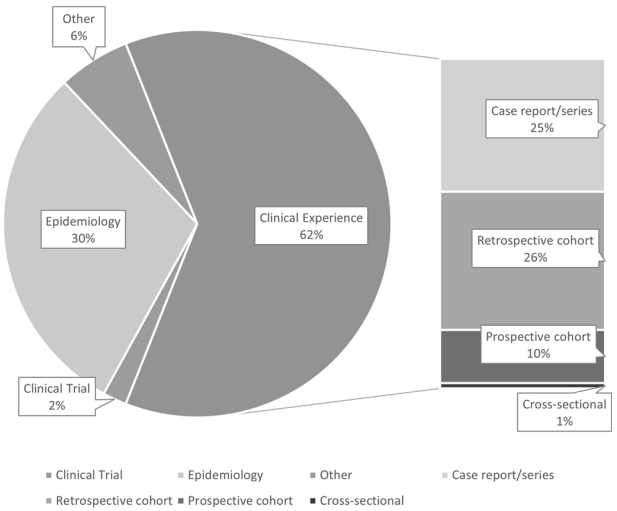

Fig. 2 Article types from the top 100 most cited articles on ophthalmic trauma. Distribution of T100 publications by article type: clinical experience (blue), epidemiology (yellow), clinical trial (orange), other (green).

article [20], *Cornea* published the third most cited article [21], while *Ophthalmology* published the remainder of the top five most cited articles [22–24]. The impact factor of journals from the most recent WoS journal citation report (2019) had a strong positive correlation with the number of T100 articles ($r = 0.856$, $p < 0.01$) and their combined number of citations ($r = 0.831$, $p < 0.001$). The majority (77) of the T100 papers were published in *Ophthalmology* (45), *Archives of Ophthalmology* (17), and the *American Journal of Ophthalmology* (15).

Among research institutions that have published multiple T100 papers, Wilmer Eye Institute, Johns Hopkins University, had the most articles (10) followed by Massachusetts Eye and Ear Infirmary, Harvard University (7). The first author and last author's affiliated institution was used to determine the institutions credited with the article. Moreover, among countries with multiple T100 papers, most of the articles originated from the USA (67).

Authors who have published the most T100 papers are Ferenc Kuhn (3), Peter E. Liggett (3), Stephen J. Ryan (3), and James M. Tielsch (3). The range of authors listed in a single article was 1 to 13 authors. The median number of authors was four, and there were four articles with a single author. In total, there were 93 papers with unique first authors and 94 unique last authors.

DISCUSSION

Ophthalmic trauma is a preventable cause of vision loss that can drastically affect one's quality of life [25]. There have been numerous publications, especially within the last three decades, dedicated to studying ophthalmic trauma to better understand its risks, outcomes, and management. There were noticeable trends observed between the T100 articles and the journals in which they were published. A significant positive correlation was found between the journal impact factor and the number of T100 articles it published and their total citations. The majority (77) of T100 articles were published in high-ranking journals (impact factor >4.00), specifically, *Ophthalmology*, *Archives of Ophthalmology* (now *JAMA Ophthalmology*), and the *American Journal of Ophthalmology*. This is similar to a bibliometric analysis of intravitreal injection papers [26]. These findings speak to the clinical utility of not only ophthalmic trauma papers but highly cited papers in general, as these journals also may prefer to select studies that are deemed important for all practicing ophthalmologists regardless of subspecialty [16].

Table 2. Journals of top 100 most cited articles on ophthalmic trauma.

Journal	Number of articles	Total citations	Impact factor[a]	Article rank
Ophthalmology	45	5563	8.470	2, 4, 5, 6, 7, 9, 11, 12, 13, 16, 17, 21, 22, 24, 28, 29, 30, 31, 33, 34, 37, 39, 40, 41, 42, 43, 45, 47, 49, 54, 55, 56, 62, 65, 67, 75, 76, 77, 81, 85, 88, 94, 96, 99, 100
Archives of Ophthalmology[b]	17	1555	6.198	35, 36, 38, 46, 51, 52, 61, 66, 70, 71, 72, 74, 78, 89, 93, 95, 97
American Journal of Ophthalmology	15	1748	4.013	1, 10, 18, 20, 26, 48, 53, 60, 69, 79, 83, 84, 87, 90, 91
British Journal of Ophthalmology	8	809	3.611	15, 25, 50, 57, 63, 68, 86, 98
Ophthalmic Plastic and Reconstructive Surgery	4	484	2.455	14, 58, 59, 64
Eye	2	251	1.331	8, 27
Optometry and Vision Science	2	217	1.458	32, 92
BMC Ophthalmology	1	71	1.413	80
Cornea	1	79	2.215	3
Graefe's Archive for Clinical and Experimental Ophthalmology	1	247	2.396	23
Japanese Journal of Ophthalmology	1	134	1.725	73
Journal Francais D Ophtalmologie	1	85	0.636	19
Ophthalmic Epidemiology	1	143	1.500	44
Retina—The Journal of Retinal and Vitreous Diseases	1	106	3.649	82

[a]Obtained from 2019 Web of Science Journal Citation Report.
[b]*JAMA Ophthalmology*.

The majority (67) of the most cited ophthalmic trauma articles originated from the USA, which is similar to previous bibliometric studies within ophthalmology [26–28]. This trend has been attributed to a combination of the size of the US ophthalmology community, its resources, research output, and that many journals are US-based [27]. Bias from US authors and reviewers may also play a role [29, 30]. This trend may be changing, however, where many recent bibliographic papers show tremendous growth in the number of papers published by institutions outside of the USA [6, 14]. There may be a publication time bias, however, where the relatively new papers may not have been in existence long enough to garner citations, and newer journals may not be indexed yet.

Of the T100 papers on ophthalmic trauma, 26, 26, and 27 papers studied open-, closed-, and both open/non-open-globe injuries, respectively. Among these papers, a variety of traumatic sequelae were studied (32 articles published articles; 4334 total citations), but the most common was endophthalmitis (eight articles; 859 total citations) [22, 23, 31–35]. This is not surprising as endophthalmitis is a major concern in any traumatized eye and its development has significant effects on clinical course [36].

The second most studied sequelae were traumatic optic neuropathy, and these investigations were driven by the motivation to establish a consensus on the proper method of clinical management [31, 32, 34, 35]. An important study of note is the International Optic Nerve Trauma study, which was the first organized study to investigate the treatment of indirect traumatic optic neuropathy [22]. This investigation was initially intended to be a randomized, controlled, pilot study but due to the rarity of the condition, recruiting eligible patients proved to be a significant challenge. Consequently, it was transformed into a comparative, nonrandomized, noncontrolled interventional study that concluded there was no clear benefit for either corticosteroid therapy or optic canal decompression. This study exemplified a major hallmark, but also a challenge, in ophthalmic trauma literature: the paucity of clinical trials and the obstacles associated with conducting one. The least frequent type of research study in this bibliometric analysis was interventional, randomized clinical trials (2). Eye injuries have a heterogeneous presentation with many confounding variables that make it difficult to control for significant individual variability [37]. This consequently makes it challenging to independently evaluate various risk factors and treatment modalities [22]. In addition, up to a quarter of patients with ophthalmic emergencies can be lost to follow-up from the emergency department [38]. Hence, the majority of ophthalmic trauma literature has been limited to observational clinical experiences (60) consisting mostly of descriptive case studies or reports (25) and analytical cohort studies (34). This highlights the need for the future of research in these topics through clinical trials.

The second most common type of research study was epidemiological studies. While there were 30 epidemiological research articles related to ophthalmic trauma, only a portion of the studies were focused primarily on mechanical eye injuries (16 articles; 1487 total citations) [2, 4, 39–49]. Since ophthalmic trauma is considered to be an avoidable cause of vision loss with significant medical, social, and economic consequences, it is expected that many studies seek to understand the incidence and risk factors of ophthalmic trauma to create preventative interventions and reduce its national burden. The remaining 14 epidemiology articles related to other topics: keratitis (4), endophthalmitis (4), corneal ulcerations (2), pediatric eye injuries (2), proliferative vitreoretinopathy (1), and war injuries (1).

A major milestone in ophthalmic trauma literature was the creation of a standardized system for classifying mechanical globe trauma [20, 24]. Previously, the terminology used by ophthalmologists varied considerably, and this impinged proper discussions of ophthalmic trauma. Thus, landmark classification articles receive a high number of citations because any scientific investigation on ophthalmic trauma needs to describe the mechanism of injury or type of trauma involved in the study to effectively communicate eye injury information. Classification articles are less common in comparison to other topics within the T100 articles. Yet, despite having fewer articles, the average

citation per article is higher (233 citations per article) than any other topic, which suggests that individual articles on this topic have had the greatest impact within the field.

This study has several limitations. The list of the T100 most cited articles generated differs depending on the database used, the search parameters, and the search terms used. First, we used the WoS due to its extensive database and widespread use in bibliometric analysis, but literature predating 1980 is scarce and cataloging is less reliable. There is variation between the WoS and other databases like Google Scholar or Scopus. Hence, using multiple databases would provide a more comprehensive picture of the literature [50, 51]. Second, our search only included journals within the field of ophthalmology, which could exclude trauma papers published in high-impact basic science journals and other general medical journals, that may have potentially been within the T100 most cited articles. Third, a broad list of search terms was used that led to over 15,000 results, which were manually searched to the T100. This presents a greater possibility of human error or bias in selecting relevant ophthalmic trauma articles. Finally, our study determines the impact of an article through the number of citations it has received since publication. It is important to note, however, that potentially more impactful articles simply may not have had the time to generate the citation counts as older articles. Older, yet highly impactful articles may also have been missed in our search because their contents have become common knowledge; hence, they are cited less frequently [27].

Overall, this study is a bibliometric analysis of the 100 most cited articles in ophthalmic trauma. We found many studies originated from the U.S. and were published in leading *Ophthalmology* journals. The most common topics studied were pathological conditions secondary to ophthalmic trauma, specifically endophthalmitis, and traumatic optic neuropathy. Many studies have been limited to clinical experiences due to the challenges of conducting a proper clinical trial with traumatic eye injuries. Most of the literature is comprised of observational clinical and epidemiological studies. Lastly, despite having a fewer number of publications, a standardized system of classification for mechanical eye injuries was a major development in the field of ophthalmic trauma with a significant impact on citations.

Summary

What was known before

- Ophthalmic trauma has a significant impact on quality of life and is associated with poor vision outcomes.
- There are numerous bibliometric studies within ophthalmology that have identified several publication trends in various subspecialty research topics, but none on ocular trauma.

What this study adds

- A historical perspective of ophthalmic trauma literature that identifies trends in the most highly cited papers.
- Demonstrates a paucity in clinical trial research in ophthalmic trauma.

DISCLAIMER

The view(s) expressed herein are those of the author(s) and do not reflect the official policy or position of the San Antonio Military Medical Center, the Walter Reed National Military Medical Center, the U.S. Army Medical Department, the U.S. Army Office of the Surgeon General, the Department of the Air Force, the Department of the Army, Department of Defense, the Defense Health Agency, or any other agency of the U.S. Government.

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COMPETING INTERESTS

The authors declare no competing interests.

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