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3D BIOPRINTING IN DENTISTRY: BIBLIOMETRIC ANALYSIS

Abstract. The World Health Organization (WHO) estimates that oral diseases affect about 3.5 billion people. According to the National Institute of Dental and Craniofacial Research Oral Health Surveillance Report, 2019, nearly 90% of adults between the ages of 20 and 64 had tooth decay, and this percentage did not change significantly between the NHANES 1999-2004 and 2011-2016 cycles. Literature search was conducted in the Scopus database using the keywords “tooth,” “teeth,” “bioprinting,” “3D bioprinting,” and “three-dimensional bioprinting.” A total of 107 publications were retrieved, with 102 being in the English language. Performance analysis and science mapping were performed using the Bibliometrix R package in the R-studio. Analysis shows upward trend of scientific publications over the period from 2016 to 2023. China maintains a leading position in the number of publications among countries. The figure illustrates that Sichuan University holds the leading position with a total of 16 publications. The journal “Bioprinting” ranks among the top six journals, followed by “Cells” and “Biofabrication”. Chen J, Guo W, and Zhang X stand out, each having three published works. “Bioprinting” and “tissue engineering” are the most commonly used keywords by authors in the period from 2016 to 2023. Based on the provided information on 3D printing in dentistry, it can be concluded that China makes a significant contribution to research in this field.
Key words: tooth, 3D bioprinting, three-dimensional bioprinting.

Introduction

The World Health Organization (WHO) estimates that oral diseases affect about 3.5 billion people [1]. According to the National Institute of Dental and Craniofacial Research Oral Health Surveillance Report, 2019, nearly 90% of adults between the ages of 20 and 64 had tooth decay, and this percentage did not change significantly between the NHANES 1999-2004 and 2011-2016 cycles [2]. The estimates show that the average global prevalence of complete tooth loss is almost 7% among people aged 20 years and older. However, in people aged 60 years and older, the global prevalence is much higher at 23% [1].

Tooth loss is usually the endpoint of chronic oral disease, mainly dental caries and severe periodontal disease, but can also be caused by poor oral hygiene, microbial plaque, periodontal disease, gender, coronal caries, dietary habits, xerostomia, low socioeconomic status and infrequent dental visits [3-7]..

Tooth loss can bep sychologically traumatic, socially disruptive and functionally limiting. Poor and socially disadvantaged members of society are disproportionately affected byoral diseases. There is a very strong and consistent association between socio-economic status (income, occupation and education level) and the prevalence and severity of oral diseases [5]. This association exists from early childhood to old age and in populations in high-, middle- and low-income countries. Treatment of oral diseases is expensive and usually not covered by universal health coverage (UHC)(8).In most low- and middle-income countries, services for the prevention and treatment of oral diseases are insufficient [1].

The burden of oral and other non-communicable diseases can be reduced with treatments such as dentures, fillings and implants. But there is a good alternative – 3D printing of teeth. Recently, with the development of industrial technology, 3D printing technology has developed rapidly and is gradually being introduced into various fields, including construction, transportation, electronics and medicine. However, this method has some problems, such as vascularization, innervation and problems in selecting dense bioinks, which scientists around the world are working to solve. The aim of our study is to conduct a bibliometric analysis to investigate the trend of 3D printing in the field of personalized medicine.

Materials and Methods

Search strategy.

The following scheme outlines a literature search strategy aimed at studying 3D bioprinting in dentistry. Literature search was conducted in the Scopus database using the keywords "tooth," "teeth," "bioprinting," "3D bioprinting," and "three-dimensional bioprinting." A total of 107 publications were retrieved, with 102 being in the English language. Subsequently, original articles and reviews were selected. Some publications were excluded from the analysis due to their irrelevance to the research topic: 9 books and 48 articles. For bibliometric analysis, 45 publications were chosen.The study involved the analysis of journals, authors, countries, and institutions publishing articles in the field of 3D bioprinting.The article selection process is demonstrated in Figure 1.

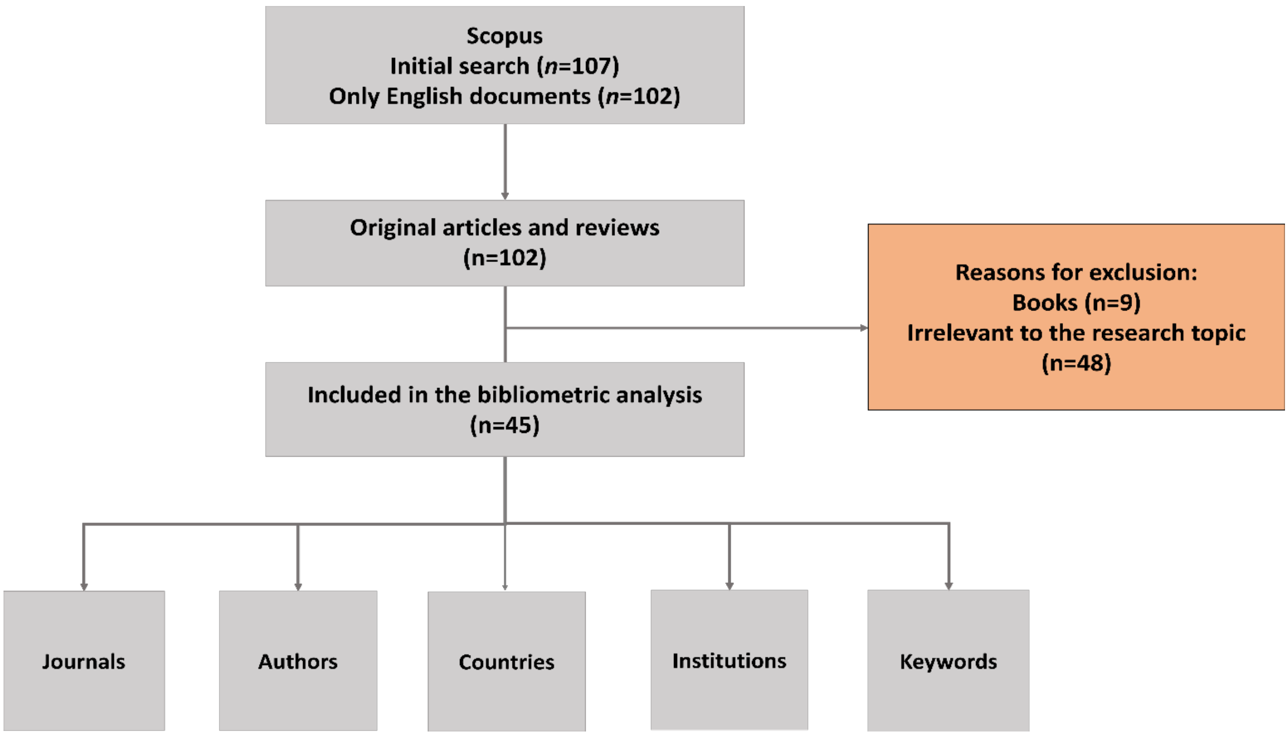

Figure 1 – Literature selection flowchart

Study selection and data extraction

The extraction of obtained publications' data was conducted by two authors (Zh.B. and A.Zh.) based on the titles of abstracts and the full texts of articles relevant to the research topic. In case of disputes, they referred to a third author.

Performance Analysis

Performance analysis and science mapping were performed using the Bibliometrix R package (http://www.bibliometrix.org; accessed on 20 March 2024) in the R-studio programming environment, version 4.3.1. The data were analyzed using the Biblioshiny tool. Graphs presented by Biblioshiny were redrawn using Excel. We assessed local publication trends and calculated the average total citations per article for each year. The most prolific journals were identified by the number of publications, while the core journals in the field were detected by implementing Bradford's law [9].

Results

Annual Scientific Production

The Figure 2 illustrates the dynamics of scientific publications over the period from 2016 to 2023. In the initial years of the study period (2016-2018), the number of publications grew slightly, remaining at a relatively low level. However, in 2019, there was a sharp increase, with the number of publications rising from 2 to 7. Subsequently, there was a decrease in 2020, with the number of publications reaching 4. However, in the following years, in 2021, the number of publications significantly increased again to 8, and then in 2022 and 2023, it reached 9.

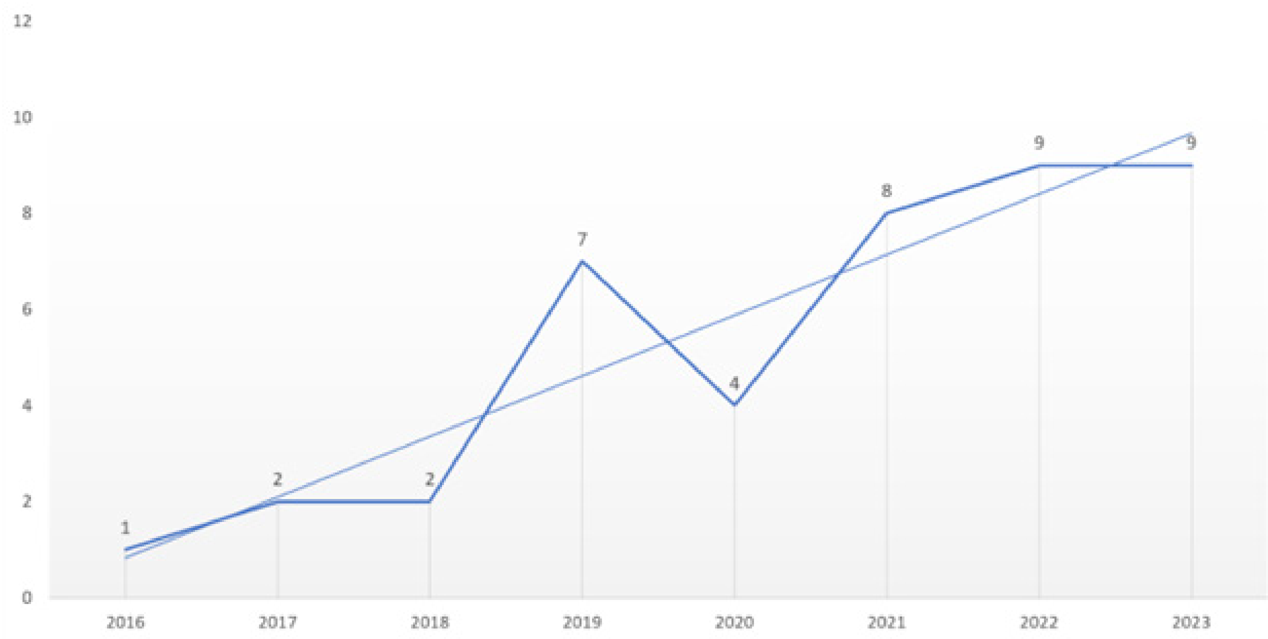

Figure 2 – Annual Scientific Production

Most productive countries, country collaboration and funding sources

In Figure 3A, spanning from 2016 to 2024, China maintains a leading position in the number of publications (n=63), marked by significantly higher indicators compared to other countries in the context of 3D bioprinting research. Following China are the United States and Korea, with 23 and 20 articles respectively. Additionally, Figure3B demonstrates international scientific collaboration among different countries. The diagram clearly indicates that China and the USA are the most active participants in international scientific collaboration, with a strong connection between China and the USA. Meanwhile, Australia, Turkey, and the United Kingdom are notable recipients of collaboration. Moreover, Figure 3C presents the major funding countries, with China leading the pack, followed by the United States and other countries, as shown in the graph. Out of the 18 represented funding organizations, eight from China, with the USA following in second place with four organizations.

Chord diagram demonstrates international scientific collaboration among different countries in the field of 3D bioprinting. The area of each circle is proportional to the number of scientific documents originating from the respective country. The thickness of the lines connecting countries reflects the degree of collaboration, where thicker lines indicate more intense interaction (B). The eight most active funding organizations investing in research related to 3D bioprinting technology (C).

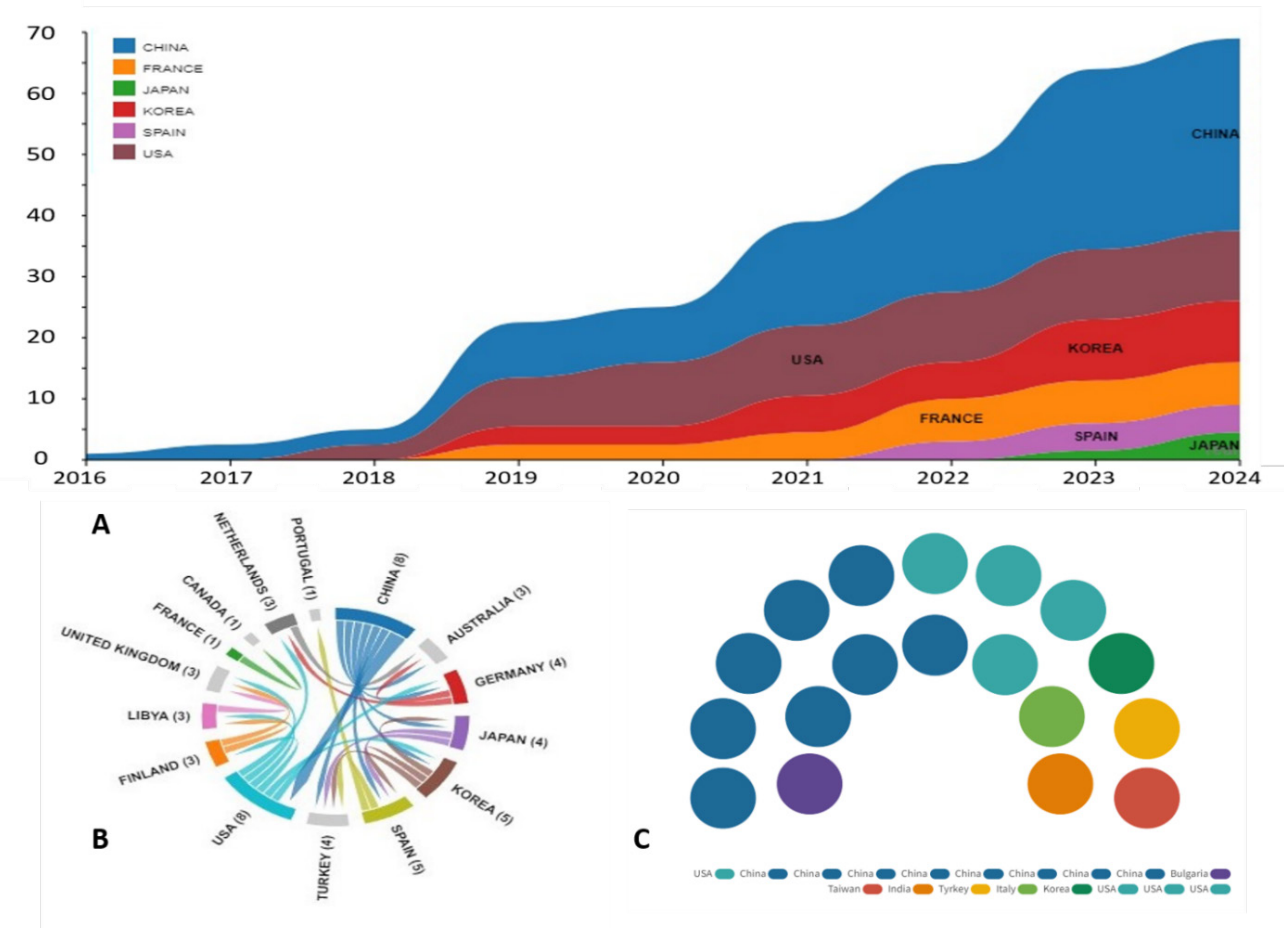

Figure 3 – The annual number of publications in the most productive countries from 2016 to 2024 in the context of 3D bioprinting research (A)

Most relevant institution

The figure illustrates that Sichuan University holds the leading position with a total of 16 publications. Following Sichuan University are Dankook University and Universiti Kebangsaan Malaysia, each with five publications. Institutions with the highest productivity are depicted in Figure 4. Additionally, as evident from Table 1, among the top 10 universities and medical centers, 7 are educational institutions in China. Other countries also contribute to research in this field: Malaysia, the Netherlands, the USA, Bulgaria , and Germany.

Journals

Bradford's Law describes the distribution of scientific articles across various journals. Figure 5 identified six core journals, constituting a significant portion of the total number of articles published on the research topic. The journal "Bioprinting" ranks among the top six journals, followed by "Cells" and "Biofabrication." Table 2 shows that both "Bioprinting" and "Cells" journals have four publications each (n=4). However, "Bioprinting" and "Annals of 3D printed medicine" are indexed solely in the Scopus database, with percentiles of 89 and 36, respectively, under the subject categories of Computer Science Applications and Health Informatics, and are not represented in the Web of Science Core Collection database. The journal with the highest Impact Factor (IF) in the list of cited sources is "Acta Biomaterialia" (IF=9.7), followed by "Biofabrication" (IF=9.0) and "Cells" (IF=6.0).

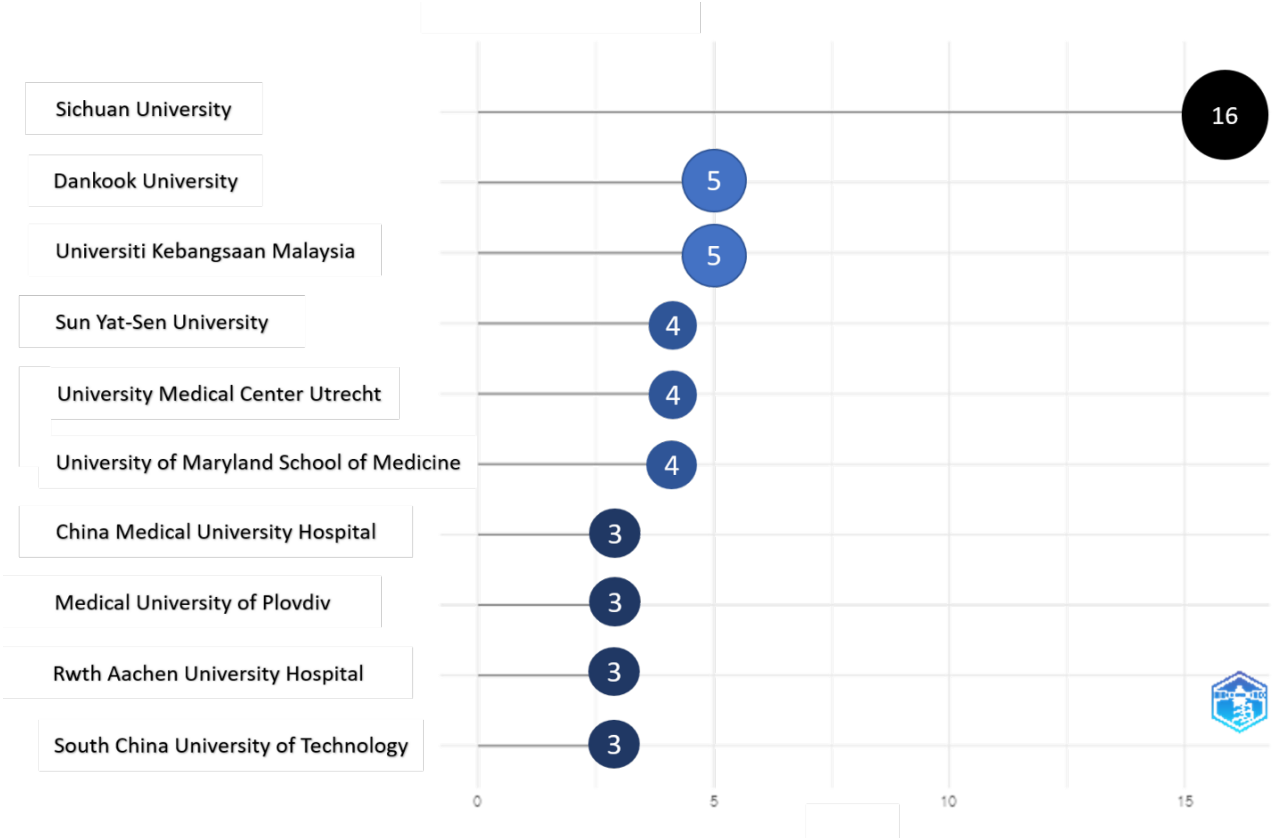

Figure 4 – Most relevant affiliations

Table 1 – Key institutions contributing to publication

Ranks	Universities	Countries	Publications
1	Sichuan university	China	16
2	Dankook university	China	5
3	Universiti Kebangsaan Malaysia	Malaysia	5
4	Sun Yat-Sen university	China	4
5	University medical center Utrecht	Netherlands	4
6	University of Maryland school of medicine	USA	4
7	China medical university hospital	China	3
8	Medical university of Plovdiv	Bulgaria	3
9	Rwth Aachen university hospital	Germany	3
10	South China university of technology	China	3

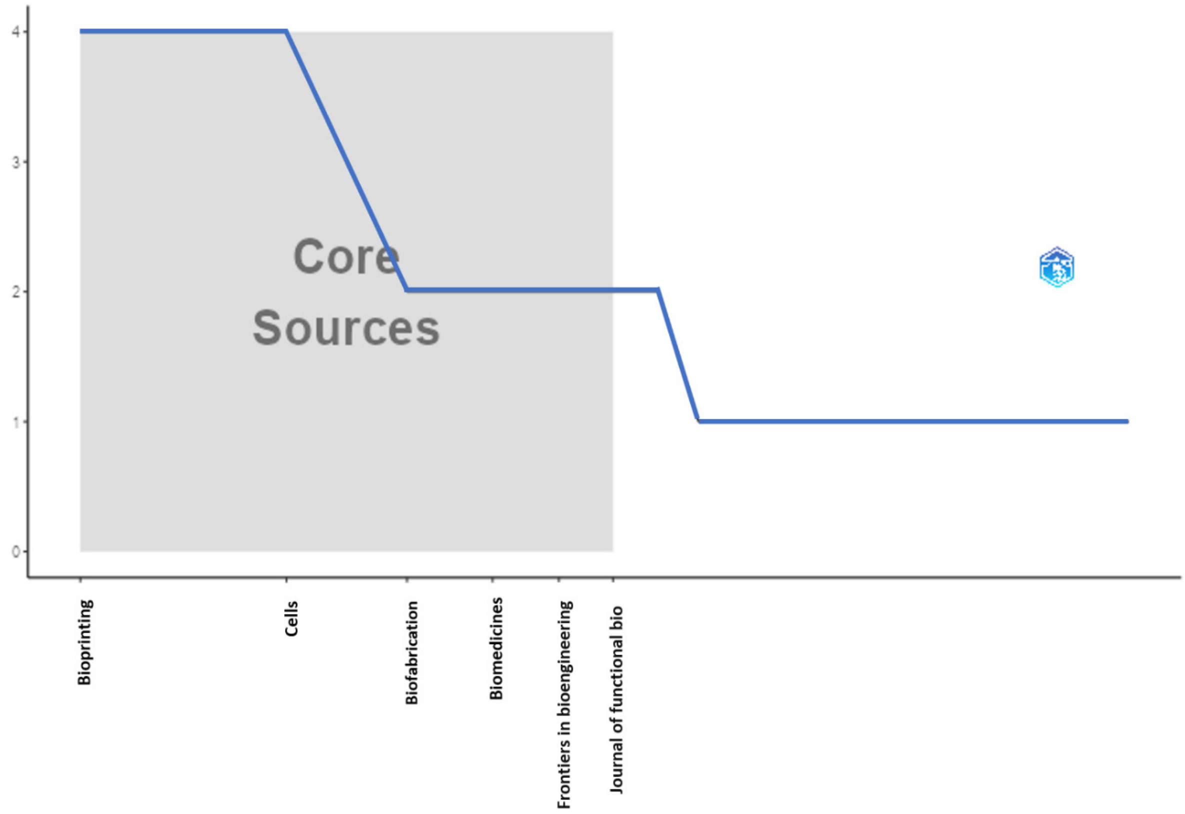

Figure 5 – Six core journals and the number of papers on the study topic published per journal in 2016–2023

Table 2 – Most relevant journals

Ranks	Sources	Articles	IF	JCR Category (Quartile)
1	Bioprinting	4	-	-
2	Cells	4	6.0	Cell biology – SCIE (Q2)
3	Biofabrication	2	9.0	Engineering, biomedical – SCIE (Q1); Materials science, biomaterials – SCIE (Q1)
4	Biomedicines	2	4.7	Biochemistry & molecular biology – SCIE (Q2); Medicine, research & experimental – SCIE (Q2)
5	Frontiers in bioengineering and biotechnology	2	5.7	Multidisciplinary sciences – SCIE (Q1)
6	Journal of functional biomaterials	2	4.8	Engineering, biomedical – SCIE (Q2); Materials science, biomaterials – SCIE (Q2);
7	Materials	2	3.4	Chemistry, physical – SCIE (Q3); materials science, multidisciplinary – SCIE (Q3);
8	Acs biomaterials science and engineering	1	5.7	Materials science, biomaterials – SCIE (Q2);
9	Acta biomaterialia	1	9.7	Engineering, biomedical – SCIE (Q1); Materials science, biomaterials – SCIE (Q1)
10	Annals of 3d printed medicine	1	-	-

Most relevant authors

This graph in Figure 6 illustrates the most prolific authors and the number of their publications in this field. Notably, Chen J, Guo W, and Zhang X stand out, each having three published works, while the remaining authors have two published works each.Zhang published 2 articles with a total annual citation count of 20.33 in 2019. However, Chen published the first article in this field in 2019, and the latest article was published in 2023, indicating his sustained interest in this topic.

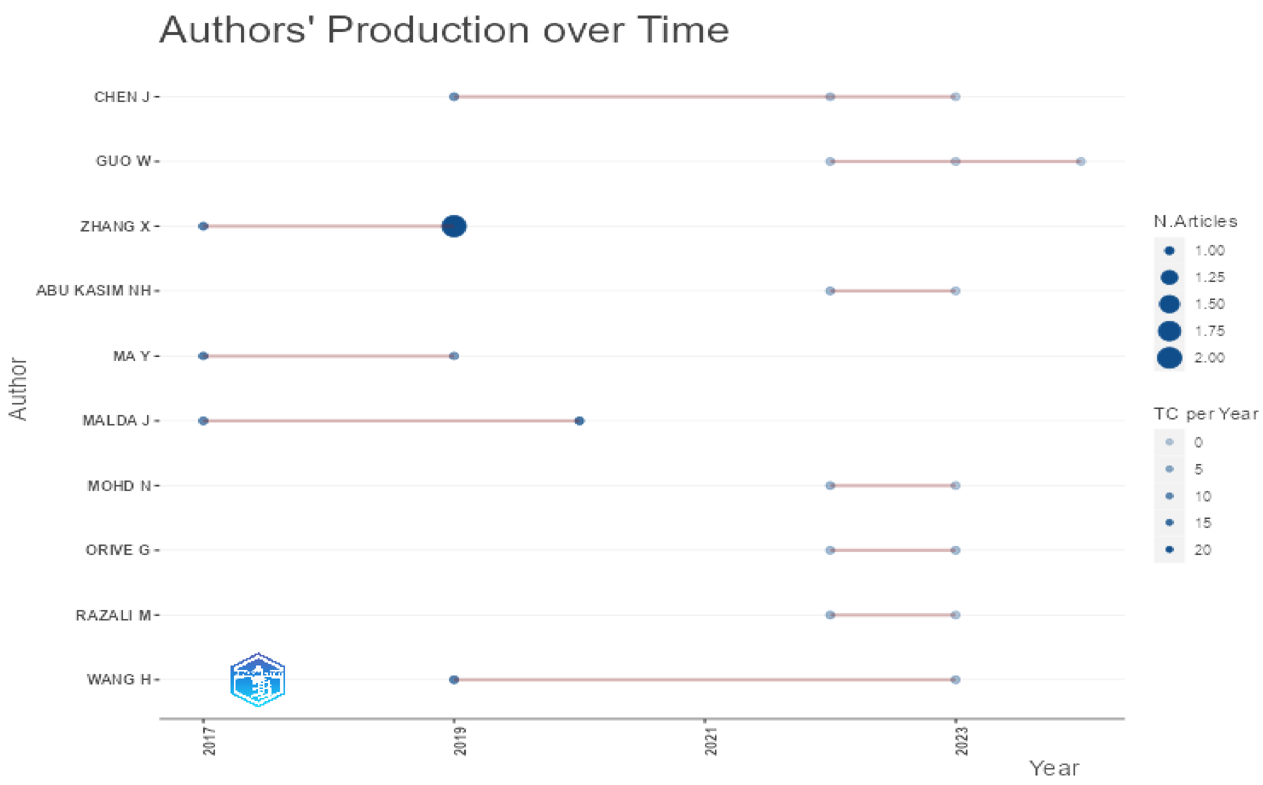

Figure 6 – Most relevant authors

Most relevant keywords

"Bioprinting" and "tissue engineering" are the most commonly used keywords by authors in the period from 2016 to 2023 (Figure 7). The next most frequently used term is "3D printing." Furthermore, terms such as "bioprinting" and "tissue engineering" demonstrate significant growth in occurrence. However, some terms, such as "gelatin" and "hyaluronic gel," do not show such a pronounced increase in frequency of mention (Figure 8).

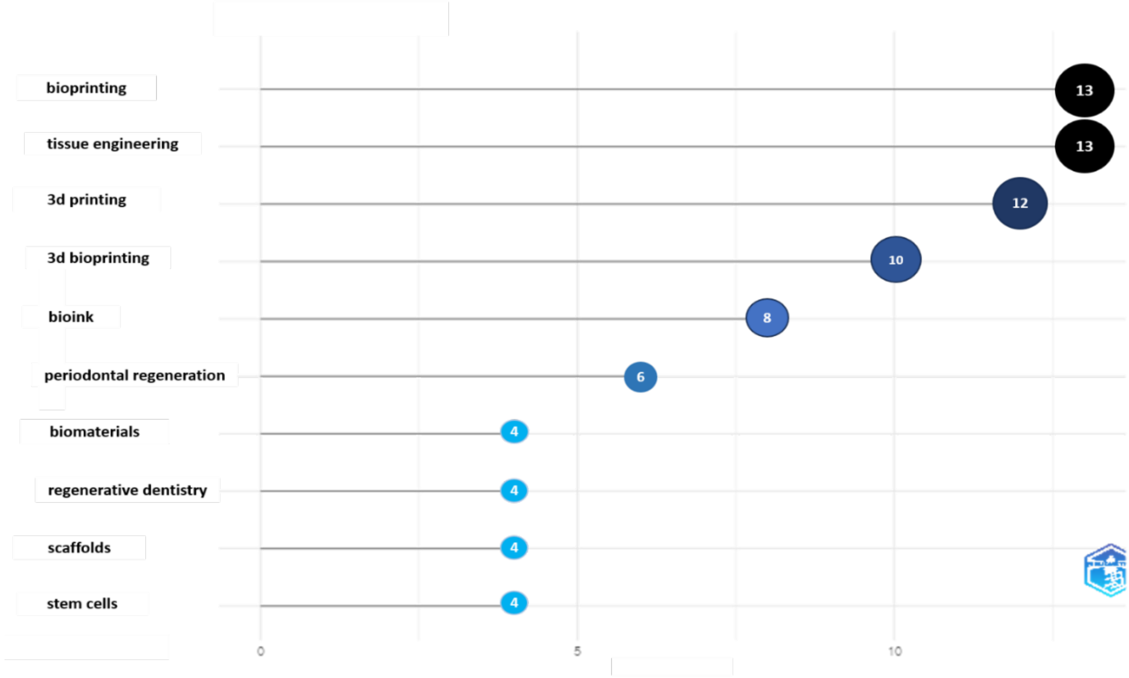

Figure 7 – Most frequently used author keywords.Each circle represents the relative frequency of each term's usage in scientific publications

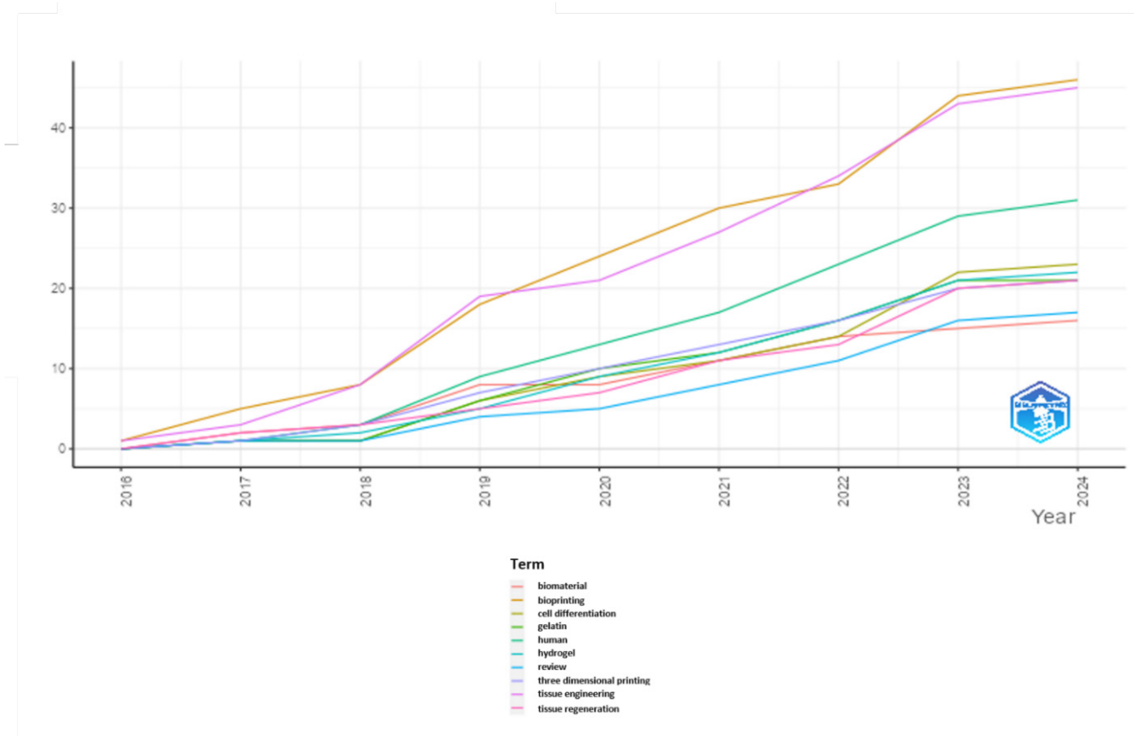

Figure 8 – Words` frequency over time

Discussion

This bibliometric analysis aims to illustrate the scope and characteristics of the scientific literature on 3D bioprinting research in dentistry. The time frame for our analysis was determined based on the earliest articles available in the Scopus database, from 2016 to 2023. Some notable findings include the contribution of world powers and institutions to 3D printing research in dentistry and medicine, authors and journals collaborating on research, and the most common keywords used by authors.

The analysis revealed a significant increase in the number of research articles on 3D bioprinting as an innovation in dentistry in recent years [10-11]. This upward trend indicates a growing recognition of the critical importance of understanding 3D printing in dentistry. The increasing volume of scientific research underscores the urgent need to address the challenges associated with 3D bioprinting in dentistry on a global scale. These challenges include the development of new methods for treating and regenerating oral tissues. Much attention is also being paid to exploring innovative approaches to improving the effectiveness and quality of dental procedures, such as the creation of bioprinted dental implants and prosthetics[12-13].The field of 3D bioprinting in dentistry is actively evolving and gaining interest both nationally and internationally.China[14]., the USA[15]., South Korea[16].andJapan [17]stand out as the main leading countries in this area of research, with high levels of publications and funding. International scientific cooperation, especially betweenChina and the USA[18], plays a key role in advancing science and technology in this field. It is also important to note the active participation of funding organizations, especially in China, which indicates a significant interest in the development of this technology. Countries actively publishing in this field are those with high income levels. This indicates that developed economies, with significant financial and technological resources, have the ability to conduct research in this area.

According to our bibliometric analysis, China has made a significant contribution to the field of 3D bioprinting, with several universities involved in research, accounting for 50% of the total publications. Sichuan Medical University in China was the most active among institutes and medical institutions, representing 32% of publications. It is important to note that mentioning a specific university emphasizes its significant contribution to scientific research. Authors such as Chen J, Guo W and Zhang X [14.19.20] also played a key role, with three publications each, indicating China's significant interest in this area.

Leading journals in the field of 3D bioprinting in dentistry include publications that specialise in cell biology, engineering and scientific journals that are dedicated to biomaterials. In addition, the journals included in the core sources are journals with high impact factors, indicating their high influence [21-23]. The selection of such authoritative peer-reviewed publications is crucial to ensure the credibility of research findings, which in turn ensures the high quality of the presented data [24].This is important because many policymakers and healthcare providers rely on high-quality evidence to make decisions [25]. Authors also consider a number of factors when deciding which journals to submit their work to. These factors include impact factor, JCR category and the availability of open access [26].

This study examined various complex concepts related to 3D bioprinting in dentistry and identified key terms used by authors. These key words, such as "bioprinting" and "tissue engineering", have the highest number of mentions, indicating their high relevance and widespread use in the scientific literature. It is also worth noting other key terms such as "3D printing", "bioink" and "periodontal regeneration".

Conclusion

Based on the provided information on 3D printing in dentistry, it can be concluded that China makes a significant contribution to research in this field. Most of the countries actively involved in publishing articles belong to high-income countries. This may be associated with their higher economic growth and larger investments in the development of 3D technologies. China, leading the list, demonstrates active participation in research, emphasizing its importance in the advancement of this technology in dentistry.

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