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Exploratory Analysis of Technological Domains in Bioprinting Patents

Análise Exploratória de Domínios Tecnológicos em Patentes de Bioimpressão

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Abstract

Bioprinting uses additive manufacturing techniques with bioinks to construct three-dimensional biological structures, showing great promise in fields such as regenerative medicine, tissue engineering, and pharmacology. Given the growing impact of this technology in the health sector, this study aimed to analyze trends and technological domains in patents related to bioprinting. The methodology adopted an exploratory and quantitative approach, with data collected from the Orbit Intelligence platform over the past 20 years. Relevance filters and semantic groupings were applied based on the Medical Subject Headings (MeSH) descriptor. The results indicate a continuous increase in patent filings, with notable contributions from the United States, China, Japan, and Europe. The predominant technological classification was B33Y (additive manufacturing), with the main assignees being research and development institutions. The most relevant domains involve implantable structures, manufacturing processes, and innovative materials, highlighting the strategic potential of bioprinting in the global technological landscape.

Keywords: Bioprinting; Technological Domains; Patent Analysis.

Resumo

A bioimpressão utiliza técnicas de manufatura aditiva com *bioinks* para construir estruturas biológicas tridimensionais, sendo promissora em áreas como medicina regenerativa, engenharia de tecidos e farmacologia. Com o crescente impacto dessa tecnologia na saúde, este estudo teve como objetivo analisar tendências e domínios tecnológicos em patentes relacionadas à bioimpressão. A metodologia adotou abordagem exploratória e quantitativa, com coleta de dados realizada na plataforma Orbit Intelligence, para os últimos 20 anos, e utiliza filtros de relevância e agrupamentos semânticos com base no descritor Medical Subject Headings (MESH). Os resultados indicam aumento contínuo no número de depósitos, com destaque para Estados Unidos, China, Japão e Europa. A classificação tecnológica predominante foi a B33Y (manufatura aditiva), sendo os principais depositantes instituições de pesquisa e desenvolvimento. Os domínios mais relevantes envolvem estruturas implantáveis, processos de fabricação e materiais inovadores, demonstrando o potencial estratégico da bioimpressão no cenário tecnológico global.

Palavras-chave: Bioimpressão; Domínio Tecnológico; Análise de Patentes.

Technological Areas: Biomedical Engineering, 3D Printing in Healthcare, and Intellectual Property.

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1 Introduction

3D printing, or additive manufacturing, is defined as "[…] the set of the most diverse techniques for transforming raw materials into a three-dimensional physical object, built layer by layer from a computer-aided digital design […]" (Sampaio et al., 2022, p. 752). It is considered a revolutionary technology, invented in 1984 by Charles W. Hull, co-founder of 3D Systems Corp. (California), whose patent was granted in 1986 (US4575330A) by the United States Patent and Trademark Office (Hull, 2015). It is currently recognized as one of the emerging technologies associated with the so-called Industry 4.0 (Khorasani et al., 2022). Hull's printer was based on stereolithography, a technology that solidifies resins through ultraviolet light, enabling the fabrication of objects from digital data and marking the beginning of the 3D printing revolution.

Hull's patent was identified by Sampaio et al. (2023) as one of the fundamental milestones in the scientific and technological development of this technology. It has been classified by several studies and institutions as an innovative, emerging, general-purpose technology with substantial economic potential (Berman, 2012; Rifkin, 2012; Mehrpouya *et al*., 2019; Andrade, 2023).

The historical process of scientific and technological evolution in 3D printing was presented by Sampaio et al. (2023), who demonstrated that, beginning in the 1990s, there was a noticeable increase in the number of scientific publications and patent applications related to the subject. Furthermore, from the 2000s onward, a significant expansion can be observed when compared with the entire period analyzed (1950–2018), as documents produced during this period account for 97.24% of all scientific articles and 89.46% of all patent applications identified in the study.

A report published by the European Patent Office (EPO, 2023) indicated that the growth in 3D printing patent applications has been remarkable over recent decades. Between 2013 and 2020, patent families related to the technology grew at an average annual rate of 26.3%. This growth was nearly eight times faster than that observed across all technology fields combined during the same period, which reached only 3.3%. Likewise, Galina and Leta (2019) demonstrated that scientific production related to 3D printing has expanded significantly over time, exhibiting an average annual growth rate of 10.18%.

It is important to highlight that the first scientific article on 3D printing was published by Kodama in 1981. In this pioneering work, Kodama described a method for creating plastic models through the solidification of a photopolymer using ultraviolet radiation, emphasizing that the technique enabled the production of objects with highly complex structural geometries (Queiroz, Reis, & De Oliveira, 2023). This study marked the beginning of the 3D printing revolution, which has since evolved considerably, becoming increasingly accessible and versatile while encompassing a broad range of technologies and applications across multiple sectors. Today, it is virtually impossible to identify an economic sector that does not incorporate 3D printing solutions, ranging from agriculture to the automotive, aerospace, pharmaceutical, construction, design, food, educational, and healthcare sectors.

Galina and Leta (2020) argue that the field of 3D printing research is inherently multifaceted, extending beyond the disciplines of engineering, computer science, and materials science, where the technology originally emerged. Their study demonstrated that health sciences, particularly medicine, have become increasingly interconnected with 3D printing in both scientific publications and conference proceedings. Furthermore, the expansion of research activity is especially evident in studies associated with Biochemistry, Genetics, and Molecular Biology, suggesting a recent shift in 3D printing research toward the health sciences domain.

The application of 3D printing in healthcare is highly promising and disruptive, with its principal benefits arising from the customization and personalization of products (Alzoubi, Aljabali, & Tambuwala, 2023), such as prostheses; substantial reductions in manufacturing costs (Koprnicky, Šafka, & Ackermann, 2018); the potential elimination of transplant rejection (Agarwal *et al*., 2020); and its virtually unlimited flexibility and rapid prototyping capabilities for healthcare applications (Javaid *et al*., 2022).

This specialization of 3D printing focused on tissues and organs became known as bioprinting, involving the use of biomaterials, commonly referred to as "bioinks," including cellular materials, proteins, polysaccharides, among others (Oficina Española de Patentes y Marcas, 2021). Galina and Leta (2020) identified, through a keyword co-occurrence network of scientific articles on 3D printing, that the terms bioprint and bioplotter began to gain prominence between 2013 and 2017. Specialized scientific journals dedicated to the field, namely the International Journal of Bioprinting and Bioprinting, were launched in 2015 and 2016, respectively, highlighting the recent nature of this phenomenon.

Examples of applications and developments in healthcare include the printing of cells and tumors for disease research (Zhao *et al*., 2014); the fabrication of cartilage, bones, teeth, blood vessels, and cellularized skin (Michael *et al*., 2013); the production of tissues, organs, organic molecules, and living organisms (Mironov, 2003; Boland *et al*., 2003); the development of vascular grafts, tracheal splints, cardiac tissue, cartilaginous structures, and molecular models for research purposes (Murphy & Atala, 2014); dental crowns, customized implants, and anatomical models (Ventola, 2014); as well as biological systems intended to replace animals in drug testing.

It is important to emphasize that progress in the field of bioprinting has been remarkably rapid. The first organ printed from living cells, a bladder, was produced in 1999. In 2002, a detailed miniature nonfunctional kidney was created. This was followed

by the first blood vessels in 2010, the first liver in 2012, pancreatic tissue in 2018, a heart valve in 2019, and a tongue equipped with nanosensors in 2020 (Rezvani Ghomi *et al*., 2021).

Among the most recent advances, particular attention should be given to bioprinting experiments conducted under microgravity conditions aboard the International Space Station, aimed at assessing the feasibility of printing complete organs in an environment considered favorable for such purposes. This initiative also points toward the future possibility of establishing biomanufacturing facilities beyond Earth's atmosphere (Sims, 2021).

Bioprinting should therefore be regarded as an emerging technological development area with substantial potential for direct application, making its scientific and technological evolution highly relevant for ongoing monitoring and analysis.

The evolution of any technology can be monitored by examining the technological domains of patent applications filed over time. For this purpose, the International Patent Classification (IPC) system, established and continuously refined since 1971 under the coordination of the World Intellectual Property Organization (WIPO), is widely employed and currently adopted by more than 100 countries.

The IPC established a classification system based on branches or categories of technology, that is, the technical field of knowledge that enabled the conception of an invention. The system comprises eight sections: A, Human Necessities; B, Performing Operations and Transporting; C, Chemistry and Metallurgy; D, Textiles and Paper; E, Fixed Constructions; F, Mechanical Engineering, Lighting, Heating, Weapons, and Blasting; G, Physics; and H, Electricity. These sections are divided into classes and subclasses, while subclasses are further subdivided into groups and subgroups. It should be noted that periodic revisions are carried out to update the classification system in response to emerging technologies, including developments related to bioprinting.

This approach establishes an objective system for accessing patent documents, overcoming barriers such as language limitations in keyword-based information retrieval. Consequently, the IPC should be understood as a valuable tool for accessing the technological content contained in patent documents. With more than 70,000 technological classification subdivisions, it enables highly precise retrieval of protected products and processes associated with specific technological aspects.

Within this context, the present study aims to analyze the evolution of patent family filings related to bioprinting, with a particular focus on technological domains.

2 Methodology

The initial stage of data retrieval consisted of defining technical descriptors related to bioprinting based on the controlled vocabulary of the Medical Subject Headings (MeSH). The platform used to retrieve patent families was Orbit Intelligence, developed by Questel and recognized by WIPO for its high-quality patent data. This credibility is evidenced by the platform's use in the report *WIPO Technology Trends 2019: Artificial Intelligence* (WIPO, 2019).

The data for this study were retrieved on June 21, 2024, covering the previous 20 years and using patent families as the unit of analysis. The search strategy was structured into three steps. In the first step, three groups of terms were defined. The first group comprised terms related to 3D printing and its variations. The second group included terms associated with the application of 3D printing in healthcare, such as biofabrication. The third group consisted of synonyms related to bioprinting.

Four analyses were conducted: (i) the evolution of the number of patent families over time; (ii) the International Patent Classification (IPC); (iii) countries; and (iv) assignees with the highest number of patent family filings. All these dimensions are associated with technological domains, enabling the mapping of bioprinting evolution and the identification of applications that demonstrate industrial protection interest for commercial exploitation.

For analyses based on rankings, a filter was applied to consider only the top 20 classifications.

3 Results and Discussion

The results are presented in the following sections: data retrieval; the evolution of patent families over time; the most prominent IPC classifications and their respective technological domains; the leading technological domains and key countries; and the technological diversity of the largest assignees.

3.1 Data Retrieval

To illustrate the relationships among the three groups of terms employed, as well as their intersections and the progression of the search results, these relationships were graphically represented using a Venn-Euler set diagram, as shown in Figure 1. Additionally, the terms corresponding to each group were included in the diagram.

The first two groups were combined through an intersection process (Step 2), meaning that terms related to both groups had to be present in the title or abstract of the patent document. This procedure resulted in the retrieval of 461 patent families.

The result of this intersection was subsequently combined with the bioprinting group (Step 3), yielding a total of 1,116 patent families. It is important to note that this result differs from the simple sum of the partial results obtained in Step 3 (461 + 675 = 1,136), because 20 patent

families within the bioprinting group had already been retrieved in the previous step. Consequently, duplicate records were eliminated from the analysis.

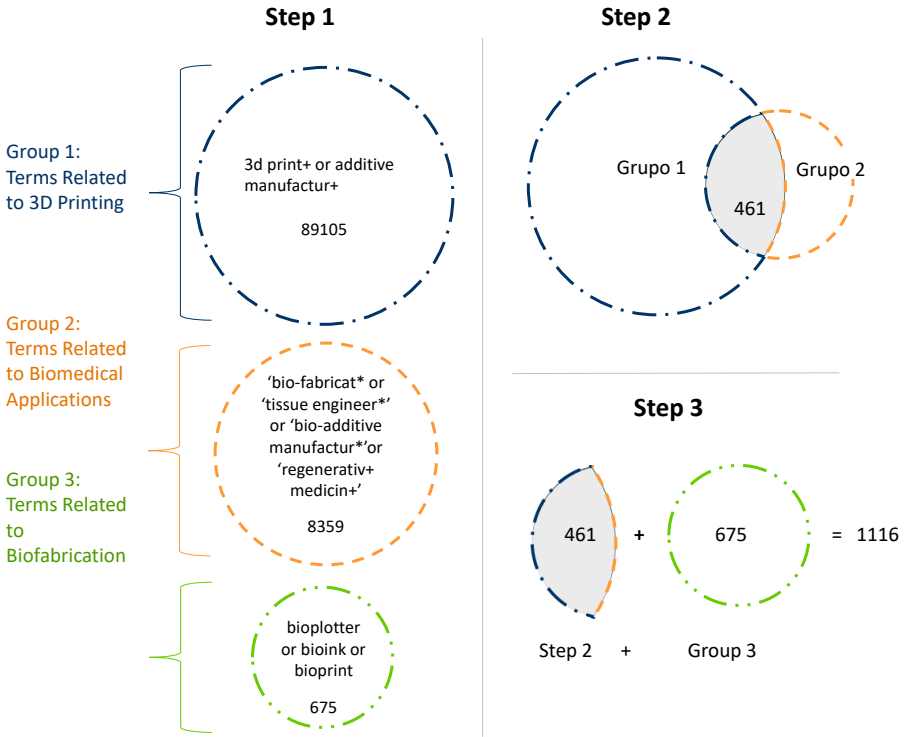
3.2 Evolution of Patent Families Over Time

The evolution of the number of patent families related to bioprinting over the last 20 years is presented in Graph 2. The earliest patent family identified dates back to 1989; however, only from 2010 onward were patent families consistently filed in every subsequent year. The dotted line in Graph 2 represents the total number of patent families. It should be noted that data collection was conducted in June 2024 and, due to the 18-month confidentiality period following the filing date, as well as the legal timeframes applicable to Patent Cooperation Treaty (PCT) applications, a lower number of documents is expected for the two most recent years of the sample, since the data have not yet been fully consolidated.

The three leading technological domains are highlighted by the colored columns in Graph 2. It is important to emphasize that a single patent family may be associated with multiple technological domains. Consequently, the sum of technological domain occurrences exceeds the total number of patent families.

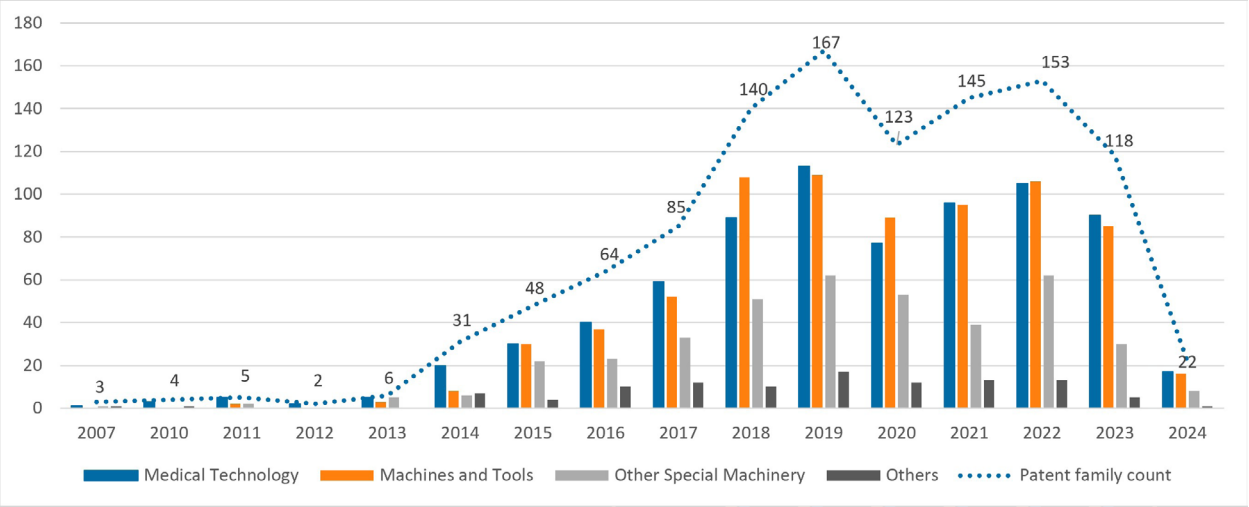
Graph 2 clearly demonstrates the substantial increase in patent filings, as reflected by the slope of the growth curve across three distinct periods. The first notable growth phase occurred between 2013 and 2017, when the number of patent families increased from six to 85. The second significant growth period took place between 2017 and 2018, representing the steepest increase observed throughout the analyzed period, with the number of patent families rising from 85 to 140. Subsequently, a decline in patent filings can be observed, coinciding with the COVID-19 pandemic, a period during which intellectual and financial resources were largely redirected toward addressing challenges associated with the global health crisis. Beginning in 2020, patent filings resumed their upward trajectory, continuing to grow until 2021. Thereafter, as expected due to confidentiality requirements and applicable legal timeframes, the number of patent families appears lower than projected. However, this result should be interpreted with caution, as it does not fully reflect the actual volume of filings corresponding to the two most recent years of the analyzed time series.

Graph 1 – Intersection of the Descriptors Used in the Bioprinting Patent Search Strategy



Source: Prepared by the authors

Graph 2 – Evolution of the Total Number of Patent Family Filings by Year, Indicating the Technological Domains



Source: Prepared by the authors

It is noteworthy that, although the earliest patent families were associated with the Mechanical and Electrical Engineering domains, patent families related to Medical Technologies began to emerge from 2010 onward. Another noteworthy observation is that only in 2018 did the Machines and Tools domain surpass Medical Technologies for the first time, with these two domains subsequently alternating between the first and second positions. The three most prominent technological domains are Medical Technologies, accounting for 37.44% of all occurrences, Machines and Tools, with 36.80%, and Other Special Machines, with 19.75%. The remaining domains exhibit substantially lower frequencies.

These technological domains are examined in greater detail in the subsequent analyses.

3.3 The Most Prominent IPC Classifications and Their Technological Domains

Box 1 presents the relationships between the 20 IPC classifications with the highest number of patent family filings, categorized according to their respective technological domains.

The most prominent IPC classifications in terms of patent filings are B33Y, which relates to the Additive Manufacturing of Three-Dimensional Objects and accounts for 22.1% of all filings; A61L, which covers Methods or Apparatus for Sterilizing Materials or Objects in General, representing 17.7%; and B29C, which refers to the Shaping or Joining of Plastics, accounting for 10.9%. Collectively, these IPC classifications represent 50.7% of all patent filings.

IPC classification B33Y stands out as the most prominent within the Machines and Tools domain, with 740 records, while also demonstrating substantial relevance in the Medical Technology domain, with 504 patent family filings. In turn, A61L leads the Medical Technology domain, totaling 649 filings. The third most significant classification, B29C, concentrates the largest number of documents within the Other Special Machines domain, with 323 patent families. Finally, classification C12N, related to Microorganisms or Enzymes, is particularly prominent in the Biotechnology domain, accounting for 268 patent families.

Regarding the technological domains with the highest number of patent families, Machines and Tools ranks first with 2,427 patent families, followed by Medical Technology with 2,304, Other Special Machines with 1,510, and Biotechnology with 1,416.

Among the five technological domain groups identified, Mechanical Engineering is the most representative, accounting for 40.2% of all filings (4,181), with Machines and Tools and Other Special Machines serving as its leading domains. The Instruments group represents 26.0% of the total, followed by Chemistry with 32.7%, Electrical Engineering with 1.0%, and, finally, Other Fields with 0.1%.

3.4 Leading Technological Domains and Key Countries

The classification of technological domains by country for a ranking of the top 20 nations is presented in Box 2. As shown, eight countries are located in Europe (Sweden, France, Türkiye, the United Kingdom, Germany, Spain, Italy, and Poland); six are in Asia (China, South Korea, India, Japan, Singapore, and Taiwan); two are in the Americas (the United States and Brazil); one is in Eurasia (Russia); and one is in Oceania (Australia). In addition,

Box 1 – Total Patent filings by ipc classification and technological Domain

Group	Instruments					Mechanical Engineering							Eng. Elétrica					Chemistry												Others fields			Total	% (10399)
IPC	Analysis of Biological Materials	Measurement	Medical Technology	Control	Optics	Machines and Tools	Other Special Machines	Textile and Paper Machines	Thermal Processes and Apparatus	Transport	Engines, Pumps, and Turbines	Handling	Audiovisual Technology	Computer Technology	Electrical Machinery, Apparatus and Energy	Telecommunications	Semiconductors	Basic Materials Chemistry	Biotecnology	Environmental Technology	Materials Metallurgy	Microstructural and Nanotechnology	Fine Organic Chemistry	Surface Technology and Coating	Macromolecular Chemistry and Polymers	Pharmaceuticals	Food Chemistry	Chemistry Engineering	Civil Engineering	Other Consumer Goods		
B33Y	27	14	504	8	9	740	343	28	3	1	0	6	2	17	2	4	1	77	252	2	30	7	7	12	96	67	7	32	0	1	2299	22,1
A61L	20	4	649	5	10	448	184	19	0	1	0	2	0	9	1	3	0	67	170	1	19	6	9	6	106	86	4	9	0	1	1839	17,7
B29C	11	10	161	6	4	301	323	24	3	1	0	5	2	9	2	1	1	36	132	1	7	3	3	10	31	18	3	28	0	1	1137	10,9
C12N	36	5	159	8	3	181	106	20	0	1	0	5	0	5	2	2	1	37	268	1	3	5	6	6	37	60	5	12	0	0	974	9,4
A61F	7	5	210	4	3	125	61	15	0	0	0	1	0	6	0	2	0	9	51	0	5	1	0	6	9	26	1	6	0	1	554	5,3
C12M	19	10	87	5	2	144	94	21	2	1	0	7	1	5	1	1	2	16	194	0	2	2	1	7	10	24	2	26	0	1	687	6,6
A61K	13	1	88	0	2	69	43	5	0	0	0	1	0	2	0	1	1	12	41	0	2	3	10	0	31	106	2	3	0	1	437	4,2
C09D	4	2	63	0	0	72	41	3	0	0	0	0	0	2	0	0	0	103	43	0	2	3	5	1	21	7	2	4	0	0	378	3,6
C08L	1	0	73	0	1	67	67	0	0	0	0	0	0	0	0	0	0	16	31	0	3	3	2	1	94	16	1	0	0	0	376	3,6
C08J	0	0	60	0	3	47	76	1	0	0	0	0	0	0	0	0	0	10	22	0	2	1	4	0	67	19	0	0	0	0	312	3,0
G01N	47	16	28	5	1	34	18	7	0	0	0	2	0	3	1	0	0	6	47	0	0	2	1	4	1	14	0	6	0	0	243	2,3
C07K	2	0	29	0	0	19	10	1	0	0	0	1	0	0	0	0	1	8	34	0	2	3	4	2	10	17	1	1	0	0	145	1,4
A61P	9	0	31	0	0	21	10	2	0	0	0	0	0	0	0	0	0	4	21	0	0	1	2	2	5	38	0	1	0	1	148	1,4
C12Q	18	2	20	1	0	19	12	2	0	0	0	0	0	0	0	0	0	6	38	0	0	2	1	3	4	12	0	1	0	0	141	1.4
A61B	3	1	36	4	0	21	11	3	0	0	0	2	0	1	0	2	0	3	14	0	1	0	0	1	1	4	1	2	0	1	112	1.1
B41J	3	5	19	2	1	21	19	36	0	0	0	1	2	3	0	2	0	3	23	0	0	0	0	3	0	3	0	6	0	0	152	1.5
B29K	0	2	21	0	2	32	33	3	1	1	0	0	0	0	1	0	0	7	12	0	0	1	0	2	5	2	2	3	0	0	130	1.3
C08G	0	0	28	0	2	19	17	0	0	0	0	0	0	0	0	0	0	4	5	0	0	0	3	0	33	9	0	1	0	0	121	1.2
C08F	0	0	19	0	4	20	15	0	0	0	0	0	0	0	0	0	0	6	6	0	1	0	3	0	29	5	0	1	0	0	109	1.0
B29L	2	1	19	1	1	27	27	5	1	0	0	0	0	1	0	0	0	2	12	0	0	1	0	1	2	0	0	2	0	0	105	1.0
Soma %	*222*	78	2304	49	48	2427	1510	195	10	6	0	33	7	63	10	18	7	432	1416	5	79	*44*	*61*	*67*	*592*	*533*	*31*	*144*	*0*	*8*	10399	
(10399)	*26.0%*					*40.2%*							*1.0%*					*32.7%*											*0.1%*				

Source: Prepared by the authors

two organizations whose data represent the innovation efforts of multiple countries are included in the Box: the European Patent Organisation (EPO), through the European Patent Office, which encompasses patent filings from virtually all European countries as a regional patent office; and the World Intellectual Property Organization (WIPO), a specialized agency of the United Nations responsible for administering the Patent Cooperation Treaty (PCT), which includes patent filings from all 157 contracting states. Therefore, these organizations should not be directly compared with individual countries.

Although the United States pioneered the development of most technologies related to 3D printing, China currently leads in the number of patent applications, accounting for 37.6% of the total. This leadership is particularly evident in domains related to Medical Technology, with 371 patent families; Machines and Tools, with 350; and Other Special Machines, with 148, reflecting a strong emphasis on the Mechanical Engineering and Instruments technological groups. The United States accounts for 26.0% of patent applications and exhibits a more diversified technological profile than China, with notable concentrations in Machines and Tools (155 patent families), Medical Technology (154), and Biotechnology (134). Ranking third, South Korea holds 13.7% of the patent applications, concentrated primarily in Machines and Tools, with 91 patent families; Medical Technology, with 69; Biotechnology, with 59; and Other Special Machines, with 58.

The four most important technological domains in the field of bioprinting across the majority of countries are Medical Technology (742 filings), Machines and Tools (731), Other Special Machines (392), and Biotechnology (383). These domains exhibit little variation in their relative rankings, reflecting the consistent importance of these areas for technological development and global innovation.

The top five countries in the ranking account for 85.8% of all patent applications, while each of the remaining 12 countries holds a share of less than 2%. Notably, the three leading countries, China, the United States, and the Republic of Korea, collectively represent 77.4% of all patent filings.

The importance of the technological groups, in terms of the total number of patent filings, follows the order: Mechanical Engineering, accounting for 40.3%; Chemistry, representing 29.6%; and Instruments, with 28.4%. It is worth noting that the Chemistry group encompasses 11 technological domains; Mechanical Engineering comprises seven domains; Electrical Engineering includes five; Instruments also contains five; and the Other Fields group consists of only two technological domains.

Countries ranked between 10th and 20th place exhibit a more limited technological focus, with no patent filings in several technological domains.

3.5 Technological Diversity of the Leading Assignees

Box 3 presents the ranking of the 20 largest assignees, categorizing them as either companies or universities. Among these organizations, nine are companies and 11 are universities.

While companies demonstrate, on average, an interest in approximately 11 technological domains, universities exhibit activity in around six technological domains.

The companies with the greatest technological diversification are Revotek, a Chinese company founded in 2014 and specialized in 3D bioprinting and bioengineering, with activities spanning 16 technological domains; Cellink Bioprint, a Swedish company founded in 2016 and recognized as a leader in the field of 3D bioprinting through the development of bioprinters and bioinks, with 15 domains; and, tied with 13 domains each, Organovo, an American company founded in 2007 and specialized in the development of human tissue models for medical research, and Aspect Biosystems, a Canadian company founded in 2013 and focused on 3D microfluidic bioprinting and tissue engineering.

Among the universities with the highest degree of technological diversification, the most prominent are Pohang University of Science and Technology and Sungkyunkwan University, both from the Republic of Korea, with eight technological domains each. They are followed by Zhejiang University, Shenzhen University, and Tsinghua University, all from China, with activities distributed across seven technological domains.

Among the top 20 assignees, Organovo stands out as the only organization with a well-balanced distribution across three of the four major technological groups, comprising 26 patent families in Instruments, 23 in Mechanical Engineering, and 22 in Chemistry. Its primary focus lies in Biotechnology, with 13 patent families, and Medical Technology, with 12, reflecting the company's strong interest in biotechnological applications.

The assignees Revotek, Cellink, Rokit Healthcare, Zhejiang University, Aspect Biosystems, Poietis, Sichuan Revotek Biotechnology, Shanghai University, Peking University, and Regenovo exhibit a greater commercial interest in the Mechanical Engineering group, particularly within the domains of Machines and Tools and Other Special Machines. This pattern highlights a strong emphasis on the development of machinery and equipment. In contrast, Donghua University and Sungkyunkwan University demonstrate a stronger focus on Medical Technologies.

Among the top 20 assignees, the three leading organizations account for 30% of all patent family filings, while the top five collectively represent 43% of the total patent filings.

Box 2 – Number of patent applications by country and technological domain

Group	Instruments					Mechanical Engineering							Electrical Engineering					Chemistry												Others fields		Total	% (2944)
Countries	Analysis of Biological Materials	Measurement	Medical Technology	Control	Optics	Machines and Tools	Other Special Machines	Textile and Paper Machines	Thermal Processes and Apparatus	Transport	Engines, Pumps, and Turbines	Handling	Audiovisual Technology	Audiovisual Technology	Electrical Machinery, Apparatus and Energy	Telecommunications	Semiconductors	Basic Materials Chemistry	Biotecnology	Environmental Technology	Materials Metallurgy	Microstructural and Nanotechnology	Fine Organic Chemistry	Surface Technology and Coating	Macromolecular Chemistry and Polymers	Pharmaceuticals	Food Chemistry	Chemistry Engineering	Civil Engineering	Other Consumer Goods		
China	4	1	371	2	1	350	148	5	0	0	0	0	0	6	0	1	0	12	76	0	21	2	3	3	76	21	0	5	0	0	1108	37.6
USA	24	6	154	7	4	155	113	17	1	1	0	4	1	6	2	2	1	27	134	1	2	5	4	6	24	42	3	19	0	1	766	26.0
Republic of Korea	5	5	69	1	1	91	58	5	1	2	0	0	2	4	1	2	0	52	59	1	2	4	2	2	15	12	1	7	0	0	404	13.7
Índia	3	1	38	0	4	28	6	2	0	0	0	2	1	1	1	1	0	7	14	0	2	1	1	1	4	12	1	1	0	2	134	4.6
EPO	1	1	27	1	0	26	11	0	0	0	0	0	0	1	1	1	0	7	21	0	1	0	1	0	7	5	1	2	0	0	115	3.9
WIPO	1	1	11	1	0	13	10	2	1	0	0	0	1	0	0	0	1	2	10	0	2	0	0	1	1	2	0	4	0	0	64	2.2
Austrália	3	3	9	1	0	11	10	5	0	0	0	1	0	0	0	0	0	1	10	0	1	0	0	0	1	4	0	0	0	0	60	2.0
Australia	2	2	7	0	1	14	9	2	0	0	1	1	0	1	0	0	0	0	12	1	1	0	0	1	0	1	0	2	0	0	58	2.0
Sweden	1	0	8	0	0	11	7	4	0	0	0	1	0	0	0	0	0	0	11	0	0	0	0	0	1	3	0	2	0	0	49	1.7
France	2	1	8	0	1	4	1	0	0	0	0	0	0	0	0	0	0	1	6	0	0	0	0	0	2	3	0	0	0	0	29	1.0
United Kingdom	0	0	11	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	8	0	0	0	0	0	0	2	0	0	0	0	24	0.8
Russia	0	0	4	0	1	4	3	1	0	0	0	0	0	1	0	0	0	0	3	0	0	0	1	0	2	1	0	0	1	1	23	0.8
Brazil	0	0	3	0	0	2	1	3	0	0	0	0	2	1	0	2	0	0	6	0	0	0	0	0	1	0	1	0	0	0	22	0.7
Japan	0	0	7	0	0	2	1	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	3	0	0	0	0	18	0.6
Türkiye	0	0	3	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0	6	0	0	1	0	0	1	1	0	0	0	0	18	0.6
Spain	0	1	2	0	0	4	4	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	13	0.4
Singapore	0	0	2	0	0	4	3	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	12	0.4
Italy	0	0	3	0	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	11	0.4
Taiwan	0	0	3	0	0	2	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	1	0	0	0	10	0.3
Poland	0	0	2	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0.2
Soma	46	22	742	13	14	731	392	46	3	3	1	10	7	22	5	9	2	111	383	3	32	13	12	15	138	113	8	43	1	4	2944	
	837					1186							45					871											5			
% (2944)	28.4%					40.3%							1.5%					29.6%											0.2%			

Source: Prepared by the authors

Box 3 – Assignees by Technological Domain

Group			Instruments					Mechanical Engineering					Electrical Engineering				Chemistry										Total	% (653)
		Technological Domain	Analysis of Biological Materials	Measurement	Medical Technology	Control	Optics	Machines and Tools	Other Special Machines	Textile and Paper Machines	Thermal Processes and Apparatus	Handling	Audiovisual Technology	Computer Technology	Electrical Machinery, Apparatus and Energy	Semiconductors	Basic Materials Chemistry	Biotecnology	Environmental Technology	Materials Metallurgy	Microstructural and Nanotechnology	Fine Organic Chemistry	Tecnologias de superficie e revestimento	Macromolecular Chemistry and Polymers	Pharmaceuticals	Eng. Chemistry		
Assignees		Organovo	8	4	12	2	0	5	9	9	0	0	0	2	0	0	2	13	0	0	0	0	1	0	5	1	*73*	11.18
		Revotek	1	1	12	1	0	16	15	2	1	0	1	0	0	1	1	9	0	1	0	0	2	0	1	5	*70*	10.72
		Cellink Bioprinting	1	1	5	1	2	12	10	3	1	0	0	2	0	0	0	10	0	1	0	0	1	0	2	2	*54*	8.27
		Rokit Healthcare	0	2	4	0	0	13	9	2	1	0	0	1	1	0	0	6	1	0	0	0	0	0	2	0	*42*	6.43
		Zhejiang Univ.	0	0	13	0	0	12	6	1	0	0	0	0	0	0	0	6	0	0	0	0	0	2	1	0	41	6.28
		Boc	2	2	4	0	0	7	5	0	0	1	0	0	0	0	2	8	0	0	1	0	0	2	2	1	*37*	5.67
		Sichuan Univ.	0	0	14	0	0	11	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	5	1	0	*35*	5.36
		Aspect Biosystems	2	1	5	1	0	5	5	1	0	0	0	1	0	0	0	3	0	0	1	1	0	0	2	2	*30*	4.59
		Poietis	0	0	4	0	0	7	5	3	0	1	0	0	0	0	0	7	0	0	0	0	0	0	1	2	*30*	4.59
		Pohang Univ. of Sci. & Tech. Postech	0	0	7	0	0	6	2	1	0	0	0	0	0	0	7	4	0	0	0	0	0	1	1	0	*29*	4.44
		Shenzhen Inst. - Chinese Acad. Sci.	0	0	9	1	0	6	3	0	0	0	0	0	0	0	0	4	0	0	0	0	0	1	2	0	*26*	3.98
		Sichuan Revotek Biotechnology	1	0	4	0	0	9	5	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	1	*26*	3.98
		South China Univ. Of Technology	0	0	12	0	0	11	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	*26*	3.98
		Shanghai Univ.	0	0	5	0	0	10	7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	*24*	3.68
		Tsinghua Univ.	0	0	7	0	0	7	2	1	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	1	22	3.37
		Peking Univ.	0	0	7	0	0	8	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	*20*	3.06
		Yangzhou Univ.	1	0	7	0	0	6	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	20	3.06
		Donghua Univ.	0	0	9	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	*17*	2.60
		Sungkyunkwan Univ.	0	0	6	0	1	2	1	0	0	0	0	0	0	0	1	3	0	0	1	0	0	0	1	0	*16*	2.45
		Regenovo Biotechnol.	0	0	2	0	0	6	2	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	*15*	2.30
		Soma	16	11	148	6	3	165	97	23	3	2	1	6	1	1	13	92	1	*4*	*3*	*1*	*4*	*16*	*21*	*15*		
			184					290					9				170										*653*	
		% (653)	28.18%					44.41%					1.38%				26.03%											
			Company					University																				

Source: Prepared by the authors

4 Final Considerations

The study analyzed 1,116 patent families related to bioprinting, seeking to understand the evolution of technological domains within this field. The main findings can be highlighted as follows:

Substantial Growth in Patent Activity: A significant increase in the number of bioprinting patent filings can be observed, particularly between 2013 and 2017 and again from 2020 onward. This growth reflects both the advancement of the field and the increasing interest in bioprinting technologies.

Predominant Technological Domains: The most frequently represented technological domains in bioprinting patents are Machines and Tools (37.7%), Medical Technology (37.4%), and Other Special Machines (19.7%). These findings indicate that research and development activities in bioprinting are primarily concentrated on equipment, medical devices, and specialized technologies designed for bioprinting applications.

Concentration of Patents in Asia and the United States: The majority of bioprinting patent families (85.8%) originate from Asian countries, particularly China and the Republic of Korea, as well as the United States. This geographical concentration highlights the leading role of these countries in the technological development of bioprinting.

Companies and Universities as Assignees: Companies demonstrate broader technological diversification, with activities spanning approximately 11 technological domains on average. Notable examples include Cellink, a Swedish company, and Revotek, a Chinese company, both specializing in 3D bioprinting. Universities, by contrast, focus on approximately six technological domains. The most diversified academic institutions include Pohang University of Science and Technology and Sungkyunkwan University, both from the Republic of Korea, each active in eight technological domains, as well as Zhejiang University, Shenzhen University, and Tsinghua University, all from China. These universities pursue research across multiple bioprinting-related fields, including biotechnology, mechanical engineering, chemistry, and the development of machinery and equipment.

5 Future Perspectives

Given the substantial growth in bioprinting patent filings, this technology is likely to become increasingly strategic at the intersection of engineering, biotechnology, and healthcare. Particular attention should be given to its potential for the development of functional organs, personalized therapies, and biological models applied to precision medicine. Monitoring the evolution of this technology will be essential, as its integration into healthcare-related fields remains a very recent phenomenon.

The findings presented in this study may serve as a foundation for more in-depth investigations into bioprinting, while also supporting the formulation of innovation strategies and technological intelligence initiatives. The analysis further enabled the identification of gaps that may be explored in future research, thereby expanding the development potential of this emerging field.

Furthermore, given the strategic importance of this technological sector, increased investments in infrastructure and regulatory frameworks aimed at supporting biofabrication are expected. Such developments may contribute to establishing bioprinting as a key driver of innovation with growing scientific, healthcare, and economic impacts.

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