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Pro-Metrics

ORIGINAL ARTICLE

Fracture research from India between 1989 to 2022: A scientometric study

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ABSTRACT

Objective. Research on fractures has increased rapidly in India in recent years, but no bibliometric study has been performed on this subject. From the Scopus database, we aimed to examine the bibliometric characteristics, trends, and current status of India's fracture research and publications between 1989 and 2022.

Design/Methodology/Approach. We identified the key organizations, authors, journals, and important keywords, besides studying and visualizing their collaborative interactions using VOSviewer and Biblioshyn software.

Results/Discussion. The 1046 India fractures research publications were identified and cited 8927 times. External funding was received by 1.91%, and 11.95% had international collaboration. The 894 authors from 304 organizations and publishing in 88 journals were involved in India's fracture research. The most productive organization was AIIMS, New Delhi. The most impactful organization was JIPMER, Pondicherry; the most productive author was V. Trikha. The most productive journal was the Indian Journal of Orthopaedics (n=257), and the most impactful journal was Acta Orthopaedica. Femur was the top anatomical location studied for fracture research, followed by Humerus and Tibia. Hip fractures were the most emphasized fracture research areas in older people, in contrast to Humerus, and Femur fracture research in adolescents and children. Delhi was the epicentre of research.

Conclusions. This study is the first comprehensive bibliometric analysis of India's fracture research over 30 years. It provided an insight into its current and past research status and hopes to guide scholars to understand research frontiers and directions in fracture-related research.

Keywords: bibliometrics; bone; fracture; high cited publications; India; orthopaedics; scientometrics.

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1. INTRODUCTION

Fractures are usually the result of traumatic events like falls, road traffic accidents (RTA) and sports injuries. Other causes are osteoporotic fractures, stress or insufficiency fractures, and pathological fractures. The pathophysiology of fractures encompasses many factors that determine bone strength (bone mass, bone quality, age and skeleton geometry) and the frequency, nature and effects of injuries. Each of these factors becomes more prevalent with advancing age, resulting in an exponential increase in the prevalence of osteoporosis-related fractures in elderly individuals (Pfeiffenberger *et al.,* 2021).

Fractures are considered a public health concern as they impose significant healthcare impact and health burden on an individual level, the public medical system and the whole society. They also increase mortality and disability (Häussler *et al.,* 2006; Rawhki *et al.,* 2020), especially in people with osteoporosis (Joshi *et al.,* 1998). They are also responsible for work absence and decreased productivity, significantly impacting health and quality of life (Krishna and Mehta, 2000; Khajuria *et al.,* 2011; Medical News Today, 2023). Therefore, studying the various aspects of fracture research should help scholars and policymakers evaluate and formulate public health decisions and implement appropriate fracture control measures. Thus, fractures and their consequences are of high interest in current and future medical care.

A bibliometric method is an application of mathematical and statistical methods of statistical analysis of scientific communication. It is an accepted and established methodology for assessing a particular subject's characteristics and major developmental trends based on publications. It also provides a better understanding of how research is produced, organized, and interrelated. It can measure the contribution and impact of an individual author, journal, institution, or country by relevant parameters on a specific topic (Khalil *et al.,* 2015; Mohan and Joyce, 2015; Bornmann and Leydesdroff, 2014). Another advantage of bibliometric analysis is mining valuable information and visually displaying it intuitively.

A large number of fracture-related articles have been published in recent years. However, the trend of fracture research is unclear. It is also a challenge to analyze the research on this topic comprehensively. This bibliometric analysis will provide a quantitative and qualitative assessment of India's fracture research over the last three decades. Various scholars have utilized the bibliometric analysis methodology for assessing and evaluating the current status and trends of research in multiple types of fractures, including ankle (Zeng *et al.,* 2022), calcaneus (Goedderz *et al.,* 2022), distal radius (Grant and Chung, 2021; Jones *et al.,* 2017), femoral neck (Peng *et al.,* 2022), hips (Hu *et al.,* 2022; Zhang *et al.,* 2021; Wu *et al.,* 2021; Agar and Sahin, 2022), maxillofacial (Tekin and Bahsi, 2021), odontoid (Donnally *et al.,* 2019), olecranon (Marder *et al.,* 2022), osteoporosis vertebral compression (Li *et al.,* 2022), proximal humerus (Cantrell *et al.,* 2019), Sacral (Huang *et al.,* 2020), scaphoid (Irwin *et al.,* 2020), spine fracture (Donally *et al.,* 2019), and thoracolumbar fractures (Ankomah *et al.,* 2018; Vazquez *et al.,* 2022).

In India, no estimates exist of the incidence and burden of different types of fractures. Fracture rates have increased threefold in Asia over the last 30 years, with India and China leading in this area (GBD2019 Fracture Collaborators, 2021; Ministry of Road Transport Highways, 2023). Due to the rising number of fracture cases over the past few decades, it has been increasingly recognized as a critical topic in orthopedic research, resulting in many publications reporting the results of various fractures from India. A review of the current and past literature on this topic from India can lead to a better appreciation of current management practices. No comprehensive study of national incidence, prevalence, and years lived with disability (YLDs) of fractures exists in India, and no bibliometric study on India's fracture research has been published. This bibliometric analysis aims to identify the most influential publications on India's fracture research, explore the research directions, analyze the research status and trends, and provide related information.

2. MATERIAL AND METHODS

The Scopus database was interrogated for identification, retrieval, and downloading

of relevant manuscripts published between 1989 and 2022 in the topic domain through a structural search in the Scopus database using the following search strategy on 2nd December 2022. The following keywords terms 'fractures", "orthoped* or "orthopaed" were searched in "title" and 'source title" fields. From the 1046 literature records, various bibliographic records of each record were extracted, and statistical analyses were performed. The following is the search strategy employed to retrieve the data:

((TITLE(fracture) AND TITLE(orthoped* or orthopaed*)) AND PUBYEAR > 1988 AND PUBYEAR < 2023) OR ((TITLE(fracture) AND SRCTITLE(orthoped* or orthopaed*)) AND PUBYEAR > 1988 AND PUBYEAR < 2023) AND (LIMIT-TO (AFFILCOUNTRY,"India"))

A full document record, including title, date of publication, author, countries/regions, published journal name, keywords, and abstract,was downloaded from the Scopus database as a Txt file and imported into Microsoft Excel 2019 for further data processing and graph plotting. From the obtained 1046 literature records, data extracted from each document including the general information about the annual number of publications, citation frequency, average citations per item, original countries and institutions, authors, journals, funding agencies, and H-index were extracted and statistical analysis performed.

VOSviewer and Excel software were used for collecting and analyzing the retrieved data. Excel software, in particular, was used to identify various details of the publication, including title, author, journal, institution, country, year of publication, citation reports, and the number of published articles. VOSviewer, in particular, was used for visualizing the co-authorship of countries, authors, and organizations, the journal co-citations, and keywords co-occurrence. We used a visual approach to analyze the essential keywords from the literature and classified them into 3 clusters (diagnosis, treatment, and complications). The thickness of the connecting line indicates the link strength of the two keywords. In the network visualization map created by VOSviewer, different nodes represent various parameters, such as countries, organizations, authors, journals, and keywords. The node's size in the map is proportional to the number of publications, references or occurrences. Total link strength (TLS) represents the connection strength between the nodule and other nodes.

3. RESULTS

3.1. Growth of India's fracture research

The 1046 papers on India's fracture research were reported during the last 34 years (1989-2022) (Supplementary Table 1). The yearly publications on fractures from India, increased from only 03 in 1989 to 93in 2022 (Figure 1), registering an annual average growth rate of 23.95%. The cumulative Indian publication has risen from 75 (from 1989 to 2005) to 971 (from 2006 to 2022), registering an absolute growth of 1194.67%. The highest number of papers (n=93) were published in 2020. However, the global share of India's publications was 3.77% from 1989-2022, which increased from 1.08% (1989-2005) to 4.67% (2006-2022). These 1046 papers have received 8927 citations, averaging 8.53 citations per paper (CPP).

3.2. Fractures by Anatomical Location

By anatomical locations, the most significant number of papers were on Femur (298 papers and 28.49% share), followed by Humerus (112 papers and 10.71%), and Tibia (105 papers and 10.04%), etc. (Fig. 2). In terms of CPP, the most significant impact was made by Clavicle (13.79), followed by Forearm (12.95), Hips (12.64), Spine (12.,34), and Humerus (10.9), etc. (Supplementary Table 2).

3.3. Citation impact of the papers

In terms of citation impact per paper, Osteoporotic fractures registered the highest impact (16.89), followed by the fractures of the Humerus (13.13), Clavicle (13.05), Thoracolumbar Spine (12.91), Ulna (12.86), Pilon (12.75), Intertrochanteric femoral (12.62), Hip (12.44), Monteggia (12.25), Spinel (12.10), Subtrochanteric femur (11.47), Femoral Neck (10.80), Vertebra (10.0), Tibia (9.99), and Femur (9.64).

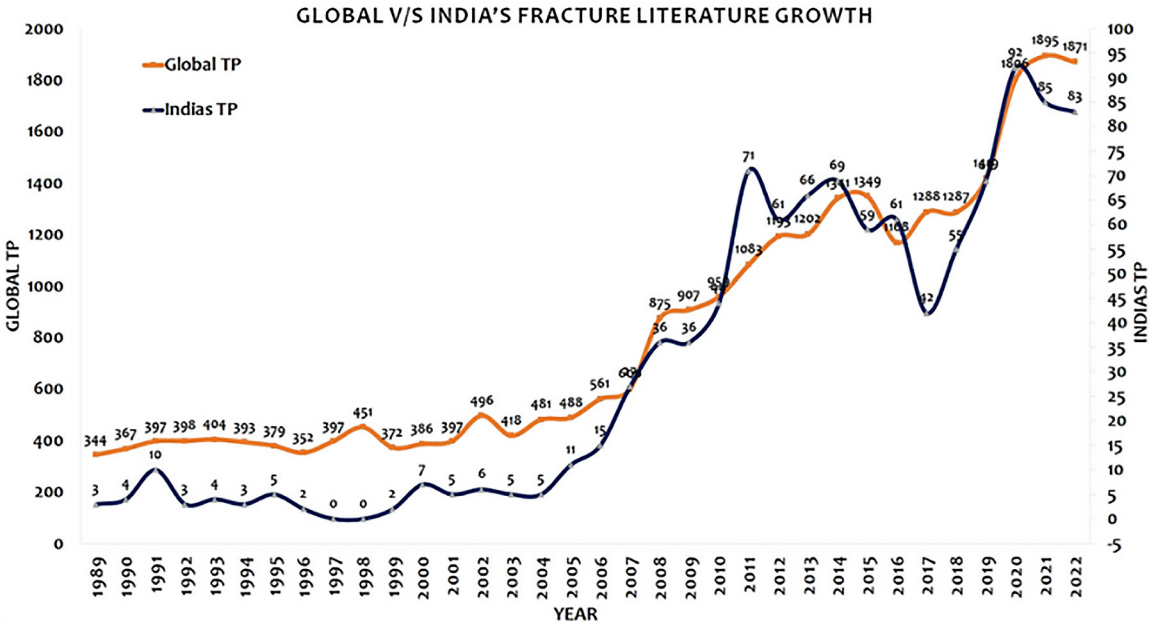

Figure 1. Global vs India's Fracture Literature Growth between 1989-2022.

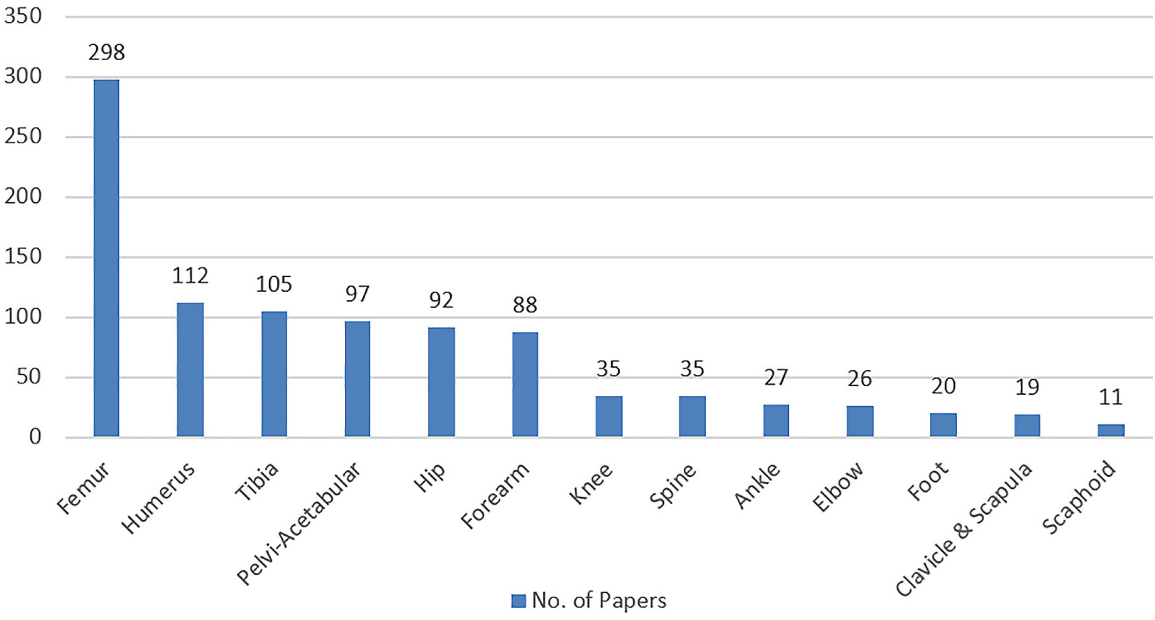

Figure 2. Distribution of publications by anatomical location of the fractures.

3.4. Fracture Type by Population Age Groups

Among the 1046 papers, 425 were focused on the adult population, 207 on aged, 2002 on children and adolescents, and 188 on middle age population group. There is an overlapping of papers among these population age groups, as more than one fracture can be reported in each paper (Supplementary Table 3).

3.5. Significant Keywords

4448 author keywords appeared in 1046 papers on India's fracture research. Among them, 2940 keywords appeared only once. 989 keywords occurred 2-5 times, 219 keywords occurred 6-10 times, 265 keywords occurred 11-100 times, and 35 keywords occurred 101 – 710 times, respectively. The important

keywords with the comparatively largest frequency of occurrence were "Osteosynthesis" (n=242), "Fracture Healing" (n=238), "Fracture Fixation" (n=188); and "Fracture Fixation, Internal" (n=166), "Surgical Techniques" (n=145), "Fracture Nonunion" (n=139), Intra-medullary Nailing" (n=137), etc. (Supplementary Table 4).

Eighty-eight keywords with a frequency of 10 or more were chosen for the co-occlusion network. The co-occurrence keyword analysis examined the frequency of two co-occurred keywords. We used a visual approach to analyze the important keywords from the literature and constructed a keyword co-occurrence network map, which classified the 88 keywords into 5 clusters. As shown in Figure 3, we can identify the clusters in different colors representing different research directions.

The keyword co-occurrence network map (Figure 3) was constructed with the help of VOSviewer. The higher the frequency of co-occurrence of two words, the closer the relationship between them, indicated by the position of the two words. The node size means how often the keyword appears with other keywords. Figure 3 presents the 88 keywords, which are classified into 5 clusters, and each cluster is presented with a particular color. The 88 keywords have 2704 links with total link strength (TLS) of 15705:

- Cluster 1 (Red, 28 keywords) includes Ankle Fractures, Fracture Healing, Antibiotic Agent, Bone Graft, Bone Transplantation, etc.
- Cluster 2 (Green, 23 keywords) includes vitamin D, weight-bearing, osteoporosis, hip dislocation, hip fractures, etc.
- Cluster 3 (Blue, 18 keywords) includes osteosynthesis, fractures, injury, etc.
- Cluster 4 (15 keywords)
- Cluster 5 (4 keywords)

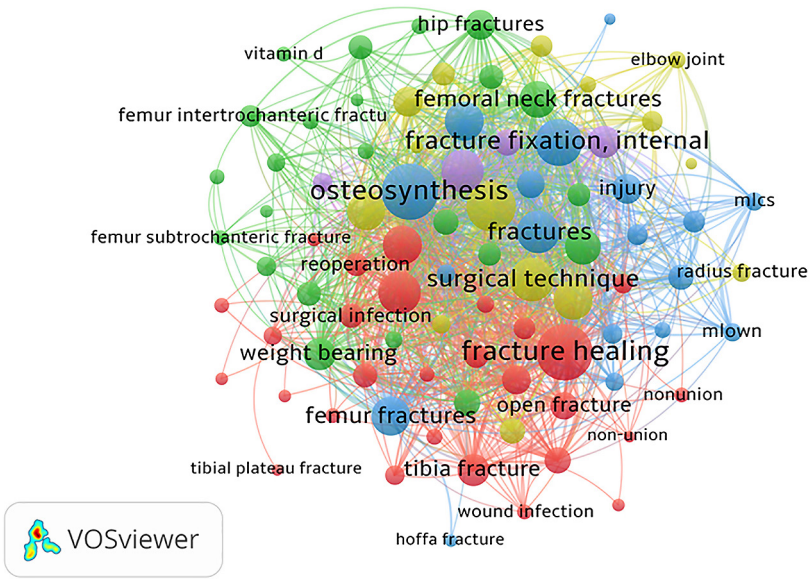

Figure 3. Co-occurrence network of the significant keywords.

3.6. Most Productive and Most Impactful Organizations

In all, 304 organizations participated in 1046 Indian papers on fracture research, of which 256 organizations published 1-5 papers each, 20 organizations 6-10 papers each, 19 organizations 11-20 papers each, 7 organizations 21-50 papers each and 2 organizations 101-20 papers each. The top 30 organizations (Supplementary Table 5) individually published 9-120 papers and published 752 papers and 6565 citations, accounting for 71.89% and 73.54% share in total Indian papers and citations. Further analysis showed that 8 organizations contributed more than the average group productivity (25.07) of all 30 organizations (Table 1). The 8 organizations registered CPP and relative citation index (RCI) of more than average value (8.73 and 1.02) of all 30 organizations (Table 1).

No.	Affiliations	TP	TC	CPP	RCI
	Most productive organization				
1	AIIMS, New Delhi	120	984	8.20	0.96
2	PGIMER, Chandigarh	101	807	7.99	0.94
3	UCMS, Delhi	46	386	8.39	0.98
4	Guru Teg Bahadur Hospital, Delhi	42	352	8.38	0.98
5	MAMC, Delhi	35	575	16.43	1.93
6	VMMC & Safdarjung Hospital, New Delhi	33	265	8.03	0.94
7	Pt. B.D. Sharma PGIMS, Rohtak	33	436	13.21	1.55
8	Dr. Ram Manohar Lohia Hospital, New Delhi	26	221	8.50	1.00
	Most impactful organizations				
1	Jawaharlal Institute of Postgraduate Medical Education & Research, Pondicherry	13	227	17.46	2.05
2	MAMC, Delhi	35	575	16.43	1.93
3	Mayo Institute of Medical Sciences	11	168	15.27	1.79
4	King George's Medical University, Lucknow	11	148	13.45	1.58
5	Pt. B.D. Sharma PGIMS, Rohtak	33	436	13.21	1.55
6	Indraprastha Apollo Hospital, New Delhi	17	224	13.18	1.54
7	Christian Medical College & Hospital, Ludhiana	9	89	9.89	1.16
8	Lady Harding Medical College, New Delhi	20	177	8.85	1.04

Table 1. Profile of top 8 most productive and most impactful organizations.
Note: TP: Total Papers, TC: Total Citations, CPP: Citations per paper, RCI: Relative Citation Index.

3.7. Authorship network

We, by using VOSviewer software, identified the network map of co-authorship coupling between the top 30 institutions. The thickness of the lines demonstrates the strength of the co-authorship relationship and represents the number of published articles by node size (Figure 4). In the visual analysis, UCMS, Delhi, and GTB Hospital, Delhi, have the highest Total Link Strength (TLS) (n=54 each), followed by PGIMER, Chandigarh (44), AIIMS, New Delhi (39), MAMC, Delhi (35), and VMMC & Safdarjung Hospital (25,) etc. Furthermore, the strongest coupling relationship through bilateral collaboration (n=41 links) was reported by MAMC, Delhi and Lok Nayak Hospital, Delhi (n=12), KMC Manipal and MAHE, Manipal (n=10), AIIMS, New Delhi and PGIMER, Chandigarh and PGIMER, Chandigarh and Dr. RMLH, Delhi (n=9 each). It was observed that the strongest collaborative linkages were among organizations organically linked (varying from 12 to 41), and comparatively medium collaborative linkages were observed across organizations (ranging from 2 to 9).

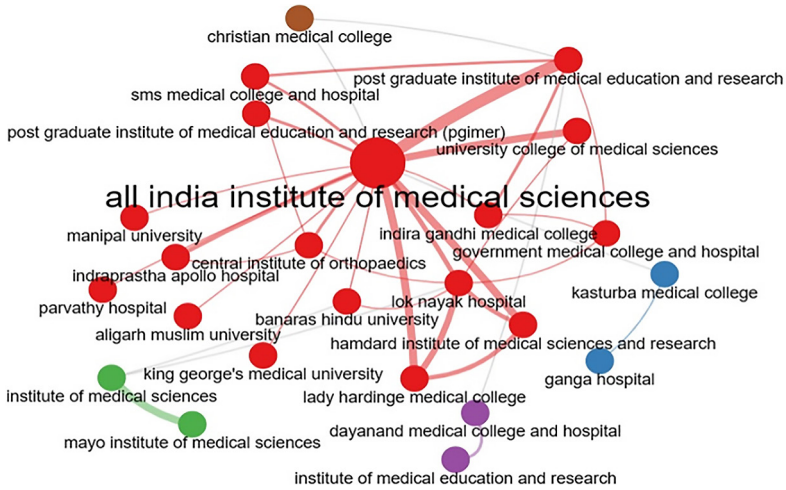

Figure 4. Top 30 most productive organization's collaborative author's network.

All 30 organizations are found to be distributed in 5 clusters shown in different colors. Cluster 1 (Red, 23 organizations) includes AIIMS, New Delhi, Indraprastha Apollo Hospital, New Delhi, MAHE, Manipal, PGIMER, Chandigarh, AIIMS, Bhopal, AIIMS, Rishikesh, AIIMS, Bhopal, Lokmanya Tilak Municipal Medical College, Mumbai, UCMS, Delhi, BHU, Varanasi, AMU, Aligarh, etc. Cluster 2 (Blue, 2 organizations) includes Ganga Hospital, Coimbatore Kasturba Medical College, and Manipal. Cluster 3 (Green, 4 organizations) comprises the Mayo Institute of Medical Sciences and the Institute of Medical Sciences (Varanasi). Cluster 4 (Lavender, 2 organizations) includes IMER and Cluster 5 (Orange, one organization) Christian medical college, Vellore.

3.8. Most productive and most impactful authors

In all, 894 authors participated in 1046 Indian papers on fracture research, of which 820 authors published from 1 to 5 papers each, 49 from 6 to 10 papers each, 18 from 11 to 20 papers each, and 7 authors from 21 to 41 papers each. The top 30 authors individually published 9-41 papers and published 478 papers and 3842 citations, accounting for 45.70% and 43.60% share in total Indian papers and citations. Among the top 30 authors, 10 were from PGIMER, Chandigarh, 9 from AIIMS, New Delhi, and 3 from Pt. BDS PGIMS, Rohtak. Table 2 describes the profile of the 8 most productive and impactful Indian authors. (Table 2). Further analysis showed that 10 authors contributed more than the average group productivity (15.93) of all 30 authors. The 17 authors registered CPP and RCI more than the average value (8.14 and 0.95) of all 30 authors.

Figure 5 depicts the top 30 most productive author co-authorship networks created using VOSviewer software. Each element represents an author, and the total number of papers of the author determines the size of these elements. The network counts 9 clusters. All these 30 authors have 73 links and 296 TLS.

No.	Name of the authors	Affiliation of the author	TP	TC	CPP	RCI
		Most Productive Authors				
1	V. Trikha	AIIMS-New Delhi	41	170	4.15	0.49
2	S. Aggarwal	PGIMER-Chandigarh	27	230	8.52	1.00
3	S.K. Tripathi	PGIMER-Chandigarh	25	221	8.84	1.04
4	S. Mittal	AIIMS-New Delhi	24	22	0.92	0.11
5	R. K. Sen	PGIMER-Chandigarh	24	201	8.38	0.98
6	M. S. Dhillon	PGIMER-Chandigarh	22	255	11.59	1.36
7	R. Malhotra	AIIMS-New Delhi	21	294	14.00	1.64
8	V. Kumar	PGIMER-Chandigarh	20	147	7.35	0.86
		Most Impactful Authors				
1	S. Bhan	AIIMS-New Delhi	9	177	19.67	2.31
2	R. Singh	Pt. BD Sharma PGIMS, Rohtak	14	208	14.86	1.74
3	N. K. Magu	Pt. BD Sharma PGIMS, Rohtak	15	215	14.33	1.68
4	R. Malhotra	AIIMS-New Delhi	21	294	14.00	1.64
5	R. Vaishya	Indraprastha Apollo Hospital, New Delhi	13	176	13.54	1.59
6	O. N. Negi	PGIMER-Chandigarh	12	159	13.25	1.55
7	R. Rohilla	Pt. BD Sharma PGIMS, Rohtak	12	158	13.17	1.54
8	A. S. Gavaskar	Parvathy Hospital, Chennai	12	148	12.33	1.45

Table 2. Profile of top 8 most productive and 8 most impactful authors.
Note: TP: Total Papers, TC: Total Citations, CPP: Citations per paper, RCI: Relative Citation Index.

Except for two, all 28 authors have a TLS ranging from 2 to 60. The highest TLS (60) was depicted by S. Aggarwal, followed by V. Trikha (45), V. Kumar (42), R.K. Sen (41), etc. Based on TLS, the author pairs having the largest collaborative linkages among them was S.K. Tripathi – R.K. Sen (19 linkages), V. Trikha – S. Mittal (17 linkages), and S. Aggarwal – V.

Kumar (15 linkages,), etc. It was observed that the strongest collaborative linkages were among authors from the same organization, and comparatively weak collaborative linkages were observed among authors across various organizations.

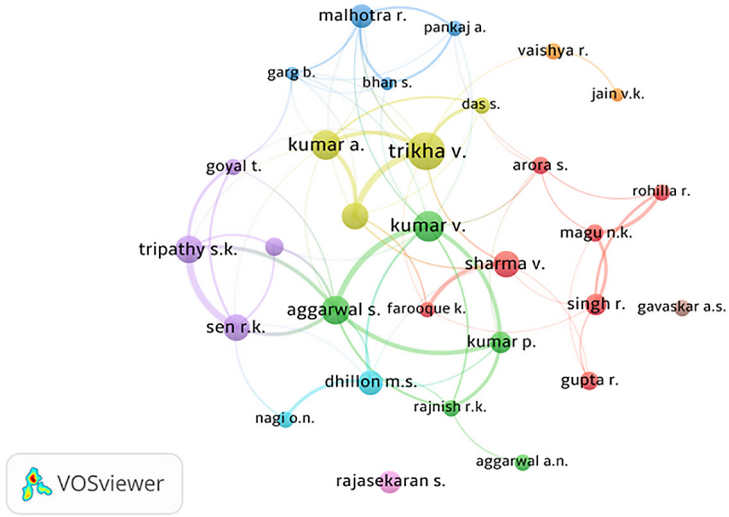

Figure 5. Top 30 most productive authors collaborative authors' network.

3.9. Most productive & impactful journals

The 1046 papers were published in 88 journals. The details of publications in the top 8 most productive journals are provided in Table 3. *Indian Journal of Orthopaedics* (257 papers with 24.57% share), *Journal of Clinical Orthopaedics & Trauma* (175 papers and 16.73% share), and *International Orthopaedics* (77 papers and 7.36% share) were the leading journals to publish India's fracture research. The most impactful journals in terms of CPP were: *Acta Orthopaedica* (31.2), *Journal of Orthopaedics & Traumatology* (19.55), and *Journal of Orthopaedic Surgery* (Hong Kong) (17.21).

S. No	Name of the journal	TP	TC	CPP	%TP
	Most Productive Journals				
1	Indian Journal of Orthopaedics	257	2020	7.86	24.57
2	Journal of Clinical Orthopaedics & Trauma	175	851	4.86	16.73
3	International Orthopaedics	77	1146	14.88	7.36
4	European Journal of Orthopaedic Surgery & Traumatology	63	334	5.30	6.02
5	Malaysian Orthopaedic Journal	40	111	2.78	3.82
6	Journal of Orthopaedic Surgery (Hong Kong)	38	654	17.21	3.63
7	Journal of Orthopaedic Surgery	37	300	8.11	3.54
8	Journal of Orthopaedic Trauma	34	464	13.65	3.25
	Most Impactful Journals				
1	Acta Orthopaedica	5	156	31.2	0.48
2	Journal of Orthopaedics & Traumatology	22	430	19.55	2.1
3	Journal of Orthopaedic Surgery (Hong Kong)	38	654	17.21	3.63
4	Orthopaedics & Traumatology	5	83	16.6	0.48
5	Clinics in Orthopaedic Surgery	6	93	15.5	0.57
6	International Orthopaedics	77	1146	14.88	7.36
7	Journal of Orthopaedic Surgery & Research	7	104	14.86	0.67
8	Journal of Orthopaedic Trauma	34	464	13.65	3.25

Table 3. Profile of top 8 most productive and 8 most impactful journals.
Note: TP: Total Papers, TC: Total Citations, CPP: Citations per paper.

The co-citation network of journals is displayed in Figure 6, where these top 30 journals are spread over 10 clusters with 105 links and 310 TLS. It is observed that the top journals with the largest TLS were the Indian Journal of Orthopaedics (154), followed by the Journal of Clinical Orthopaedics & Trauma (98), and International Orthopaedics (61).

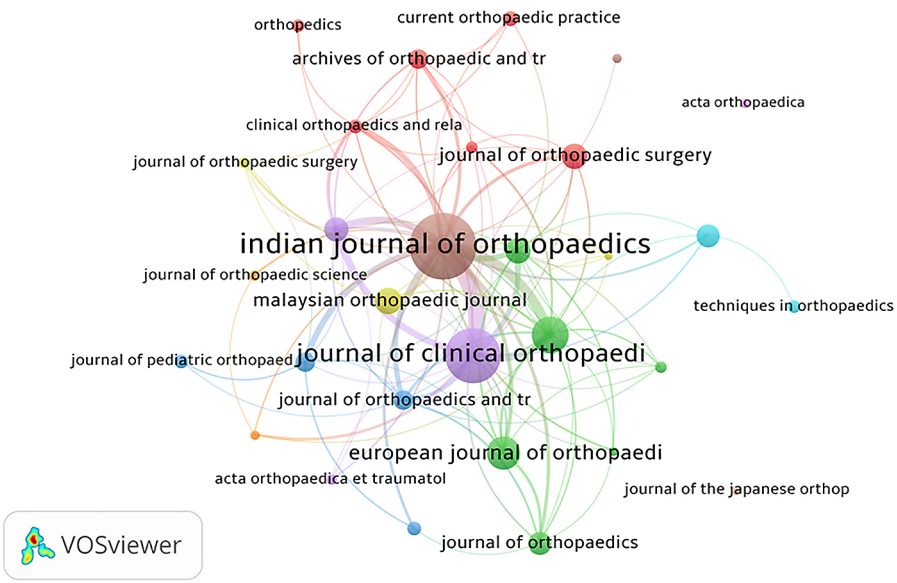

Figure 6. Co-citation network of journals.

3.10. High-Cited Papers

The 14 (1.34%) of 1046 papers on India's fracture research have received 50 or more citations. They are assumed here as high-cited papers (HCPs). These 14 HCPs received 1354 citations, averaging 96.71 CPP, and five of these were involved in only one organization (zero collaboration), and 9 involved two or more organizations: 2 national collaborations and 7 international collaborations. There are 17 Indian authors contributing to these HCPs and were from PGIMER, Chandigarh (2 papers), 2 and 1 paper each by other organizations, namely AIIMS-New Delhi, MAMC-Delhi, UCMS-Delhi, JIPMER-Pondicherry, KGMU-Lucknow, Indraprastha Apollo Hospital-New Delhi, IISc-Bangalore, Sancheti Institute of Orthopaedics & Rehabilitation-Pune, Jawaharlal Nehru Medical College-Belgaum, Grant Medical College-Mumbai, etc. The 14 HCPs were published in 10 journals, with a maximum of 4 papers in *International Orthopedics* (IF=3.479) and one paper each in 9 other journals. A list of the top 10 HCPs is provided in Supplementary Table 6.

Figure 7 demonstrates the citation's life-cycle pattern of the top 10 HCPs. In the initial years after publication, articles generally receive a small but growing number of citations until they eventually reach a peak, from which they decline. Among the top 10 HCPs, the paper by 'Dhanwal, D.K (2011)' received the highest number of citations during the study period. However, the article by 'Garg N.K. (1993)' has been cited 135 times.

4. DISCUSSION AND FINAL CONSIDERATIONS

India has an enormous burden of fractures related to increasing RTA, domestic, occupational, sports, and other injuries. The RTA has risen from 3,68,828 in 2020 to 4,22,659 in 2021, and the deaths related to accidents by 16.9% Ministry of road transport and highways, 2023; National Crime Records Bureau, 2023). Taking cognizance of the increasing RTA and the impact of the injuries resulting from these, the Government of India has implemented a scheme to establish several designated Trauma Care Facilities (TCFs) across India at every 100 km on the National and State Highways. So far, 116 such trauma centres have been commissioned across India (MOHFW, 2023). Despite

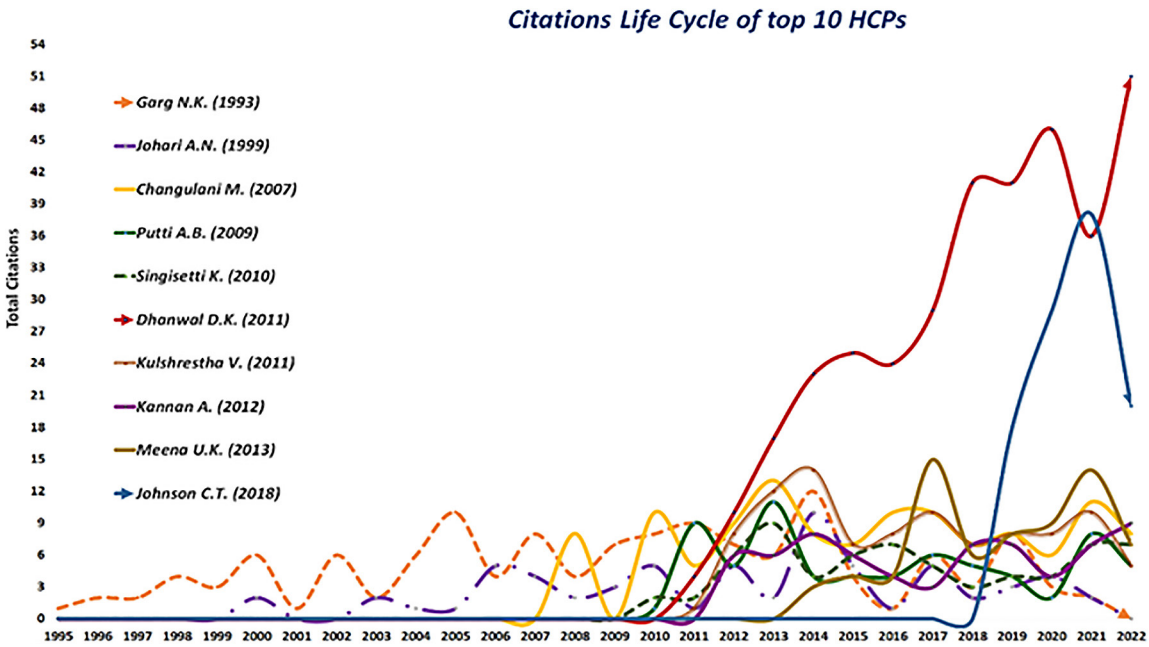

Figure 7. Citations life cycle of top 10 high-cited papers.

the vast magnitude of the problem of fractures, research on fracture-related issues has not been done in India. This study found 1046 such publications in the Scopus database in the last 34 years (1989-2022) from Indian authors, accounting for only 3.77% of the global share. We, however, noticed that publications related to fractures from India grew at an annual average growth of 23.94% over the last three decades and more so in the recent past. From 2006 to 2022, the number of publications has risen to 971 from 75 between 1989-2005, with an absolute growth of 1194.7%.

Recently, a study has made efforts to measure the incidence, prevalence, and years lived with disability (YLDs) for fractures (including total fractures and fracture subcategories) to quantify the burden of fractures at global, regional, and national levels for all ages, both sexes and over time from 1990 to 2019 (Wu et al, 2021). In addition, the existing epidemiological studies of fractures have focused on specific regions or countries or specific types of fractures or anatomical sites (Karl et al, 2015; Azagra et al, 2014; Allareddy et al, 2011; Kaas et al, 2010). The incidence and prevalence of various fractures in India are unknown due to the lack of a national registry. Hence, we believe there is an urgent need to develop a national fracture register.

The fractures-related research at the global and national level has rarely been studied from a bibliometric perspective. Among international studies, Sun *et al.* (2017) examined the quantity and quality of worldwide research in fracture surgery during 2005-14, based on paper and citation numbers using the Web of Science (WoS) database. Balwin *et al.* (2013) studied 100 most cited articles in fracture surgery and identified their characteristics to determine qualities that make an article high-cited in this field. At the national level, only one bibliometric study is available, where Dong *et al.* (2016) studied the characteristics of the most-cited articles on fracture surgery by Chinese authors. Bibliometric and visualized analysis are appropriate tools for describing the present status and predicting future trends concerning the research of interest. This study delineates India's fracture research's current status and research trends. The leading researchers, contributing institutions, countries, and their cooperation relationships are identified, and the critical publications with high citations are highlighted.

We found that international collaboration in Indian research was 11.95%, and these publications received a much higher CPP (15.52%) than an average CPP of 8.53%. Hence, it is a logical need to expand international collaboration, which will help improve research output and

impact, and quality. We observed the strongest collaborative linkages among organizations organically linked, and comparatively medium collaborative linkages were observed across organizations. Delhi was the epicentre of fracture-related research in India (with 30.4% publications), and the authors from institutions in Delhi, Mumbai, and Chandigarh together contributed more than 50% of the total publications.

Most publications (80.69%) were related to the adults and elderly, and in adults and pediatric fractures were less published (19.31%). The most focused anatomical locations in India's fracture research were on Femur (28.49%), Humerus (10.71%), and Tibia (10.04%). The publications related to fractures in aged people were mainly on hip fractures, whereas in children and adults, these were on Femur, Humerus, and Tibia.

Keywords are the core of the research field of a paper. The accuracy and frequency of keywords are two crucial factors affecting the research focus of co-occurrence recognition. Of the 4448 authors' keywords identified in 1046 India's papers, we first identified 88 important keywords having a frequency of occurrences of more than 10. Among important keywords, the highest frequency was reported by "Osteosynthesis" (n=242), followed by "Fracture Healing" (n=238), "Fracture Fixation" (n=188); and "Fracture Fixation, Internal" (n=166), "Surgical Techniques" (n=145), "Fracture Nonunion" (n=139), Intra-medullary Nailing" (n=-137), etc.

Despite having a large population of 1.4 billion in India, currently, there are only four Orthopaedic journals that are indexed in Scopus [IJO, 2023; JCOT, 2023; JOO, 2023; JAJS, 2023), namely the Indian Journal of Orthopaedics (IJO), Journal of Clinical Orthopaedics and Trauma (JCOT), Journal of Orthopaedics (JOO), and Journal of Arthroscopy and Joint Surgery (JAJS). In this review, we noticed that among the top 5 most productive journals, two were Indian: IJO (n=257) and JCOT (n=175). The other foreign journals were International Orthopaedics (n=77), European Journal of Orthopaedic Surgery & Traumatology (n=63), and Malaysian Orthopaedic Journal (n=40). At the same time, the top five most impactful journals were Acta Orthopaedica, Journal of Orthopaedics & Traumatology, Journal of Orthopaedic Surgery (Hong Kong), Orthopaedics & Traumatology, and Clinics in Orthopaedic Surgery in terms of CPP. We believe that there is a scope and need for more journals related to trauma and Orthopaedics from India to fill the vacuum and the need for publishing the research of authors from India and other neighboring countries.

This study provides insights into publication performances and research characteristics using select indicators. It has identified the leading institutions, authors, journals, research areas, and collaboration patterns between countries, organizations, and authors. The themes of the research plan and the cooperation between the country, institutions, and authors were determined and studied. The pace of India's research is expected to increase in this area. In addition, we also noticed that the distribution of research by organizations and authors is uneven. Collaboration and research communication between organizations and authors must be substantially enhanced. The study also identifies the research trends and hotspots (as reflected in keyword frequency) by analyzing author keywords and type of fracture research. It was observed that the management of fractures in Indian patients is drawing more attention from orthopedic surgeons, and these research topics are expected to continue to be research hotspots and focus shortly. Citation, number-based identification of essential papers, will help current practitioners gain insight into past and current trends in their respective fields and provides the foundation for further investigations.

We feel that the findings from this study can help and guide fracture prevention, mitigation, treatment, and resource allocation efforts, which will help policymakers to prioritize locations and age groups with the highest incidence and disability due to fractures. Furthermore, it provides crucial information for policymakers and medical professionals on the most burdensome fracture sites and the types of injury contributing to the most significant burdens from fractures. The study results indicate that fractures remained a critical public health issue in India, despite the availability of better diagnosis, treatment, and prevention of fractures over recent years. There is a need to build guidelines that should provide recommendations for using

strategies to reduce the incidence of fractures while considering residents' multi-morbidities and life expectancy.

Additionally, as fracture research has been a developing research field in recent years, some recently published, high-quality papers may have a low citation frequency due to their short publication time. There is, therefore, a discrepancy between the research results and the actual situation. Lastly, bibliometric analysis is only a tool, and the results may vary from what you see in real-world research.

We identified 1046 peer-reviewed publications on India's fracture research (between 1989 and 2022) in the Scopus database. These papers received 8927 citations, averaging 8.53 citations per publication. 126 papers (10.02%) received more than 20 citations. The distribution of research by organizations and authors was uneven, with international collaboration at 15.08%. Delhi was the epicenter of the research. Fractures in adults and older people were reported much more than pediatric fractures.

5. CONCLUSIONS

This study is the first comprehensive bibliometric analysis of India's fracture research over 30 years. It provided an insight into its current and past research status and hopes to guide scholars to understand research frontiers and directions in fracture-related research.

Contribution statement

RV: Conceptualization, Literature search, Writing and Editing the manuscript, Final approval, and submission.

BMG: Conceptualization, Literature search, Data curation, Formal analysis, Writing and Editing the manuscript, Final approval.

MK: Literature search, Data curation, Formal analysis, Writing and Editing the manuscript, Final approval.

AV: Literature search, Data curation, Formal analysis, Writing and Editing the manuscript, Final approval.

Conflict of interest

The authors declare that there is no conflict of interest.

Statement of data consent

The data generated during the development of this study was included in the article.

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Abbreviations used

1	AIIMS, New Delhi	All India Institute of Medical Sciences, New Delhi
2	PGIMER, Chandigarh	Postgraduate Institute of Medical Sciences, Chandigarh
3	UCMS, Delhi	University College of Medical Sciences, Delhi
4	MAMC, Delhi	Maulana Azad Medical College, Dehi
5	Pt. B.D. S. PGIMS, Rohtak	Pt. B.D. Sharma PGIMS, Rohtak
6	Dr RMLH, New Delhi	Dr. Ram Manohar Lohia Hospital, New Delhi
7	GMCH, Chandigarh	Government Medical College & Hospital, Chandigarh
8	CMC, Vellore	Christian Medical College & Hospital, Vellore
9	LHMC, New Delhi	Lady Hardinge Medical College, New Delhi
10	KMC, Manipal	Kasturba Medical College, Manipal
11	BHU, Varanasi	Banaras Hindu University, Varanasi
12	MAHE, Manipal	Manipal Academy of Higher Education, Manipal
13	AIIMS, Rishikesh	All India Institute of Medical Education, Rishikesh
14	JIPMER, Pondicherry	Jawaharlal Institute of Postgraduate Medical Education & Research, Pondicherry
15	AMU, Aligarh	Aligarh Muslim University, Aligarh
16	AIIMS, Bhubaneswar	All India Institute of Medical Education, Bhubaneswar
17	LTM Medical College, Mumbai	Lokmanya Tilak Municipal Medical, Mumbai
18	KG Medical University, Lucknow	King George's Medical University, Lucknow
19	AIIMS, Bhopal	All India Institute of Medical Education, Bhopal
20	CMCH-Ludhiana	Christian Medical College & Hospital, Ludhiana
21	ICMR	Indian Council of Medical Research

Supplementary Table 1. Growth of global and India's literature on fracture research.

Year	World	India			Year	World	India		
	TP	TP	TC	CPP		TP	TP	TC	CPP
1989	344	3	29	9.67	2008	875	36	296	8.22
1990	367	4	351	87.75	2009	907	36	441	12.25
1991	397	10	69	6.90	2010	959	44	561	12.75
1992	398	3	36	12.00	2011	1083	71	1028	14.48
1993	404	4	166	41.50	2012	1193	61	764	12.52
1994	393	3	18	6.00	2013	1202	66	592	8.97
1995	379	5	41	8.20	2014	1341	69	771	11.17
1996	352	2	12	6.00	2015	1349	59	536	9.08
1997	397	2	83	41.50	2016	1168	61	374	6.13
1998	451	0	0	0.00	2017	1288	42	274	6.52
1999	372	0	0	0.00	2018	1287	55	407	7.40
2000	386	7	119	17.00	2019	1419	69	290	4.20
2001	397	5	162	32.40	2020	1806	92	307	3.34
2002	496	6	65	10.83	2021	1895	85	88	1.04
2003	418	5	71	14.20	2022	1871	83	30	0.36
2004	481	5	113	22.60	1989-05	6920	75	1467	19.56
2005	488	11	132	12.00	2006-22	20804	971	7460	7.68
2006	561	15	199	13.27	1989-22	27724	1046	8927	8.53
2007	600	27	502	18.59					

Supplementary Table 2. Distribution of papers by anatomical location.

S.No.	Anatomical Location	TP	TC	CPP	%TP	S.No	Anatomical Location	TP	TC	CPP	%TP
1	Femur/Femoral	298	2746	9.21	28.49	11	Ankle	27	114	4.22	2.58
2	Humerus/Humeral	112	1221	10.90	10.71	12	Elbow	26	100	3.85	2.49
3	Tibia/Tibial	105	967	9.21	10.04	13	Foot	20	159	7.95	1.91
4	Hips	92	1163	12.64	8.80	14	Clavicle	19	262	13.79	1.82
5	Acetabulum	54	390	7.22	5.16	15	Scapula	19	115	6.05	1.82
6	Radius/Radial	51	399	7.82	4.88	16	Scaphoid	11	64	5.82	1.05
7	Pelvis /Pelvic	43	193	4.49	4.11	17	Hand & Finger	9	69	7.67	0.86
8	Forearm	37	479	12.95	3.54	18	Fibula	7	59	8.43	0.67
9	Knee	35	188	5.37	3.35	19	Leg	6	46	7.67	0.57
10	Spine	35	432	12.34	3.35	20	Face	1	3	3.00	0.10

Supplementary Table 3. Distribution of type of fracture by population age groups.

	Adults (425 records)						Aged (207 records)				
S.No.	Name	TP	TC	CPP	%TP	S.No.	Name	TP	TC	CPP	%TP
1	Femur/Femoral	58	591	10.19	13.65	1	Hips	46	498	10.83	22.22
2	Tibia/Tibial	50	661	13.22	11.76	2	Femur/Femoral	37	419	11.32	17.87
3	Femur Neck	47	533	11.34	11.06	3	Femur Intertrochanteric	30	248	8.27	14.49
4	Humerus/Humeral	44	829	18.84	10.35	4	Tibia/Tibial	28	376	13.43	13.53
5	Hips	41	348	8.49	9.65	5	Femur Neck	27	241	8.93	13.04
6	Acetabulum	34	306	9.00	8.00	6	Humerus	27	614	22.74	13.04
7	Femur Intertrochanteric	25	146	5.84	5.88	7	Acetabulum	12	133	11.08	5.80
8	Radius/Radial	22	159	7.23	5.18	8	Femur Sub-trochanteric	9	105	11.67	4.35
9	Clavicle	15	206	13.73	3.53	9	Proximal Femur	9	41	4.56	4.35
10	Pelvis	15	52	3.47	3.53	10	Pelvis	8	37	4.63	3.86
11	Spine	13	82	6.31	3.06	11	Femur Trochanteric	7	124	17.71	3.38
12	Femur Shaft	12	45	3.75	2.82	12	Distal Femur	7	31	4.43	3.38
13	Femur Sub-trochanteric	12	119	9.92	2.82	13	Radius/Radial	7	55	7.86	3.38
14	Proximal Femur	10	40	4.00	2.35	14	Spine	7	97	13.86	3.38
15	Calcaneal/Calcaneus	10	105	10.50	2.35	15	Femur Shaft	5	33	6.60	2.42
16	Hoffa	10	86	8.60	2.35	16	Scaphoid	5	46	9.20	2.42

Supplementary Table 4. List of significant keywords.

S.No.	Keyword	Occurrences	TLS	S.No.	Keyword	Occurrences	TLS
1	Osteosynthesis	242	1658	45	Kirsches Wire	32	242
2	Fracture Healing	238	1677	46	Pathophysiology	32	264
3	Fracture Fixation	188	1173	47	Femur Shaft Fracture	31	190
4	Fracture Fixation, Internal	166	1195	48	Fracture External Fixation	30	200
5	Surgical Technique	145	996	49	Minimally Invasive Surgery	30	235
6	Fracture Nonunion	139	1126	50	Disease Association	29	187
7	Intramedullary Nailing	137	883	51	Fractures, Ununited	29	273
8	Fractures	135	613	52	Bone Graft	28	203
9	Bone Nails	122	574	53	MLOWN	28	180
10	Bone Plates	120	865	54	Convalescence	27	251

S.No.	Keyword	Occurrences	TLS	S.No.	Keyword	Occurrences	TLS
11	Post-Operative Complications	120	906	55	MLCs	27	177
12	Femur Fractures	118	737	56	Hip Dislocation	26	183
13	Open Reduction	115	782	57	Intra-Articular Fracture	26	190
14	Range Of Motion	107	725	58	Postoperative Care	26	209
15	Femoral Neck Fractures	105	491	59	Radius Fracture	26	118
16	Fracture Reduction	100	662	60	Incidence	25	188
17	Hip Fractures	92	378	61	Elbow Joint	24	162
18	Humerus Fracture	83	482	62	Open Fracture Reduction	24	180
19	Injury	83	416	63	Fracture Immobilization	22	151
20	Tibia Fracture	82	465	64	Hospitalization	22	157
21	Weight Bearing	78	550	65	Hemiarthroplasty	21	104
22	Traffic Accident	63	448	66	Heterotopic Ossification	21	188
23	Plate Fixation	61	475	67	Orthopedic Surgery	20	150
24	Open Fracture	57	379	68	Periprosthetic Fracture	20	109
25	Fracture Fixation, Intramedullary	56	442	69	Clavicle Fractures	19	108
26	Bone Transplantation	55	416	70	Pelvis Fractures	19	94
27	Acetabulum Fracture	54	302	71	Vitamin D	19	89
28	Falling	48	345	72	Deep Vein Thrombosis	18	106
29	Functional Assessment	48	345	73	Nonunion	18	85
30	Range Of Motion, Articular	48	446	74	Proximal Femur Fractures	18	95
31	Osteoporosis	47	224	75	Wound Infection	18	152
32	Antibiotic Agent	46	380	76	Femur Subtrochanteric Fracture	17	144
33	Conservative Treatment	46	249	77	Distal Tibia Fracture	16	114
34	Debridement	46	345	78	Hoffa Fracture	14	65
35	Surgical Infection	45	391	79	Ankle Fractures	13	79
36	Harris Hip Score	44	261	80	Femur Trochanteric Fracture	13	99
37	Avascular Necrosis	43	326	81	Patella Fracture	13	79
38	Comminuted Fracture	41	265	82	Pathologic Fracture	13	57
39	Reoperation	41	353	83	Distal Humerus Fracture	12	126
40	Fracture Dislocation	40	241	84	Tibia Shaft Fracture	12	57
41	Femur Intertrochanteric Fracture	39	231	85	Non-Union	11	91
42	Joint Characteristics and Functions	38	342	86	Shoulder Fractures	11	65
43	Postoperative Infection	38	291	87	Tibial Plateau Fracture	11	58
44	Osteotomy	36	254	88	Humeral Supracondylar Fracture	10	51

Supplementary Table 5. Bibliometric profile of top 30 most productive organizations.

S.No.	Name of the organization	TP	TC	CPP	RCI	ICP	%ICP	%TP
1	AIIMS, New Delhi	120	984	8.20	0.96	10	8.33	11.47
2	PGIMER, Chandigarh	101	807	7.99	0.94	6	5.94	9.66
3	UCMS, Delhi	46	386	8.39	0.98	4	8.70	4.40
4	Guru Teg Bahadur Hospital, Delhi	42	352	8.38	0.98	3	7.14	4.02
5	MAMC, Delhi	35	575	16.43	1.93	2	5.71	3.35
6	VMMC & Safdarjung Hospital, New Delhi	33	265	8.03	0.94	5	15.15	3.15
7	Pt. B.D. Sharma PGIMS, Rohtak	33	436	13.21	1.55	1	3.03	3.15
8	Dr. Ram Manohar Lohia Hospital, New Delhi	26	221	8.50	1.00	5	19.23	2.49

S.No.	Name of the organization	TP	TC	CPP	RCI	ICP	%ICP	%TP
9	Government Medical College & Hospital, Chandigarh	24	118	4.92	0.58	2	8.33	2.29
10	CMC, Vellore	22	137	6.23	0.73	3	13.64	2.10
11	Lady Hardinge Medical College, New Delhi	20	177	8.85	1.04	0	0.00	1.91
12	Ganga Hospital, Coimbatore	20	155	7.75	0.91	2	10.00	1.91
13	Kasturba Medical College, Manipal	19	152	8.00	0.94	1	5.26	1.82
14	Indraprastha Apollo Hospital	17	224	13.18	1.54	5	29.41	1.63
15	Lok Nayak Hospital	15	131	8.73	1.02	0	0.00	1.43
16	BHU, Varanasi	14	111	7.93	0.93	2	14.29	1.34
17	MAHE, Manipal	14	78	5.57	0.65	0	0.00	1.34
18	AIIMS, Rishikesh	14	58	4.14	0.49	1	7.14	1.34
19	SMS Medical College, Jaipur	13	104	8.00	0.94	0	0.00	1.24
20	Jawaharlal Institute of Postgraduate Medical Education & Research, Pondicherry	13	227	17.46	2.05	1	7.69	1.24
21	Govt. Medical College, Srinagar	13	95	7.31	0.86	1	7.69	1.24
22	AMU, Aligarh	13	77	5.92	0.69	0	0.00	1.24
23	AIIMS, Bhubaneswar	13	95	7.31	0.86	5	38.46	1.24
24	Mayo Institute of Medical Sciences	11	168	15.27	1.79	0	0.00	1.05
25	Lokmanya Tilak Municipal Medical College, Mumbai	11	34	3.09	0.36	2	18.18	1.05
26	King George's Medical University, Lucknow	11	148	13.45	1.58	2	18.18	1.05
27	Seth G S Medical College & KEM Hospital	11	85	7.73	0.91	0	0.00	1.05
28	AIIMS, Bhopal	10	11	1.10	0.13	1	10.00	0.96
29	Christian Medical College & Hospital, Ludhiana	9	89	9.89	1.16	4	44.44	0.86
30	Indira Gandhi Medical College, Shimla	9	65	7.22	0.85	2	22.22	0.86
	Total of top 30 organizations	752	6565	8.73	1.02	70	9.31	71.89
	India's total	1046	8927	8.53	1.00			
	Share of top 30 organizations in India's total	71.89	73.54					

Supplementary Table 6. List of top 10 high-cited papers.

S.No.	Name of the authors	Title	Source	NOC
1	Dhanwal, D. K., Dennison, E. M., Harvey, N. C. and Cooper, C.	Epidemiology of hip fracture: Worldwide geographic variation.	Indian Journal of Orthopaedics, 2011 45 (1), pp. 15-22	347
2	Garg, N. K., Gaur, S. and Sharma, S.	Percutaneous autogenous bone marrow grafting in 20 cases of ununited fracture	Acta Orthopaedica, 1993, 64 (6), pp. 671-672	135
3	Changulani, M., Jain, U. K. and Keswani, T.	Comparison of the use of the humerus intramedullary nail and dynamic compression plate for the management of diaphyseal fractures of the humerus. A randomised controlled study	International Orthopaedics 2007, 31 (3), pp. 391-395.	120
4	Johnson, C. T., Wroe, J. A., Agarwal, R., Martin, K. E, Guldberg, R. E., Donlan, R. M., Westblade, L. F. and García, A. J.	Hydrogel delivery of lysostaphin eliminates orthopedic implant infection by Staphylococcus aureus and supports fracture healing	Proceedings of the National Academy of Sciences of the United States of America, 2018, 115 (22), pp. E4960-E4969	105
5	Kulshrestha, V., Roy, T. and Audige, L	Operative versus nonoperative management of displaced midshaft clavicle fractures: A prospective cohort study (2011) Journal of Orthopaedic Trauma, 25 (1), pp. 31-38. Cited 98 times.	Journal of Orthopaedic Trauma,2011, 25 (1), pp. 31-38.	98
6	Meena, U. K., Tripathy, S. K., Sen, R. K., Aggarwal, S., and Behera, P.	Predictors of postoperative outcome for acetabular fractures	Orthopaedics and Traumatology: Surgery and Research, 2013, 99 (8), pp. 929-935	69

S.No.	Name of the authors	Title	Source	NOC
7	Putti, A. B., Uppin, R. B., Putti, B. B.	Locked intramedullary nailing versus dynamic compression plating for humeral shaft fractures.	Journal of orthopaedic surgery (Hong Kong), 2009, 17 (2), pp. 139-141	68
8	Kannan, A., Kancherla, R., McMahon, S., Hawdon, G., Soral, A. and Malhotra, R	Arthroplasty options in femoral-neck fracture: Answers from the national registries	International Orthopaedics, 2012, 36 (1), pp. 1-8	67
9	Singisetti, K. and Ambedkar, M.	Nailing versus plating in humerus shaft fractures: A prospective comparative study	International Orthopaedics, 2010, 34 (4), pp. 571-576	66
10	Johari, A. N. and Sinha, M.	Remodeling of forearm fractures in children	Journal of Pediatric Orthopaedics Part B, 1999, 8 (2), pp. 84-87.	65