Global trends of the research in the fields of Biomedical Engineering during 2014-2018: A bibliometric analysis and visualisation of the data retrieved from Scopus

Puspita Mishra[1]
Assistant Librarian-NIT- Rourkela
PhD Scolar-Utkal University

Puspanjali Jena[2]
Retd.Professor
Dept of Lib. And Information Science, Utkal University

ABSTRACT: *This research paper aims to analyse the publication's detailed fields of Biomedical Engineering during 2014-2018. The authors tried to analyse a total 6084 numbers of publications in different aspects like type of publication, year, authorship patterns of articles, collaborative index, country-wise collaboration, etc. The results reveal that the maximum number of articles published in 2018 was in different journals; it was found that more than 80 countries contributed to this emerging field from 2014 to 2018, where India stands in 4th position. Collaborative papers are dominant over single-author work. Multi–authors contribute more than 93% of the total papers, whereas 6.5% of the total publications are single-authored. Continued growth is observed in the Collaborative Index(CI), which ranges from 4.97 (2014) and 5.70 (2021), with an average of 5.44 per joint-authored paper.*

Keywords: Bibliometric Analysis, Biomedical And Engineering, Authorship Pattern, Degree Of Collaboration, Collaborative Index

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1. Introduction

Bibliometric research offers a systematic and quantitative approach to studying scholarly publications' production, dissemination, and impact within a specific field or discipline. It involves analyzing bibliographic data, citation patterns, and collaboration networks to uncover valuable insights into the dynamics of scientific knowledge. Bibliometric techniques have become integral in assessing research productivity, identifying influential authors and journals, and mapping the evolution of scholarly domains over time.

Biomedical engineering is a dynamic interdisciplinary field that effectively bridges engineering, medicine, and biology, playing a crucial role in advancing healthcare technologies and improving patient well-being. With the field experiencing rapid progress, there is a pressing need for a comprehensive evaluation of research productivity in biomedical engineering journals. This introduction sets the stage for an extensive bibliometric analysis examining the complex landscape of scholarly publications within this discipline. By utilizing robust bibliometric tools and methodologies, we seek to uncover patterns, identify trends, and evaluate the impact factors of journals contributing to this innovative field. Our in-depth analysis aspires to illuminate leading journals, prolific authors, emerging themes, and collaborative networks, ultimately providing stake-

holders with valuable insights into the current state and potential future directions of biomedical engineering research.

2. Literature Review

A review of literature from the recent past is essential for keeping research relevant and informed by the latest advancements in a field. It helps researchers identify current trends, gaps in knowledge, and emerging methodologies, which can enhance the rigour and innovation of their own work. By concentrating on the most up-to-date studies, scholars ensure that their research builds on or challenges the latest findings, making their contributions more impactful. Additionally, it fosters critical thinking by encouraging the comparison of contemporary perspectives, ensuring that researchers do not rely on outdated information, which could compromise the validity of their conclusions.

Adams & Gurney (2018) examined international collaborations, and their findings align with this study. They suggest analysing publications with over 20 collaborating countries separately, comparable to approach 2 in this study, where publications with more than 100 co-authors are excluded. However, as demonstrated by the five approaches compared in this study, country rankings can vary significantly when focusing more specifically on the actual country pairs involved. A by-product of the study is inferred that international co-publications deliver a higher citation impact also when publications with the same number of co-authors are compared.

Ahmad et al., 2020 observed Periodontology 2000 boasts an exceptionally high impact factor (7.861 for 2018), unprecedented among dental journals. A bibliometric analysis from its inception in 1993 to July 2019 revealed that the top 100 most-cited articles garnered significant citations: 21,276 (Web of Science), 23,009 (Scopus), and 43,518 (Google Scholar). Citations per article ranged widely, from 118 to 827 (Web of Science), 10 to 1069 (Scopus), and 15 to 2028 (Google Scholar). The majority of first authors hailed from the USA (51%), followed by Switzerland (14%) and Australia (10%). The Forsyth Institute, USA, led the top dental institutions with nine frequently cited articles, showcasing the journal's high impact through insightful and timely reviews from renowned researchers worldwide.

Sahu & Parabhoi in 2020 studied the five years of literature from 2014-2018 in the field of LIS. They studied 1357 papers by 2884 authors; the majority were published in 2018 (25.2%). Bhardwaj R.K. was the most productive author, with 15 publications. Collaboration was prevalent, with 20.78% single-authored, 43.92% double-authored, 22.11% three-authored, and 13.19% with more than three authors. The overall Degree of Collaboration (DC) for five years was 0.79, peaking in 2018 (0.81) and dipping in 2014 (0.76). Of the papers, 824 received 4490 citations, while 533 had none. The "DESIDOC Journal of Library and Information Technology" was the preferred journal with the most citations. Co-citation analysis highlighted "Scientometric" and "Annals of library and information studies," while keywords like "Bibliometric," "Scientometric," and "India" were commonly used in the last five years.

Zhu et al 2021 accessed 77,772 funded nursing-related research publications from the Web of Science spanning 2008–2018. Among the top 20 institutions associated with these publications, 15 were from the United States, predominantly higher education institutions. The most common disciplines covered were oncology, psychiatry, and paediatrics. The leading journals publishing nursing-related funded research included the Journal of Clinical Nursing, Advanced Nursing, and the International Journal of Nursing Studies. The study concludes that nursing-related research has been gaining increased attention over the examined period.

Nayak et al., 2021 in their study focused on papers published in the ASLIB Journal of Information Management from 2014 to 2021, using the Scopus database for bibliographic data extraction and VOSviewer package for visualization. The research period uncovered 311 papers with 2534 citations. Notable trends include the highest number of documents (52) in 2020 and the most citations (558) in 2015. 827 authors from 51 nations contributed, with an average citation per document (ACPD) of 8.15. Collaboration levels ranged from 0.74 to 0.84, with an average degree of collaboration at 0.786. The study suggests that the ASLIB Journal publishes high-quality research across library and information science topics. Journal metrics from Scopus include a Cite score of 3.3, SJR of 0.558, and SNIP of 1.132.

Naveed et al 2021 studied The Library Quarterly (LQ), an academic journal in library science since 1931. They conducted the study from 2010 to 2019 using bibliometric techniques, revealing 469 documents published in LQ during this period. Articles and book reviews dominate with 45.416%, followed by editorial material at 7.676%. The research emphasizes LQ's global engagement in research support services. This paper is valuable for researchers and educators interested in understanding contemporary publication trends in LQ, providing insights for future studies. Islam & Roy (2021) in their paper assessed the publication contributions of Library and Information Science (LIS) researchers based in Bangladesh in leading journals indexed by Web of Science (WoS) and SCOPUS from 1971 to 2020. The study involved analysing bibliographic information from 266 LIS publications and utilized VOSviewer software for the science mapping of bibliometric networks. The findings indicate increased joint authorship and international collaboration over time, with researchers from 20 countries collaborating with Bangladeshi LIS researchers. Faculty members and the Department of Information Science and Library Manage

ment (ISLM) at Dhaka University emerged as Bangladesh's most prolific authors and LIS department. The compiled data and findings offer insights for Bangladeshi LIS researchers and practitioners, helping them assess focus areas, identify strengths and weaknesses, and guide future research directions.

Garg & Singh, in 2021 examined 699 papers published in Library & Information Science Research (LISR) from 1994 to 2020, utilizing Google Scholar to gather citation data until April 30, 2021. It investigated the geographical distribution of articles, identified prominent institutions and authors, and assessed the impact of countries, institutions, and authors using citation per paper (CPP) and *i-10* index as impact indicators. The analysis revealed a peak in article publication during the 2015-2017. Among 51 contributing countries, the USA had the highest number of papers, although its CPP was lower than that of Norway and Finland. Florida State University (USA) led in institutional contributions, while the University of Illinois at Urbana-Champaign (USA) had the highest CPP. Throughout the study period, 1,389 papers garnered 74,061 citations, with only 3% (41 articles) remaining uncited.

Farooq et al 2021 conducted bibliometric analysis, on the Web of Science database due to the intense academic focus on the pandemic, explores research productivity related to COVID-19. With a refined search for the years 2019 and 2020, 6694 records were analysed. The USA and Chinese research institutions led in publications, while the Journal of Medical Virology and CUREUS emerged as popular journals. Multi-authored publications surpassed single-authored ones. The analysis reflects a robust local research response from China, primarily in large research teams. As the virus spreads globally, subsequent studies are expected to capture a more comprehensive global research response.

Ensslin et al.,2022, focused on investigating scientific publications related to the sustainable management of libraries in higher education institutions (HEIs).The study selected and analyzed 24 articles using the ProKnow-C intervention instrument to guide the bibliometric analysis, generate contextual knowledge, and discuss the results, emphasising that authors from American continent countries are prominently engaged in researching the subject. It also underscored the shift from a singular focus, primarily centered on the environment, to a more comprehensive multidimensional perspective.

Baber et al., 2022 examined the yearly publication, field category productivity, citation structure, most cited resources, documents, most-cited authors, most productive authors, and country in digital literacy. The findings indicate a consistent publication rate in the field, predominantly within the education and library domains, with the USA as the leading country. Notable emerging themes include 'Fake News,' 'Competence,' 'Educational Technology,' 'Health Literacy,' 'Self-Efficacy,' and notably, 'COVID-19.' The study further highlights that COVID-19 has been a subject of examination and is associated with themes such as fake news, higher education, social media, and information literacy.

Siddique et al.,(2023) Provided an overview of the dynamics and state of Library and Information Science (LIS) research in the Arab region from 1951 to 2021. The study reveals a notable upward trend in publications, particularly in the last four years, with the highest number of studies published in 2020. Kuwait and Saudi Arabia emerged as the top countries in LIS research production, with Kuwait University, King Fahd University of Petroleum and Minerals, and Imam Abdulrahman Bin Faisal University being the most prolific institutions. The major areas of interest for researchers include academic libraries, social media, bibliometrics, information-seeking behaviour, information literacy, and knowledge management.

Feng, S.et al. (2024)**,** in their study**,** uncovered both the characteristics of retractions and the connections between them in molecular biology using citation network analysis. The findings provide useful insights for preventing mistakes and misconduct in the field. The authors found that he self-citation rate in community 5 is 60.00%, with the majority of papers coming from Alfredo Fusco's team, while about ten others were mostly published in *PLoS ONE*. The study also revealed a strong coupling between citing and cited retraction reasons, showing that retractions and their citations are often retracted for similar reasons. Many papers from paper mills involved in this process were published by the same publisher or even in the same journal. Recently, major topics of retractions have included PI3K (an enzyme), WNT (a protein), and lncRNAs.

Wang, J. et al.,(2014) highlighted both a global impact and a home country effect. Publications with international co-authorship receive notably more foreign citations, suggesting that international collaboration enhances research quality and boosts citation rates, especially considering the smaller foreign audience when home countries are excluded. However, domestic citations from authors' home countries grow more quickly than foreign ones, with the home country effect becoming more evident over time. This indicates the importance of increased visibility within the domestic research community. The study underscores the crucial role of international collaboration in enhancing research impact and the value of building strong research networks.

3. The Study

3.1. Aims of this study

The study aims to demonstrate the research areas of Biomedical Engineering. We summarized the distribution of the

country/ region, discipline , institution, journal, and authors of the publications. Additionally, we determined the productivity of the authors with various indicators.

3. 2. Objectives of the Study

This current study fills the gap by analysing publications in the field of bibliometrics and in the subject of Biomedical and Engineering. The objective of the current research is to find out the current trends in biomedical engineering research from 2014 to 2018. Further, the study aims to identify the newly emerging areas of research in Biomedical Engineering. The study also identified the yearly growth in citations and contributions, the most prolific authors, core journals, authorship patterns, and the degree of collaboration in the biomedical engineering field between 2014 and 2018.

3.3. Design of the Study

Quantitative content analysis is conducted to find all the publication details with various indicators like publication type, authorship pattern, institution affiliations, etc, based on the data retrieved from the Scopus database. Accordingly, the result is analysed using bibliometric indicators.

3.4. Data sources

This study used the Scopus database, commonly used in bibliometric studies, to analyse. After rigorous selection procedures and objective evaluation processes, the Scopus database was found to be the most authoritative and influential academic database.

3.5. Search strategy

The data were collected from the Scopus in January 2024. The data retrieval strategies were as follows:
TITLE-ABS KEY (biomedical AND engineering) AND PUBYEAR > 2013 AND PUBYEAR < 2019 AND (LIMIT-TO (DOCTYPE , ”ar”)) AND (LIMIT-TO (SRCTYPE , ”j”)) AND (LIMIT-TO (LANGUAGE , ”English” .

We found 6160 papers to be included in the study. Further, 76 articles have no author’s details at all. So excluding those 76, we took 6084 no articles for further study.

3.6. Data collection

The details of 6084 papers as per the format from the Scopus database were downloaded in .csv format. For easy formatting and analysis, the data format was converted to Excel, and both formats were used to analyse various aspects.

4. Data analysis

For this paper, the data was analysed using an advanced version of MS Excel and the biblioshiny package from R-Studio.

4.1. Year wise distribution of articles

From Table 1, it is observed that during 2014 to 2015, there was a significant decline of approximately 17.7% in the number of articles, indicating a notable drop in output or publication. However, this decline was followed by a recovery starting in 2016, with a growth rate of about 6.5% as the number of articles increased. The upward trend continued into 2017, albeit at

Table 1. Year-wise growth of publication with citation

Year	No Articles	AGR	CAGR	Mean TC per Art	Mean TC per Year
2014	1317	00		38.97	3.54
2015	1084	“17.7%		43.4	4.34
2016	1154	6.5%	0.34%	39.82	4.42
2017	1194	3.5%		35.53	4.44
2018	1335	11.8%		35.55	5.08

AGR - Annual Growth Rate CAGR- Compound Annual Growth Rate
MeanTCperYear (Mean Total Citations per Year), MeanTCperArt (Mean Total Citations per Article

a slower rate of 3.5%, suggesting a steady but moderate improvement. The most pronounced growth occurred in 2018, with an increase of 11.8%, highlighting a robust resurgence in article production. Overall, the data reflects a challenging period of decline followed by a gradual recovery and significant growth, suggesting that the number of articles has been on a positive trajectory towards the end of the observed period.

The data from Table 01 indicates that while the number of published articles fluctuates, the overall impact, as measured by total citations per year, has been increasing. The Mean TC per Art saw its highest point in 2015 but then stabilized, while the Mean TC per Year shows a clear upward trend. The decreasing citable years might reflect a faster-paced research environment where the relevance of articles diminishes more quickly. Overall, the combination of these metrics paints a picture of a dynamic research output environment with a growing impact over the years.

4.2. Most Related Sources

Table 02 provides lists of the Top 100 Biomedical and Engineering Journals along with the number of articles published in each. This information is crucial for understanding the distribution of research output across different sources. Though 6084 articles are retrieved from 1600+ journals, the top 100 journals with the most articles are tabulated here.

Sl.No	Sources	Articles
1	ANNALS OF BIOMEDICAL ENGINEERING	165
2	MATERIALS SCIENCE AND ENGINEERING C	110
3	ACS APPLIED MATERIALS AND INTERFACES	106
4	RSC ADVANCES	90
5	BIOMEDICAL INSTRUMENTATION AND TECHNOLOGY	73
6	IEEE PULSE	71
7	JOURNAL OF MATERIALS CHEMISTRY B	66
8	ACTA BIOMATERIALIA	64
9	JOURNAL OF BIOMEDICAL MATERIALS RESEARCH - PART A	61
10	SCIENTIFIC REPORTS	59
11	BIOMACROMOLECULES	53
12	COMPUTER METHODS IN BIOMECHANICS AND BIOMEDICAL ENGINEERING	53
13	PLOS ONE	48
14	IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING	47
15	JOURNAL OF THE MECHANICAL BEHAVIOR OF BIOMEDICAL MATERIALS	47
16	CARBOHYDRATE POLYMERS	46
17	ADVANCED FUNCTIONAL MATERIALS	41
18	ADVANCED HEALTHCARE MATERIALS	41
19	BIOMATERIALS	40
20	CELLULAR AND MOLECULAR BIOENGINEERING	39
21	COLLOIDS AND SURFACES B: BIOINTERFACES	38
22	INTERNATIONAL JOURNAL OF BIOLOGICAL MACROMOLECULES	38
23	JOURNAL OF MEDICAL ENGINEERING AND TECHNOLOGY	38
24	ACTA PHYSICA POLONICA A	37
25	ADVANCED MATERIALS	37
26	JOURNAL OF APPLIED POLYMER SCIENCE	37
27	NANOSCALE	37

28	CERAMICS INTERNATIONAL	36
29	JOURNAL OF VISUALIZED EXPERIMENTS	35
30	SURGICAL INNOVATION	34
31	BIOMEDICAL MATERIALS (BRISTOL)	33
32	INTERNATIONAL JOURNAL OF INDUSTRIAL ERGONOMICS	33
33	MEDICAL ENGINEERING AND PHYSICS	33
34	ACS BIOMATERIALS SCIENCE AND ENGINEERING	32
35	LANGMUIR	30
36	CARDIOVASCULAR ENGINEERING AND TECHNOLOGY	28
37	JOURNAL OF BIOMEDICAL MATERIALS RESEARCH - PART B APPLIED BIOMATERIALS	28
38	BIOMEDICAL SIGNAL PROCESSING AND CONTROL	27
39	JOURNAL OF MATERIALS SCIENCE: MATERIALS IN MEDICINE	27
40	NATURE COMMUNICATIONS	26
41	ACS NANO	25
42	APPLIED SURFACE SCIENCE	24
43	BIOCYBERNETICS AND BIOMEDICAL ENGINEERING	24
44	HELIYON	24
45	TRANSACTIONS OF JAPANESE SOCIETY FOR MEDICAL AND BIOLOGICAL ENGINEERING	24
46	PROCEEDINGS OF THE INSTITUTION OF MECHANICAL ENGINEERS, PART H: JOURNAL OF ENGINEERING IN MEDICINE	23
47	JOURNAL OF BIOMATERIALS SCIENCE, POLYMER EDITION	22
48	JOURNAL OF BIOMEDICAL OPTICS	22
49	MATERIALS	22
50	MATERIALS AND DESIGN	22
51	BIOMEDIZINISCHE TECHNIK	20
52	INTERNATIONAL JOURNAL OF BIOMEDICAL ENGINEERING AND TECHNOLOGY	20
53	INTERNATIONAL JOURNAL OF NANOMEDICINE	20
54	BIOMEDICAL ENGINEERING ONLINE	19
55	JOURNAL OF MEDICAL DEVICES, TRANSACTIONS OF THE ASME	19
56	LAB ON A CHIP	19
57	MACROMOLECULAR BIOSCIENCE	19
58	MATERIALS LETTERS	19
59	POLYMER CHEMISTRY	19
60	SMALL	19
61	ANGEWANDTE CHEMIE - INTERNATIONAL EDITION	18
62	BIOMATERIALS SCIENCE	18

63	JOURNAL OF BIOMEDICAL INFORMATICS	18
64	JOURNAL OF CLINICAL ENGINEERING	18
65	JOURNAL OF CONTROLLED RELEASE	18
66	PHYSICS IN MEDICINE AND BIOLOGY	18
67	POLYMERS	18
68	BIO-MEDICAL MATERIALS AND ENGINEERING	17
69	JOURNAL OF BIOMATERIALS APPLICATIONS	17
70	BIOMEDICAL ENGINEERING	16
71	IEEE TRANSACTIONS ON BIOMEDICAL CIRCUITS AND SYSTEMS	16
72	JOURNAL OF NANOSCIENCE AND NANOTECHNOLOGY	16
73	COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE	15
74	EUROPEAN POLYMER JOURNAL	15
75	JOURNAL OF BIOMECHANICAL ENGINEERING	15
76	JOURNAL OF MATERIALS SCIENCE	15
77	NATURE	15
78	PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA	15
79	SENSORS (SWITZERLAND)	15
80	BIOMEDICAL INSTRUMENTATION & TECHNOLOGY	14
81	BIOMEDICAL OPTICS EXPRESS	14
82	BIOTECHNOLOGY AND BIOENGINEERING	14
83	BMC BIOINFORMATICS	14
84	CRITICAL REVIEWS IN BIOMEDICAL ENGINEERING	14
85	INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN BIOMEDICAL ENGINEERING	14
86	JOURNAL OF MEDICAL AND BIOLOGICAL ENGINEERING	14
87	JOURNAL OF NEURAL ENGINEERING	14
88	JOURNAL OF THE AMERICAN CHEMICAL SOCIETY	14
89	MATERIALS TECHNOLOGY	14
90	MEDICAL PHYSICS	14
91	SOFT MATTER	14
92	ANALYTICAL CHEMISTRY	13
93	COLLOIDS AND SURFACES A: PHYSICOCHEMICAL AND ENGINEERING ASPECTS	13
94	COMPUTER METHODS IN BIOMECHANICS AND BIOMEDICAL ENGINEERING: IMAGING AND VISUALIZATION	13
95	INTERNATIONAL JOURNAL OF ADVANCED MANUFACTURING TECHNOLOGY	13

96	INTERNATIONAL JOURNAL OF TECHNOLOGY ASSESSMENT IN HEALTH CARE	13
97	JOURNAL OF APPLIED PHYSICS	13
98	JOURNAL OF RADIOLOGICAL PROTECTION	13
99	MRS BULLETIN	13
100	ACCOUNTS OF CHEMICAL RESEARCH	12

Table 2. Top 100 journals wrt No of Publications in Biomedical and Engineering

Annals of Biomedical Engineering stands out with the highest number of articles, reflecting its substantial influence and prominence in biomedical engineering. Its extensive publication volume suggests that it is a leading source of research in this area, providing a platform for significant advances and contributions to the field. Materials Science and Engineering C Journals stand in second position and third position, respectively.

From Fig-01, it is evident that the Annals of Biomedical Engineering emerges as the most influential journal, with the highest number of published articles, indicating its central role in the field. Journals like Materials Science and Engineering C, ACS Applied Materials and Interfaces, and RSC Advances also play significant roles, showcasing a strong interest in materials science and interdisciplinary research. Journals such as Biomedical Instrumentation and Technology and IEEE Pulse highlight the integration of technology and engineering in medical applications. Meanwhile, journals like Acta Biomaterialia and Journal of Biomedical Materials Research - Part A emphasize the specialized study of biomaterials, which are crucial for medical and biological applications. The table underscores the diversity and depth of research across different journals, each contributing to advancements in their respective areas.

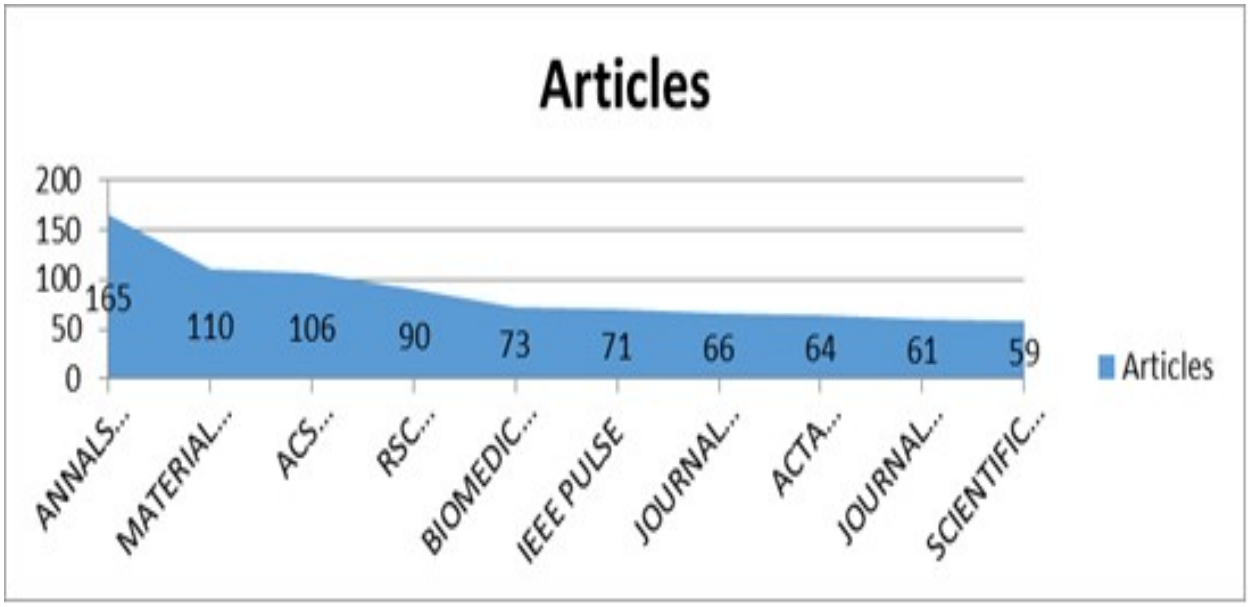

Figure 1. Most Related sources

4.3. Authorship pattern in the field of Biomedical and Engineering

The authors attempted to identify authorship patterns in articles published between 2014 and 2018. Table 3 shows the year-by-year contributions of the single and joint authors throughout the study. According to the findings, the four authors had 924 of the most significant research publications, followed by 88 by two authors. Furthermore, the authors discovered that multi-authors contributed to most of the publications during the study period. The majority of the 5693 contributions (>93%) were written collaboratively, with the remaining 390(6.5%) authored by a single author.

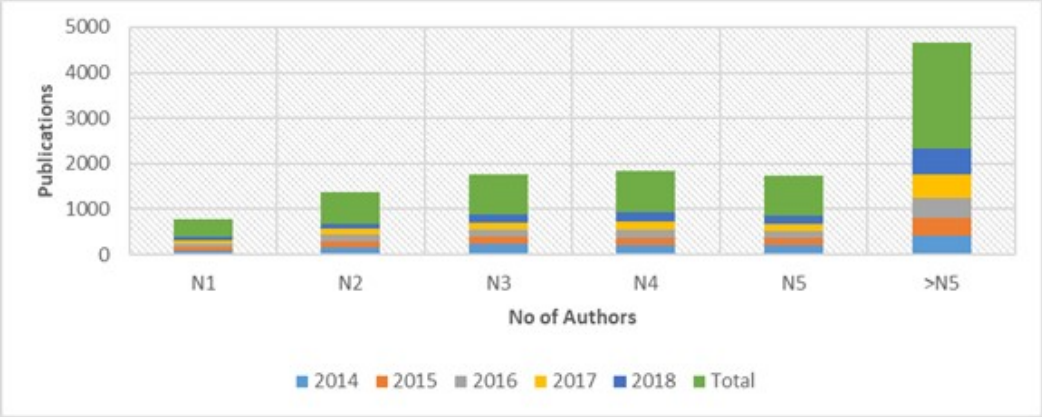

Figure 2. Showing the dominating collaborative work

From Fig 02, it is found that in the field of biomedical engineering, collaborative work dominates overall.

4.4. Co-Authorship Index with Multi-Authorship Index (MAI),

The Multi-Authorship Index (MAI), a new index that is a modification of the Co-Authorship Index (CAI) recommended by Garg and Padhi (2001), has been developed in this study to solve the shortcomings of the current method. The following is the new index's mathematical formula:

$$MAI = \frac{MAP_i / MAP}{TP_i / TP}$$

Where,
The MAI is the Multi-Authorship Index,

MAPi is the number of multi-authored papers in the ith year

MAP is the total number of multi-authored papers for all years combined

TPi is the total number of papers in the ith year

TP stands for total number of papers all years

Table 3. Authorship pattern and Degree of Collaboration in the Publications

Year	N1	N2	N3	N4	N5	>N5	Total single authored	Total multi-authored	MAI
2014	85	170	224	202	198	418	1212	1297	0.998
2015	80	129	163	170	159	387	1008	1088	0.998
2016	74	143	152	174	162	450	1081	1155	1.00
2017	82	119	155	174	161	505	1114	1196	0.996
2018	70	124	189	204	187	574	1278	1348	1.008
Total	391	685	883	924	867	2334	5693	6084	1.00

DC- Degree of collaboration, MAI- Multi-Authorship Index

Table 03 also depicts the new metric, the Multi-Authorship Index (MAI). It is inferred that the MAI has approached 1 in all the years. In 2018, it showed a maximum of 1.008. It is concluded that the research trends in the fields of Biomedical and engineering are multi-authored in most cases.

4.5. Author Productivity in the field of Biomedical and Engineering

Productivity has been calculated based on the formula cited by Singh, Verma and Singh (2021) in their study and mentioned as follows:

Author Productivity = Total number of Publications / Total number of Authors

Table 4 shows the analysis of authors' productivity in Biomedical and Engineering and identified a total average number of authors per publication of 5.15 with an average productivity per author of 0.20.

Year	Documents	No. of Authors	Avg. author Per doc.	Docs. Productivity per author
2014	1317	6137	4.66	0.21
2015	1084	5568	5.14	0.19
2016	1154	6007	5.21	0.19
2017	1194	6260	5.24	0.19
2018	1335	7348	5.50	0.18
Average			**5.15**	**0.20**

4.6. Collaboration index

$$Collaboration\ Index = \frac{Total\ authors\ of\ multi\ authored\ papers}{Total\ number\ of\ multi\ authored\ papers}$$

Table 05 and Figure 03 provide the year-wise mean number of authors per jointly authored paper. The year 2018 has the highest number of multi-authored papers, and the total number of authors of multi-authored documents are 1278 and 7284, respectively. 2014 has fewer multi-authored papers, a total number of authors, and multiple authors' documents. CI ranges from 4.97 (2014) to 5.70 (2021), averaging 5.44 per jointly authored paper.

Year	Multi-authored docs	Total Authors of multi-authored docs	Collaborative index
2014	1212	6021	4.97
2015	1008	5492	5.45
2016	1081	5937	5.49
2017	1114	6271	5.63
2018	1278	7284	5.70

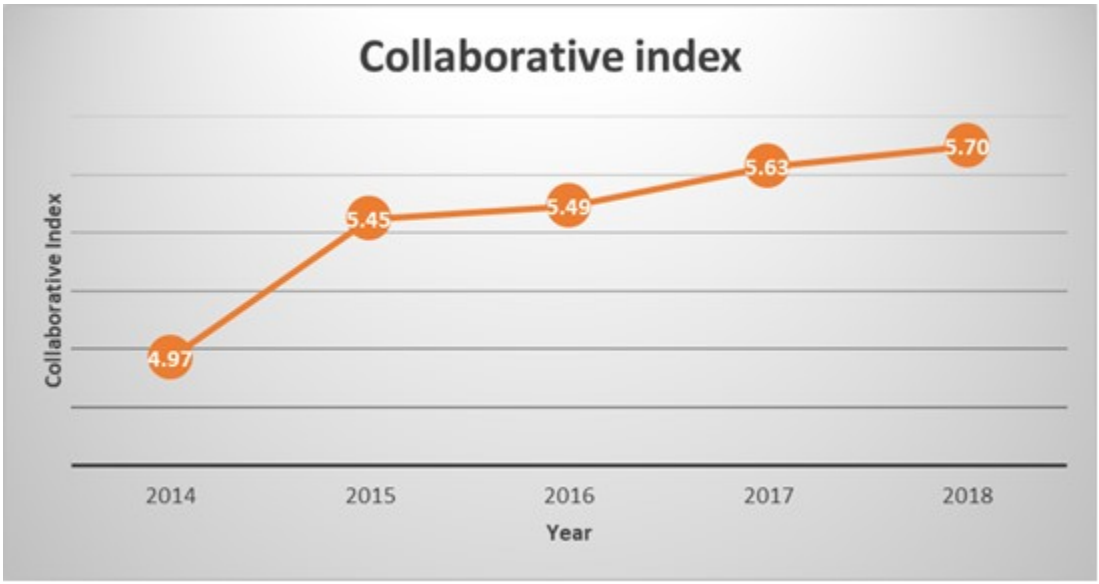

Figure 3. Collaborative Index of the Publications over the Year

4.7. Most Relevant Authors

Figure 04 shows the most relevant authors concerning publication number and the total citation count per year. The data analysed through bibliophily and visualized below in fig. 04. It is found that Wang was the top author with 93 publications, followed by Zhang and Liu, as the authors ranked 10 with 53 publications.

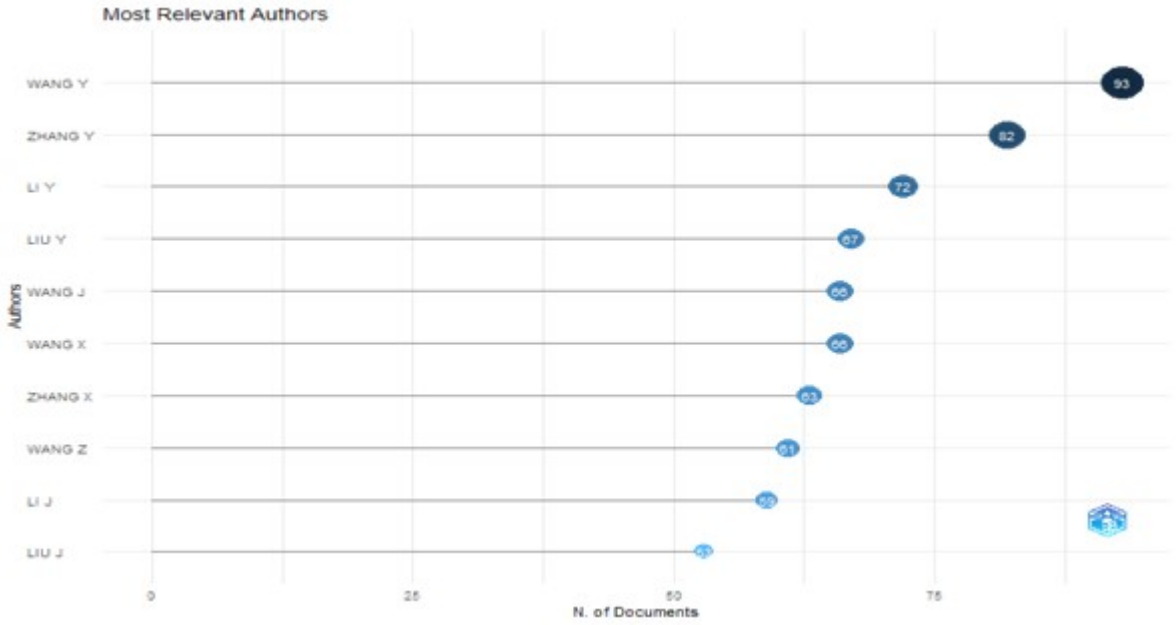

Figure 4. Top 10 most relevant authors

3.8. Corresponding Author's Countries

Using biblioshiny software, the details of the Corresponding authors' countries are visualised in Figure 05. It shows that the corresponding authors of a single country are significant with respect to multiple country publications in the field of Biomedi-

cal and Engineering. The USA was in the top position in publications, followed by China. India was in the fourth position in collaborative publication in the field of Biomedical and Engineering.

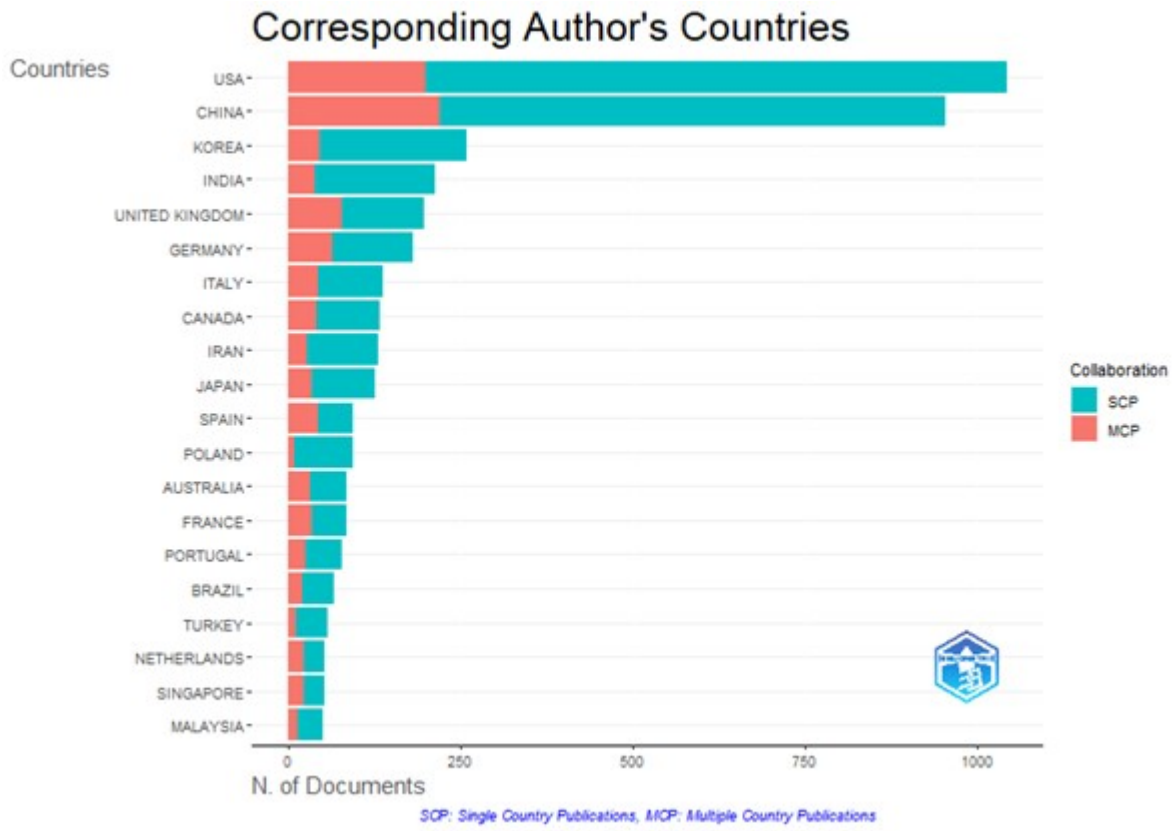

Figure 5. Corresponding Author's Countries

5. Result Analysis

The study analysed the growth patterns of research by examining publications over five years, from 2014 to 2018, and data in three-year intervals, from 1994 to 2020, in Biomedical and Engineering. The result focuses on publication growth and found a difficult decline initially, but then a steady improvement and notable growth, indicating that the number of articles has been increasing positively towards the end of the observed period. The research highlighted the most cited authors and examined both domestic and international collaboration trends. The top journal is "Annals of Biomedical Engineering," with 165 articles, indicating it is the most prolific source in this dataset. The next highest is "Materials Science and Engineering C" with 110 articles, followed by "ACS Applied Materials and Interfaces" with 106 articles. The findings reveal an overall increase in research output during the study period, with a highly uneven distribution among countries, institutions, and authors. The USA was the top contributor regarding the number of publications in corresponding authors regarding SCP and MCP. India was 4th among the countries in the field of publication and collaboration. It is found that Wang, Y was the top author with 93 publications, followed by Zhang, Y. Liu, J was the author ranked 10 with 53 publications.

6. Conclusions

The bibliometric analysis and visualization of Scopus data from 2014-2018 reveal significant growth and evolution in Biomedical Engineering research. Key journals are central to disseminating research, while emerging topics and increasing international collaboration reflect the dynamic nature of the field. Continued growth is observed in the Collaborative Index (CI), which ranges from 4.97 (2014) and 5.70 (2021), with an average of 5.44 per joint-authored paper. The research found that journals like Annals of Biomedical Engineering, Materials Science and Engineering C, ACS Applied Materials and Interfaces, etc, are the top-rated journals regarding publication and Impact Factor. The Compound Annual Growth Rate of

0.34 and the Mean Total Citations per Year show a growing trend in the field and the global and collaborative efforts driving advancements in Biomedical Engineering. This comprehensive view helps us understand the progress and future directions of research in this rapidly advancing discipline. It is concluded that the research trends in the field of Biomedical and engineering are multi-authored in maximum cases

The visualization and bibliometric analyses reveal emerging research areas and trends within Biomedical Engineering. For example, increased publications in biomaterials, medical devices, and tissue engineering could reflect new technological advances or growing research interests. This study offers valuable insights into the global landscape of Biomedical Engineering research, providing a foundation for understanding current trends, influential publications, and future directions in this rapidly evolving discipline.

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