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Classifications and level of evidence trends from the most influential literature on thoracolumbar burst fractures: A bibliometric analysis

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ABSTRACT

Background: There are known classifications that describe thoracolumbar (TL) burst type injury but it is unclear which have the most influence on management. Our objective is to investigate the association of classification publications with the quantity and type of the most influential articles on TL burst fractures.

Methods: Web of Science was searched, and exclusion and inclusion criteria were used to extract the top 100 cited articles on TL burst fractures. The effects on type, number, and other variables were separated into four eras as defined by four major classification publications.

Results: 30 out of the top 100 articles represent level 1 or 2 evidence. The most influential journal was *Spine*, accounting for 35 articles and 4,537 citations. The highest number of articles (53) was published between the years 1995-2005, culminating with the Thoracolumbar Injury Severity Classification Score (TLICS) paper. After 2005, there was an increase in average citations per year. Following 2013, the number of highly influential articles decreased, and systematic reviews (SRs) became a larger proportion of the literature. There was a statistically significant increase in the level of 1 and 2 evidence articles with time until the publication of TLICS. The predictive value of time for higher levels of evidence was only seen in the pre-2005 years (AUC: 0.717, 95% CI 0.579-0.855, $p = 0.002$).

Conclusions: In 1994, two articles marked the beginning of an era of highly influential TL burst fracture literature. The 2005 TLICS score was associated with a preceding increase in LOE and productivity. Following 2005, the literature saw a decrease in productivity and an increase in systematic review/meta-analysis (SR-MAs). These trends represent an increase in scholarly discussion that led to a systematic synthesis of the existing literature after publication of the 2005 TLICS article.

Introduction

The incidence of thoracolumbar (TL) injuries has increased in the past ten years [1]. Of all spinal fractures, 90% occur in TL levels [1]. Burst fractures resulting from high-energy injury to the vertebral bodies comprise 14% of all spinal fractures [1]. The majority of injuries to the TL spine occur at the junction (50%-60%) involving the T12 or L1; 25-40% and 10-14% of injuries occur at the thoracic and lumbar regions, respectively [1,2].

The treatment of TL burst fractures remains a topic of debate, and it is unclear which classification system is most influential in guiding treatment. Surgical decompression and biomechanical support restoration can be performed by a posterior, anterior, or combined approach, or minimally invasive techniques [3]. Conservative treatments include bracing, physiotherapy, and pharmacotherapy [4].

There are four known classifications for TL injury classification that describe burst injury [5–8]. The 1994 AO Classification and Load Sharing Classification (LSC) papers describe morphology and degree of in-

Abbreviations: TL, thoracolumbar; LSC, Load Sharing Classification; TLICS, Thoracolumbar Injury Severity Classification Score; LOE, level of evidence; ROC, receiver operating characteristic; AUC, area under the curve; SR-MA, systematic review with meta analysis; RCT, randomized controlled trial; SR, systematic review.

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jury [5,6]. In 2005, the Thoracolumbar Injury Severity Classification Score (TLICS) was described as a scoring system based on fracture characteristics, neurological status, and ligamentous integrity [7]. The latest of such classifications was published in 2013 and incorporates the 1994 AO Classification and 2005 TLICS [5,6,8]. Our objective is to analyze trends among the most influential TL burst fracture papers and their associations with the four major classification papers to describe the current state of knowledge.

Methods

Study design

This was a bibliometric analysis performed on 7/2/2021. The Web of Science was queried for using keywords ("thoracic" OR "lumbar" OR "thoracolumbar") AND ("burst" OR "A3" OR "A4") NOT ("oncology" OR "pathologic" OR "Cancer"). Exclusion criteria included (1) burst fracture not explicitly discussed, (2) not available in the English language, (3) the study was not a clinical study (i.e., cadaveric), and (4) article was one of the classification papers. Articles were organized in descending order of Times Cited and then screened by an author (J.F.D.) for inclusion and exclusion criteria using the titles and abstracts. This was reviewed by another author (S.V.) Eligible articles were then obtained for data extraction of variables of interest.

After review, we found that some noteworthy articles describing traumatic TL burst fractures that were not captured by the initial search. The keywords "injury" and "trauma" were therefore determined to be necessary for more comprehensive results. A second search was performed. These results were then checked for duplicates, screened for exclusion criteria, and integrated by citation ranking with the first search's top 100 cited articles. Classifications that include descriptions of burst fractures and their management were identified separately and those that were thought to be most clinically relevant were chosen (Original AO and LSC (1994), TLICS (2005), New AO (2013)).

Data extraction

The final articles were searched for variables of interest, including year of publication, first author, study type, and use of classification articles in the references. From the study type, the level of evidence (LOE) was determined as per classifications developed by the Centre for Evidence Based Medicine (CEBM) [20]. Timeline was divided into eras determined by the publication of the classification papers: 1990-1994, 1995-2005, 2006-2013, and 2014-present. Each era could be analyzed to determine the effect of the previously published classification article. Older papers may have greater total numbers of citations; therefore, we use the metric citations/year to attempt to correct for this when appropriate.

Statistical analysis

Statistical analyses were conducted using SPSS (IBM SPSS Statistics for Windows, Version 28.0. Armonk NY:IBM Corp). Logistic regression was performed to determine the association between variables of time and LOE. Linear regression analysis was performed to analyze the association of impact factor with LOE and citation count. Receiver operating characteristic (ROC) curves were used to determine area under the curve (AUC) to evaluate the robustness of the predictive value of time for LOE. A p-value of < 0.05 was considered significant.

Results

The initial search yielded 2,089 articles. The top 250 most cited articles were extracted for evaluation of inclusion/exclusion criteria. The second search yielded a total of 1,028 articles. After duplicates were removed and inclusion criteria applied, the top 100 articles from this search were identified. We combined the articles from each search query, removed duplicates, and developed the final top 100 list **(Fig. 1).** The final articles selected were re-ranked using their times cited in all databases, as the default rank was times cited in Web of Science (**Supplement A**). The references section of the articles were then searched for citations of the four classification papers.

General characteristics

The Top 100 most cited TL Burst Fracture articles had a range of 55-360 citations per article and were published between 1990 to 2015. The most cited article was Wood's "*Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit - A prospective, randomized study"*, published in *JOURNAL OF BONE AND JOINT SURGERY-AMERICAN VOLUM*E in 2003[9] **(Table 1).** Of the 23 journals represented, *Spine* had the most qualifying articles (35) and overall citations (4537) **(Table 2).** Countries with the most top cited articles were the United States, Netherlands, Germany and China**.** Oner, affiliated with University Hospital Utrecht in the Netherlands, was the most published and cited author amongst the top 100 most cited articles. Wood was the most cited first author (971 overall citations, 906 first author citations), while Knop was the most published first author (852 overall citations, 7 first author articles with 713 citations) amongst the top 100 most cited articles. Oner was the most cited senior author (1095 overall citations, 665 senior author citations). Retrospective studies made up 38 of the top 100 most cited articles and had the most total citations (3855), while Systematic Reviews/Meta-Analysis (SR-MA) had the most citations per article (146.71) amongst the top 100 most cited articles **(Table 3).**

Top 10 most cited articles

The Top 10 most cited articles were published between 1997 and 2014, with 9 of them from 2000 onwards. Total citations ranged from 199 - 360, and citations per year ranged from 11.24 - 24.88 (Table 1). *Spine* contains 7 of the top 10 most cited articles. Among the top 10 most cited, there are 5 randomized controlled trials, 2 SR-MAs, 2 retrospective studies, and one prospective cohort study (**Table 1**). The classifications are cited by eight of the Top 10 most cited: LSC is cited 6 times, Original AO 4 times, and TLICS once.

Journals

Of the articles in the Top 100, *Spine* was the most represented and cited journal, with 35 articles and 4,537 citations. The *European Spine Journal* and *Journal of Spinal Disorders & Techniques* followed, with 14 articles and 1,435 citations in the former and 9 articles and 1,055 citations in the latter amongst the top 100 most cited articles. The *Journal of Bone and Joint Surgery-America* was also frequently published in and cited, with 6 articles and 1,037 citations from Top 100 articles. 19 more journals held Top 100 articles and citations; however, the number of articles and citations dropped precipitously, ranging from 4 articles and 372 citations in the *Journal of Neurosurgery-Spine* to 1 article and 55 citations in *Injury-International Journal of the Care of the Injured*. (**Table 2**). No correlation between two, three, and four-year impact factor and number of citations in the Top 100 was seen.

Article types

Retrospective chart reviews were the most common study type, making up 36 of the articles and cited 3642 times, 101.19 citations per article. RCTs and prospective cohort studies were the second most common, with 23 articles and 3281 total citations and 23 articles and 2305 total citations, respectively. SR-MAs made up 6 of the articles with 828

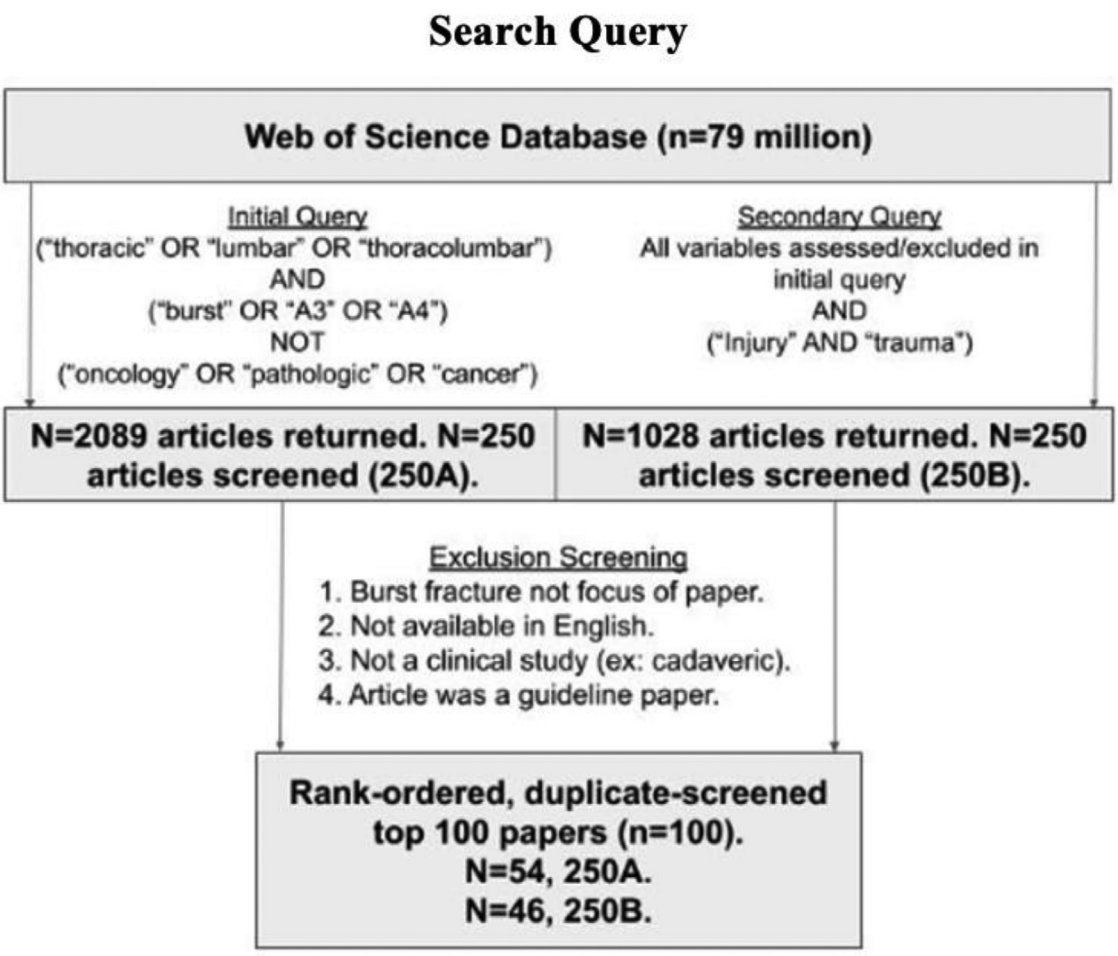

Fig. 1. Search query with inclusion and exclusion criteria applied. Search Query used to create Top 100.

citations, or 138 citations per article. Literature reviews made up 7 articles with 763 citations total, or 109 per article. There were 5 case-controlled studies with a total of 457 citations, or 91.4 citations per article. **(Table 3)**

Era descriptions

Eras were defined by the articles by Magerl et al., 1994, McCormack et al., 1994, Vaccaro et al., 2005, and Vaccaro et al., 2013 [5–8]. 1990 is the start of the first era since it marks the oldest paper in the Top 100. The year of publication of each classification system marks the final year of the era. The highest number of articles regarding TL burst fractures was 53 in the 1995-2005 era **(Table 4)**. In the 2006-2013 era, 39 articles were published. From 2014 to present, there have been 6 publications in the Top 100. Only two articles in the Top 100 were published before the 1994 Magerl and McCormack classifications. The percentage of LOE 1 and 2 increased through time, with the biggest change seen with LOE 2 evidence articles **(Table 4)**. The era right after TLICS, 2006-2013, saw the highest density of publications within the Top 100, with 4.88 articles per year. This dropped to 0.88 articles per year in the era from 2014-present **(Table 4)**. There was a statistically significant increase in LOE and number of LOE 1 and 2 articles in the Top 100 most cited articles. Receiver Operating Characteristics Area Under the Curve (ROC-AUC) demonstrated that increasing years in pre-2005 showed stronger predictive value (AUC: 0.717) for increasing levels of evidence than did the post-2005 years (AUC: 0.595). **(Fig. 2)**

Most recent RCTs

The five most recent RCTs in the Top 100 assess outcomes of operative and non-operative treatment. Wood et al., 2015 evaluated 19 operative and 18 non-operative patients and concluded that in the neurologically intact patient with a stable TL burst fracture, non-operative management is optimal [9]. Bailey et al., 2014 evaluated the use of a brace in 47 patients versus no brace in 49 patients with TL burst fractures without neurological injury, concluding that no orthosis was necessary [10]. A comparison of an MIS percutaneous approach in 31 patients versus that of a paraspinal approach in 30 patients was made by Jiang et al., 2012. The study found that an MIS approach was favorable given postural reduction was achievable [11]. Jindal et al., 2012 compared short segment pedicle screw fixation and found that adjunctive fusion of the affected segment was unnecessary [12]. Farrokhi et al., 2010 looked at 42 patients in which the fracture level was excluded and 38 patients in which the fracture level was included in the fusion construct [13]. Here, they found that inclusion of the fracture level had better radiographic and clinical outcomes **(Table 5)**.

Discussion

Using the top 100 most influential articles on TL burst fractures, we show that the 2005 TLICS paper marked a critical point in the literature. In the years leading up to 2005, culminating in the TLICS article, high productivity and LOE trends suggest robust efforts of investigation. After TLICS, the subsequent years see an eventual decrease in productivity,

Table 1
General characteristics of the top 10 most cited articles.

Rank	Authors	Title	Study Type	Classification Used (Used/Available)	Journal
1	Wood et al., 2003	Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit - A prospective, randomized study	Randomized Controlled Trial	None (0/2)	JOURNAL OF BONE AND JOINT SURGERY-AMERICAN VOLUME
2	Verlaan et al., 2004	Surgical treatment of traumatic fractures of the thoracic and lumbar spine - A systematic review of the literature on techniques, complications, and outcome	Systematic Review/Meta-Analysis	None (0/2)	SPINE
3	Parker et al., 2000	Successful short-segment instrumentation and fusion for thoracolumbar spine fractures - A consecutive 4(1)/(2)-year series	Retrospective	LSC, Original AO (2/2)	SPINE
4	Alanay et al., 2001	Short-segment pedicle instrumentation of thoracolumbar burst fractures - Does transpedicular intracorporeal grafting prevent early failure?	Randomized Controlled Trial	LSC (1/2)	SPINE
5	Kaneda et al., 1997	Anterior decompression and stabilization with the Kaneda device for thoracolumbar burst fractures associated with neurological deficits	Prospective Cohort	None (0/2)	JOURNAL OF BONE AND JOINT SURGERY-AMERICAN VOLUME
6	Shen et al., 2001	Nonoperative treatment versus posterior fixation for thoracolumbar junction burst fractures without neurologic deficit	Randomized Controlled Trial	LSC (0/2)	SPINE
7	Knop et al., 2001	Late results of thoracolumbar fractures after posterior instrumentation and transpedicular bone grafting	Randomized Controlled Trial	Original AO (1/2)	SPINE
8	Mahar et al., 2007	Short-segment fixation of lumbar burst fractures using pedicle fixation at the level of the fracture	Retrospective	LSC, Original AO (2/3)	SPINE
9	Siebenga et al., 2006	Treatment of traumatic thoracolumbar spine fractures: A multicenter prospective randomized study of operative versus nonsurgical treatment	Randomized Controlled Trial	LSC, Original AO (2/3)	SPINE
10	Wood et al., 2014	Management of thoracolumbar spine fractures	Systematic Review/Meta-Analysis	LSC (1/3)	SPINE JOURNAL

Rank, author, year of publication, title, study type, classification referenced, and journal of publication of the Top 10 most-cited articles.

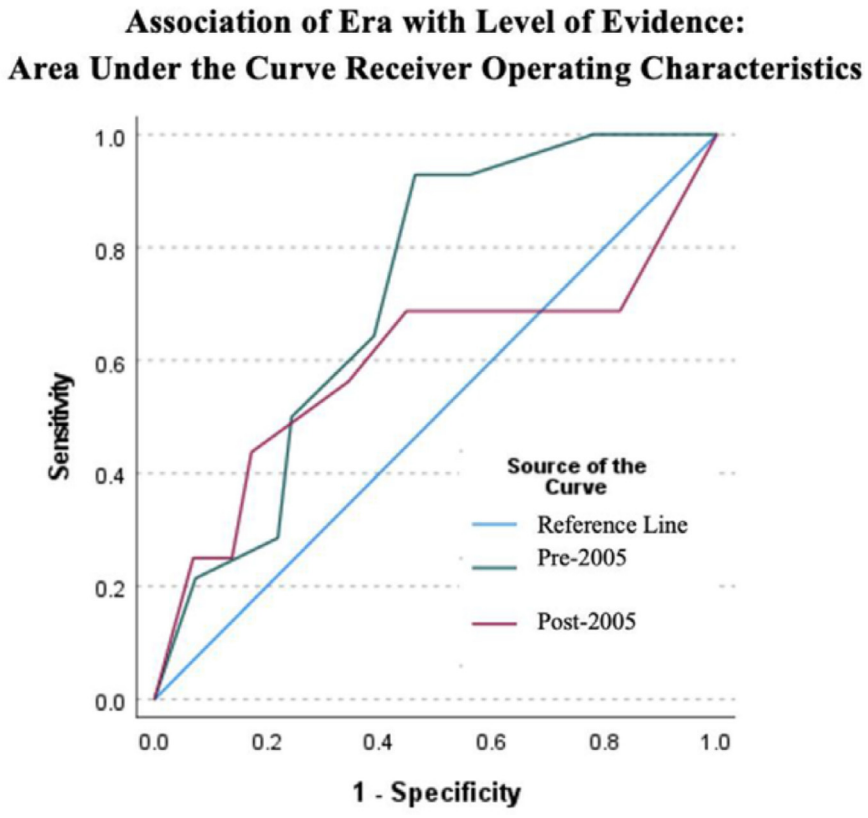

Fig. 2. Area Under the Curve Receiver Operating Characteristics. Area under the curve (AUC) analysis showing pre 2005 (0.717 95%CI (0.579-0.855) p = 0.002) shows stronger predictive value for increasing LOE than and post 2005 (0.595 95%CI (0.401-0.789) p = 0.339). An AUC closer to 1 suggests greater predictive value of the variable in question (LOE). 1-specificity is the probability that a true negative will test positive. Sensitivity is the ability of a model to correctly identify the variable in question (LOE).

Table 2
Journals represented in the top 100 most cited articles.

Name of Journal	N Articles	Total Citations
Spine	35	4537
European Spine Journal	14	1435
Journal Of Spinal Disorders & Techniques	9	1055
Journal Or Bone And Joint Surgery - American Volume	6	1037
Journal Of Neurosurgery - Spine	4	372
Unfallchirurg	4	336
Spine Journal	3	311
Surgical Neurology	3	298
Acta Neurochirurgica	3	289
Neurosurgery	2	225
Archives Of Orthopaedic And Trauma Surgery	2	213
Journal Of Neurosurgery	2	198
Journal Of Bone And Joint Surgery-British Volume	2	174
Clinical Orthopaedics And Related Research	2	169
Clinical Neurology And Neurosurgery	1	80
Orthopedics	1	80
Skeletal Radiology	1	80
American Journal Of Roentgenology	1	79
International Orthopaedics	1	75
Journal Of The American Academy Of Orthopaedic Surgeons	1	65
Spinal Cord	1	58

Journals that published the most cited articles.

Table 3
Study types of the top 100 most cited articles.

Study Type	Number of Articles	Total Citations	Number of citations/Article
Retrospective Chart Review	36	3643	101.19
Randomized Controlled Trial	23	3281	142.65
Prospective Cohort	23	2305	100.22
Systematic Review/Meta-Analysis	6	828	138
Literature Review	7	763	109
Case-Controlled	5	457	91.40

Number of articles, total citations, and number of citations per article of each study type.

and study type morphs into SR-MAs rather than prospective investigations. No other classification marks the result of such research efforts, nor has it been associated with such a dramatic change in literature trends that follow it.

A previous 2017 bibliometric review on the top 50 most influential papers on TL fractures highlights an important feature of the literature regarding burst fractures [14]. While our review only found 2 articles published before 1994, the previous TL fracture review included a total of 31 articles from the 1980s and 1990s. This suggests that the wide appreciation of burst fracture as a unique injury pattern is a relatively recent development. The differences between that study and this one are attributed to our study's selective focus on burst-type injury [1,15].

The AO classification and the TLICS score

The AO Classification is based on pathomorphological criteria, and categories are established according to the main mechanism of injury, pathomorphological uniformity, and healing potential [5]. The LSC assigns points based on fracture characteristics to guide the degree of surgical reconstruction needed [6]. Although both are comprehensive and detailed descriptions of TL spine injury, they do not address operative

Table 5
Most recent randomized controlled trials in the top 100 most cited articles.

Citations (Rank)	Author, Year	Title	Comparison Groups	N, Subjects	Conclusions
72 (75)	Wood et al., 2015	Operative Compared with Nonoperative Treatment of a Thoracolumbar Burst Fracture without Neurological Deficit	Operative treatment (posterior or anterior arthrodesis) Nonoperative treatment (body case or orthosis)	19 Operative 18 Nonoperative	Nonoperative treatment is the optimal management of the neurologically intact patient with a stable thoracolumbar burst fracture.
56 (96)	Bailey et al., 2014	Orthosis versus no orthosis for the treatment of thoracolumbar burst fractures without neurologic injury: a multicenter prospective randomized equivalence trial	Treated with early ambulation and orthosis (TLSO) No orthosis (NO)	47 TLSO 49 NO	Thoracolumbar burst fracture can be successfully treated with early mobilization and no orthosis
56 (95)	Jiang et al., 2012	Comparison of a Paraspinal Approach with a Percutaneous Approach in the Treatment of Thoracolumbar Burst Fractures with Posterior Ligamentous Complex Injury: a Prospective Randomized Controlled Trial	Percutaneous fluoroscopically-guided pedicle screw rod fixation Paraspinal fluoroscopically-guided pedicle screw-rod fixation	31 percutaneous 30 paraspinal	Minimally invasive percutaneous approach appears to be better in cases of successful postural reduction. Paraspinal approach is still recommended for patients without successful postural reduction.
60 (91)	Jindal et al., 2012	The role of fusion in the management of burst fractures of the thoracolumbar spine treated by short segment pedicle screw fixation A prospective randomised trial	Fusion in short segment pedicle screw fixation Non-fusion in short segment pedicle screw fixation	23 fusion 24 non-fusion	Adjunctive fusion is unnecessary when managing TL burst fracture with short segment pedicle screw fixation.
79 (68)	Farrokhi et al., 2010	Inclusion of the fracture level in short segment fixation of thoracolumbar fractures	Excluding fracture level Including fracture level	42 excluding fracture level 38 including fracture level	Inclusion of the fracture level into the construct has better kyphosis correction with a comparable if not better clinical and functional outcome.

Characteristics of the most recent randomized-controlled trials in the Top 100.

Table 4
Number of most cited articles, classifications used, and number of LOE 1 and 2 articles within each era.

Era	Number of articles (Top 100); Articles/Year in Era	Classifications Used by Top 100 (No. of articles that reference guideline)
1990-1994	2; 0.4	None
1995 - 2005	53; 4.82	Original AO (14 articles), LSC (10)
2006 - 2013	39; 4.88	Original AO (22), LSC (18), TLICS (3)
2014-present	7; 0.88	Original AO (2), LSC (3), TLICS (1)
Era	**Number of Level 1; Avg Citation/Year of Publication**	**Number of Level 2; Avg Citation/Year of Publication**
1990-1994	0; N/A	0; N/A
1995-2005	1; 19.06	13; 8.53
2006-2013	3; 8.11	8; 9.11
2014-present	1; 11.43	2; 8.64

Number of articles, classification used, and articles per number of years in each defined era. Number of Level 1 and 2 Evidence articles, along with average citation per year of publication

candidate selection. The large volume of literature that followed these 1994 publications attempts to answer this question. Vaccaro et al., 2005 intends to create a meaningful communication system between surgeons [7,16]. In 2013, a second AO Classification system was created by Vaccaro et al., which combines the original AO by Magerl et al., 1994 and the TLICS [5,8].

By design, the TLICS generates a numerical score for a given TL fracture. Higher values (greater than 4) indicate surgical necessity, while lower values (0-3) suggest nonoperative treatment. For those with a TLICS score of 4, there is flexibility for surgical consideration that allows room for surgeon preference. Approximately 29% of burst fractures have a TLICS score of 4, allowing for a significant amount of ambiguity [17]. We believe this built-in-ambiguity of the TLICS score has been the driver for the continued productivity of SR-MAs in the era following its publication. The TLICS score's influence and durability are emphasized by its inclusion in the new AO Classification from 2013.

Era characteristics and LOE trend

The majority of articles come from 1995-2013, representing the 2nd and 3rd eras. From these, the years 1999 and 2006 each had 10 articles. Seven articles were published in 2001 (3 in top 10), 2004 (1 in top 10), 2007, and 2010. The most articles per year come from the 1995-2005 era, representing the building evidence leading to the 2005 TLICS paper. Following the TLICS paper, a decrease in articles written per year in the 3rd and 4th era combined is eventually seen, particularly after 2013. Despite the decrease in number of articles per year, there is a large increase in the average citation per article per year. Throughout the years of the articles examined, there was a trend first towards a relative decrease in retrospective review and increase in RCT. After 2005, a new trend showed an increase in SRs and decrease in RCT. There is a statistically significant increase in the LOE as the topic evolves from retrospective analysis to more robust prospective RCT. However, this increase of LOE with time is only seen in the period leading up to 2005. Subsequent years (2005-present) show no such association with LOE increase. The exhaustion of clinical questions regarding TL burst fractures may partially explain this. TLICS may have provided the field with the current optimal decision-making tool for the management of burst fractures, explaining the apparent conclusive LOE trends.

Limitations

TLICS is cited only four times among the top 100; therefore, this study only shows a trend in the literature suggesting TLICS influence on the articles produced. The quantitative nature of bibliometrics is a limitation, as recognition may not equate to quality and impact. Citation number was used as a proxy for influence, but we must acknowledge that many factors affect both citation rates and influence. The citation number used did not control for self-citation, incomplete citing, and omission bias [18]. Although a qualitative assessment of the highlighted articles is included, a more holistic approach might include peer review and methodological analysis [19].

The use of only 100 articles is not ideal, although this was thought to be addressed by using the most influential ones. Our search strategy was carefully carried out, but some articles may have been inadvertently missed. Another limitation is that only one database, Web of Science, was used in our search strategy. Although later years are likely to have less influential papers, the fact that there are increased systematic reviews in later years suggests a degree of saturation in the literature with the topic of burst fractures.

Conclusion

The top 100 most influential papers discussing TL burst fractures represent studies with relatively high LOEs, especially in those most cited. There is an overall increase in the LOE of these articles with increasing year, particularly in the pre-2005 period. Evaluating separate eras marked by important classifications reveals a reversal of this trend after 2005. The LOE and productivity trends after 2005 appear to show an increase in scholarly discussion culminating in the 2005 TLICS article, which was followed by a systematic synthesis of the existing literature.

Disclosures

The authors declare that they have no conflict of interest.

Short Summary

Past literature trends suggest an ambiguity in the management of thoracolumbar burst fractures. Although research productivity continued to increase, level of evidence culminated with 2005 TLICS, and literature has morphed into systematic reviews rather than prospective studies.

Supplement A: Top Most Cited Articles

Declarations of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.xnsj.2022.100125.

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