Additive manufacturing technologies for biomedical engineering applications: Research trends and scientific impact

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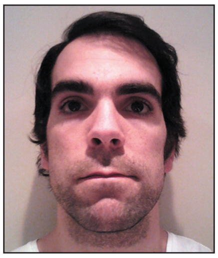

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Abstract

Additive Manufacturing (AM) technologies, technologies that produce three-dimensional parts layer by layer from a material, have the potential to revolutionize the paradigm of manufacturing. Furthermore, in recent years AM technologies have sparked intense interest for developing medical implants, devices, and scaffolds. In this context, the main objective of this article is to present an overall view of the trends and the impact of the research carried out in AM technologies for biomedical engineering applications. Therefore, to achieve the main objective, a research trend and scientific impact analysis model was designed and implemented, to carry out a bibliometric indicator analysis, in general, and a web indicator analysis, in particular. The findings obtained will advance the means of visualizing the state of research in AM for biomedical engineering technologies.

Keywords

Additive manufacturing; Biomedical engineering; Bibliometric analysis; Web indicators; Webometrics.

1. Introduction

The term "Industry 4.0" is used to indicate the fourth industrial revolution, a new industrial model enabled by the introduction of the Internet of Things into the production and manufacturing environment (**Tjahjono** *et al.*, 2017). To achieve this new paradigm, Industry 4.0 is based on a set of key technologies that, when combined, make this new industrial model possible. Thereby, nine technologies are transforming industrial production: Big data and analytics, autonomous robots, simulation, horizontal and vertical system integration, the industrial internet of things, cyber security, the cloud, augmented reality, and additive manufacturing (AM).

In this context, one of the most visible elements of Industry 4.0 is the growth of AM technologies (**Cruickshank**, 2017), technologies that can produce desired parts faster, more flexibly and more precisely than ever before, i.e., technologies that can produce higher-quality goods at reduced costs.

These technologies produce three-dimensional parts layer by layer from a material and have the potential to revolutionize the paradigm of manufacturing (**Quarshie** *et al.*, 2012). In terms of industry specifics, AM has thrived considerably in particular areas over the last few years (*AM Platform*, 2014). The technology cuts across a large number of industries and applications, and that is part of what makes its potential so compelling. Aerospace, automotive, and medical products, among others, will drive AM into the future (**Bourell**; **Leu**; **Rosen**, 2009). Specifically, in recent years AM technologies have sparked intense interest for developing, among other things, medical implants, devices, and medical scaffolds (**Singh**; **Ramakrishna**, 2017).

Thus, in recent years the research community has worked to develop and improve the knowledge landscape of these research fields; however, the trends and the impact of such work have not been analyzed. Assessing trends and the value of research is becoming increasingly important (**Thelwall**; **Kousha**, 2015a; 2015b; **Thelwall**, 2016; **Filser**; **Da-Silva**; **De-Oliveira**, 2017) and the need to evaluate the research carried out by organizations involved in research and development and innovation (R&D&I) processes has increased dramatically in recent years.

In this way, the main aims of this study are to present an overall view of the trends and the impact of the research carried out in AM technologies for biomedical engineering applications.

The findings obtained will advance means of visualizing the state of research into AM technologies for biomedical applications. This will help, on the one hand, to better understand how structured this research field is and how it is growing, as well as identify the major actors. On the other hand, it will provide a better understanding of the impact or the benefits that research into these technologies has in different fields. This study will make it possible to know the evolution of the existing literature on technologies that will change, among other things, productive systems, skills, and well-being (*OECD*, 2016), and that will have great implications for policy makers (**Campbell** *et al.*, 2011).

2. Research methodology

The main goal of the study is to present an overall view of the trends and the impact of research carried out on a technology. To do so, this article carries out a bibliometric indicator analysis, in general, and a web indicator analysis in particular.

A bibliometric analysis is a quantitative method that, based on analysis of related publications, allows the knowledge structure and the development of research fields to be examined (**Jing**; **Qinghua**; **Landström**, 2017). In this way, the simplest bibliometric indicator is the number of publications in a particular field. However, other indicators, such as cited references and citation counts, have gained importance for evaluating research performance and impact (**Holmberg**, 2015; **Marx**; **Bornmann**, 2016).

Web indicator analysis is a quantitative method that evaluates web indicators, where a web indicator is a number that is ideally associated with an aspect of research performance or impact, and that is derived from the Web and in no way based on counts of citations from academic journal articles. Therefore, different web

Figure 1. Workflow of research trends and scientific impact analysis model

indicators can show, among other things, the academic; educational; commercial and industrial; and public engagement impact of a set of publications (**Thelwall**, 2016).

Figure 1 shows the overall procedure for analyzing the trends and the impact of the research carried out on different technologies. The research methodology starts with the selection and determination of the targeted technologies; the second step consists of identifying relevant keywords; and, next is the selection of primary search engines and the adaptation of the query to the selected databases. These steps are fundamental and expert assessment is used to evaluate all of them. Next, a bibliometric indicator analysis, in general, and a web indicator analysis, in particular, are carried out. These include, on the one hand, the identification of main bibliometric indicators to obtain scientific publication trends and impact results, and on the other hand, the identification of main web indicators that further examine the knowledge of publication impact results. Finally, the state of research is visualized with the findings obtained.

2.1. Application of the proposed model to AM technologies for biomedical engineering applications

The research trends and scientific impact analysis model proposed in figure 1 were implemented for technologies for biomedical engineering applications.

Thus, we began with the selection and determination of AM technologies as targeted technologies, and more specifically, for biomedical engineering applications. This decision was made with the help of an expert in the field[1].

After that, in collaboration with the expert throughout the whole process, and based on studies in AM technologies (*Gridlogics Technologies Pvt Ltd*, 2014; **Rodríguez-Salvador**; **Río-Belver**; **Garechana-Anacabe**, 2017), a proper set of terms related to Additive Manufacturing and Bioprinting technologies was defined (see figure 2). To this end, two main terminology blocks were built: (1) Additive Manufacturing and bioprinting terms and (2) exclusion terms.

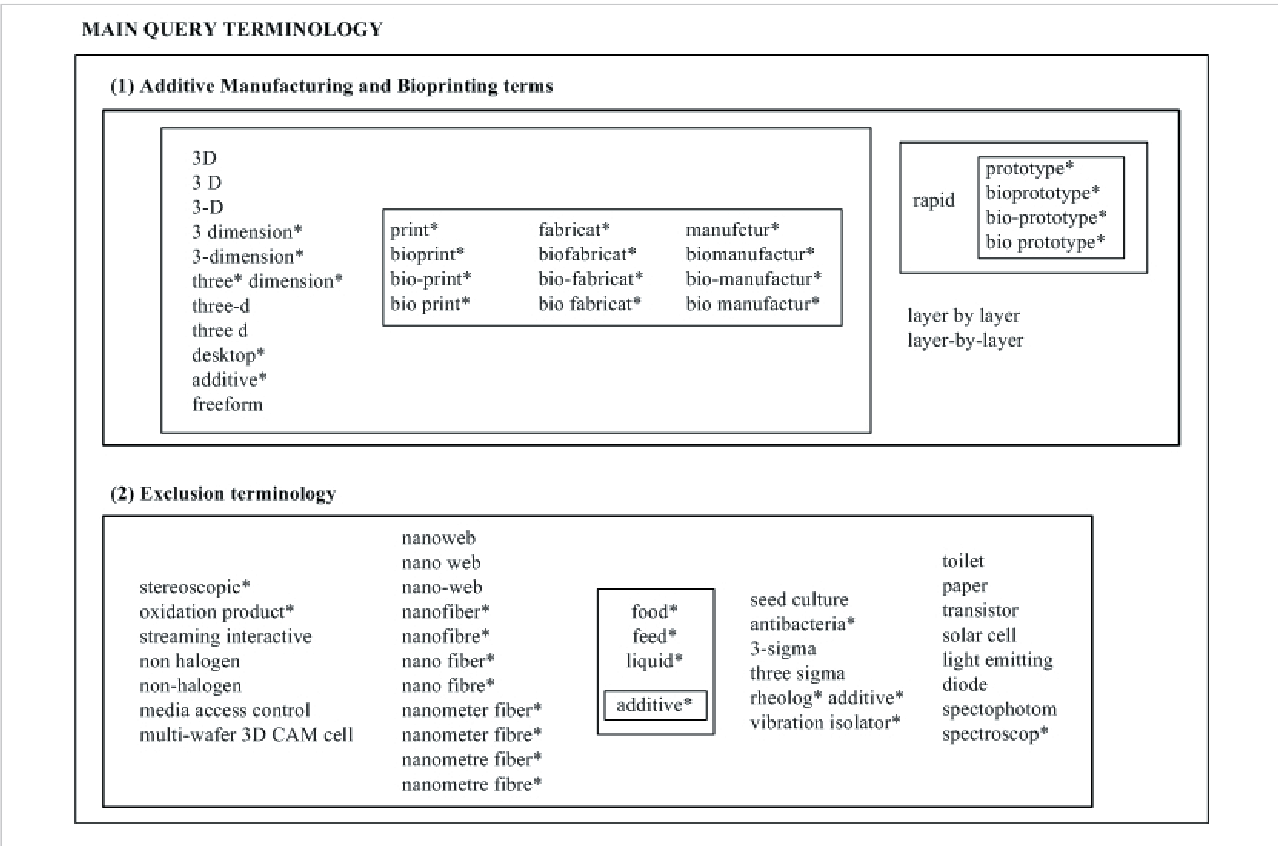

Figure 2. Main terminology related to additive manufacturing and bioprinting technologies.
Note: Words with an asterisk (*) are root words, i.e., these words plus all possible suffixes are contemplated in the query.
Based on (*Gridlogics Technologies Pvt Ltd*, 2014; **Rodríguez-Salvador**; **Río-Belver**; **Garechana-Anacabe**, 2017)

In addition, in order to find biomedical engineering applications of these technologies, the research query was completed by using the set of terms defined only in the 78 journals categorized in biomedical engineering, established in *Journal Citation Reports* (*JCR*); the *JCR* year selected was 2017 (see Appendix).

In this study, the selected primary search engine was the *Web of Science* (*WoS*) database, since it offers comprehensive coverage of scientific journals with multidisciplinary information from over 18,000 high impact journals (**Filser**; **Da-Silva**; **De-Oliveira**, 2017; *Clarivate*, 2018).

The publications obtained from the *WoS Core Collection* were gathered and analyzed, making it possible to present an overall view of the trends and the impact of the research carried out in AM technologies for biomedical engineering applications (see table 1 and figure 3).

Table 1. Analysis of the results obtained for determining research trends and impact in AM technologies for biomedical engineering applications

Research trends		
Bibliometric indicators	**Variables analyzed**	**Software to gather, clean, analyze and visualize articles data**
- Number of articles published - Cited references of the articles studied	- Publication year - Country - Affiliation - Journal - Author - Research area - Keywords	- ***VantagePoint v.10*** A powerful text-mining tool for discovering knowledge in search results from patent and literature databases (*VantagePoint*, 2018). - ***VOSViewer*** Software that allows the visualization of bibliometric networks (*VOSviewer*, 2018).
Type of documents and time span: Scientific articles, from 2000 to 2017		
Research impact		
Bibliometric indicator	**Impact type**	**Software to gather and analyze web data**
- Citation counts	- Academic impact	***Webometrics Analyst 2.0*** Free software designed to conduct automatic web analyses of various types for social science research purposes (**Thelwall**, 2009a; 2009b).
Web indicator	**Impact type**	
- *Mendeley* readers - *Wikipedia* citations	- Academic impact	
- *Google Patents* citations	- Industrial and commercial impact	
Type of documents and time span: Scientific articles (from World, USA and China), from 2006 to 2015		

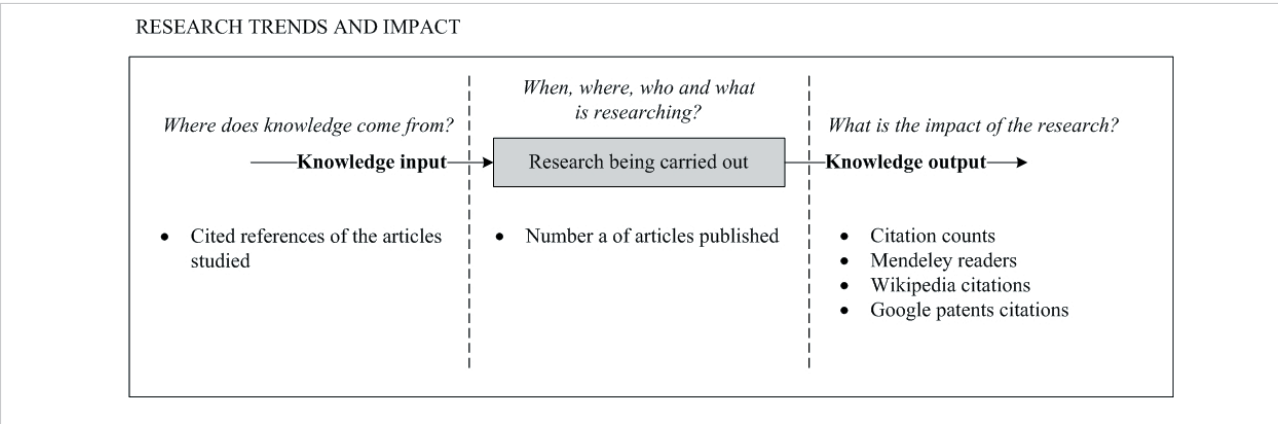

Figure 3. Research trends and scientific impact analysis model to determine research trends and impact in AM technologies for biomedical engineering applications

The two bibliometric indicators used to analyze research trend performance from the chosen variables (Publication year, Country, Affiliation, Journal, Author, Research area, and Keywords) were the usual bibliometric indicator number of articles published (when, where, who, and what is researching) and cited references of the articles studied (where does knowledge come from). The first was a quantitative output of research activity while the second brought a change of perspective and measured what the knowledge sources of AM technologies for biomedical engineering applications were (**Diem**; **Wolter**, 2013; **Holmberg**, 2015; **Marx**; **Bornmann**, 2016; **Filser**; **Da-Silva**; **De-Oliveira**, 2017).

It was not possible to obtain directly the country and the affiliation of the cited references from the *WoS* database. Therefore, all cited references under study were obtained from their DOI from the *WoS* database.

The software used to gather, clean, analyze, and visualize article data were *VantagePoint* and *VOSviewer*. As far as the mapping and clustering of bibliographic networks was concerned, the *VOS* mapping technique was used (**Van-Eck**; **Waltman**, 2007). We used the *VOSviewer* software to apply this technique (**Van-Eck**; **Waltman**, 2011). In this case, the mapping technique was performed on the basis of the co-occurrence matrix and the similarity matrix, the latter being obtained from the application in the co-occurrence matrix similarity measures, specifically known as the associative strength (**Van-Eck**; **Waltman**, 2009; 2010). The map that was defined based on similarity indicated the degree of relationship between the terms, i.e., a close position indicated a high degree of relationship between the items. In addition, the clustering technique, based on the *VOS* mapping technique (**Waltman**; **Van-Eck**; **Noyons**, 2010), made it possible to group items into research fields.

As far as the analysis of the impact of research was concerned, we used another bibliometric indicator called citation counts, i.e., how often each of the publications was cited in the *WoS* database. In addition, web indicators were also used to measure the impact of publications. Although there are many different types of web indicators, in this case, academic plus industrial and commercial impact indicators were used. The academic impact was measured from *Mendeley* readers (*Mendeley* readers of lists of scientific articles gathered) and *Wikipedia* citations (*Wikipedia* citations to a list of scientific articles gathered). And finally, the industrial and commercial impact was measured from *Google Patents* citations (citations from patents to a list of scientific articles gathered) (**Thelwall**, 2016). The software used to gather and analyze web data was *Webometrics Analyst* (**Thelwall**, 2009a; 2009b).

The type of documents analyzed was articles because, when calculating field normalized indicators, it is best to analyze only one document type—usually articles (**Thelwall**, 2018).

In the case of bibliometric analysis, articles published from 2000 to 2017 were analyzed. For impact indicator analysis, the years chosen for the analysis were from 2006 to 2015, i.e. a decade. The first few years were ignored due to the scarcity of results and it was decided that 2015 would be the last year analyzed as this left a performance interval of more than two years until the present, making it possible to analyze the impact of recently published articles in the field of interest. Also, it was analyzed if the research from predominant countries (countries with the highest number of publications) has higher impact than the world average.

3. Results

The query found 1,223 journal articles published from 2000 to 2017 concerning AM technologies for biomedical engineering applications (see appendix), and 33,868 references cited in those articles.

In order to analyze the most significant references, only those that were cited more than 5 times were taken into account. Thus, the sample was reduced to 778 documents. From those 778 documents it was possible to obtain the DOI of only 744 references, and finally, it was possible to find 737 of those documents in the *Web of Science Core Collection*. Therefore, the number of references analyzed was 737.

For impact analysis, the query used recovered the number of articles shown in Table 2 (see appendix).

Table 2. Number of articles recovered for impact analysis

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Articles	31	32	46	64	56	64	66	100	108	158

The analysis of the results obtained is described in the following sections.

3.1. Research trends

To identify where and how technologies emerge, scientific publication trends have been drawn after the results obtained from *WoS* analyses. More specifically, the section structures and analyzes the variables “Publication year”, “Country”, “Affiliation”, “Author”, “Journal”, “Keywords”, and “Research area” of the articles retrieved, and their cites, in AM technologies for biomedical engineering applications.

3.1.1. Publication year analysis

Although there were articles published after 2000, the greatest activity was in recent years. Figure 4 shows that article publication growth was exponential (the coefficient of determination is R^2 = 0.8857) and that the instant growth rate was 0.2943.

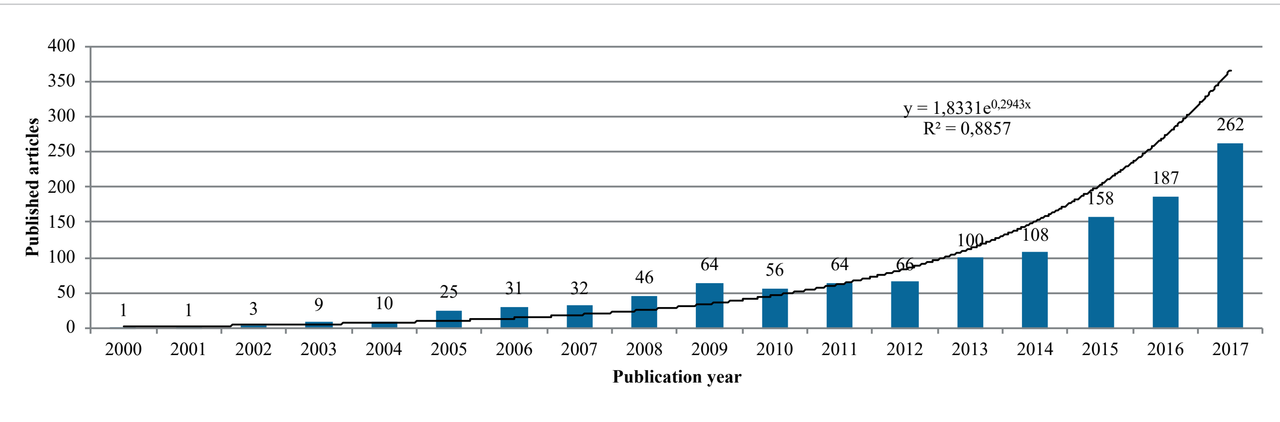

Figure 4. Annual article publications in AM for biomedical engineering applications from 2000 to 2017

It can be seen that, in recent years, AM technologies for biomedical engineering applications have become of growing interest and with very intensive article publication.

Figure 4 shows that article publication growth follows the bibliometric law of exponential growth (Derek J. de Solla Price's law) (**Ardanuy**, 2012). According to that law, the scientific production in this field is in the phase of exponential growth, i.e., it is an emerging research front.

3.1.2. Country analysis

The predominant country, by far, with the highest number of publications, and with the highest number of cited references, is the USA (see table 3). More than 34% of all articles published on AM technologies for biomedical engineering applications, and more than 50% of the references analyzed, were from that country. Therefore, the country with the greatest research activity in that field, and providing most knowledge, was the USA.

China also has extensive research activity; however, its contribution to this particular field has been secondary: despite being the second country with the highest number of publications (17.09% of the articles), it is relegated to ninth position in the rank of cited countries (3.93% of the cited references).

In addition, except on two occasions, there was a relationship between the countries that provided knowledge (countries referenced) and the countries that were researching the subject in question.

Table 3. The 10 most frequent affiliation countries and the 10 most cited countries

Research carried out in AM for BE (Where researching is)				Research used to develop research in AM for BE (Where knowledge comes from)			
#	Country	# of articles	% of articles	#	Cited Country	# of times cited	% of references
1	USA	425	34.75%	1	USA	375	50.88%
2	China	209	17.09%	2	Germany	72	9.77%
3	Germany	121	9.89%	3	Netherlands	54	7.33%
4	South Korea	100	8.18%	4	South Korea	47	6.38%
5	England	77	6.30%	5	England	41	5.56%
6	Italy	69	5.64%	6	Japan	33	4.48%
7	Japan	68	5.56%	7	France	32	4.34%
8	Netherlands	61	4.99%	8	Singapore	32	4.34%
9	Australia	52	4.25%	9	China	29	3.93%
10	Canada	48	3.92%	10	Australia	27	3.66%

3.1.3. Institution analysis

The top publishing and cited institutions are universities (see table 4).

The institution that has published the most articles about AM technologies for biomedical engineering applications is the *Massachusetts Institute of Technology* (36 articles) and the institution that has been the most cited is *Harvard University* (72 articles), closely followed by the *Massachusetts Institute of Technology* (70 articles), both from the USA.

On five occasions, the institutions from which the knowledge comes from matches the institution where the research is being developed.

3.1.4. Journal analysis

Table 5 provides an overview of the 10 journals with the most occurrences.

The journal *Biomaterials* was the most prolific journal in AM technologies for biomedical engineering applications and also the most cited.

As expected, all the journals that publish research carried out in AM for biomedical engineering are journals that specialize in biomedical engineering. Other less specific journals have also been cited, therefore the knowledge also comes from other research fields such as life and physical sciences. Even so, in this case too, there was some correspondence between journals that published articles about AM technologies for biomedical engineering applications and journals cited in these articles.

Table 4. The 10 most frequent organizational affiliations and the 10 most cited organizational affiliations

Research carried out in AM for BE (Where researching is)						Research used to develop research in AM for BE (Where knowledge comes from)					
#	Institution	Type of institution	Country	# of articles	% of articles	#	Cited institution	Type of institution	Country	# of times cited	% of cites
1	*MIT*	University	USA	36	2.94%	1	*Harvard Univ.*	University	USA	72	9.77%
2	*Pohang Univ. Sci. & Technol.*	University	South Korea	33	2.70%	**2**	*MIT*	University	USA	70	9.50%
3	*Harvard Univ.*	University	USA	32	2.62%	**3**	*Univ. Michigan*	University	USA	32	4.34%
4	*Zhejiang Univ.*	University	China	30	2.45%	**4**	*Univ. Twente*	University	Netherlands	22	2.99%
5	*Univ. Twente*	University	Netherlands	27	2.21%	**5**	*Rice Univ.*	University	USA	20	2.71%
6	*Queensland Univ. Technol.*	University	Australia	19	1.55%	6	*Pohang Univ. Sci. & Technol.*	University	South Korea	19	2.58%
7	*Shanghai Jiao Tong Univ.*	University	China	18	1.47%	**7**	*Univ. Utrecht*	University	Netherlands	19	2.58%
8	*Univ. Michigan*	University	USA	18	1.47%	**8**	*Clemson Univ.*	University	USA	18	2.44%
9	*Univ. Med. Ctr. Utrecht*	University	Netherlands	17	1.39%	**9**	*Drexel Univ.*	University	USA	18	2.44%
10	*Univ. Wurzburg*	University	Germany	17	1.39%	**10**	*Natl. Univ. Singapore*	University	Singapore	18	2.44%

Table 5. The 10 most frequent journals

Research carried out in AM for BE (Who researching is)							Research used to develop research in AM for BE (Who knowledge comes from)						
#	Journal	# of articles	Field of research	Quartile	*JCR* 2017	% of articles	#	Cited journal	# of times cited	Field of research	Quartile	*JCR* 2017	% of cites
1	*Biomaterials*	172	Engineering, Biomedical	Q1	8.806	14.06%	**1**	*Biomaterials*	164	Engineering, Biomedical	Q1	8.806	22.25%
			Materials science, Biomaterials	Q1						Materials science, Biomaterials	Q1		
2	*Biofabrication*	161	Engineering, Biomedical	Q1	6.838	13.16%	**2**	*Acta Biomater*	40	Engineering, Biomedical	Q1	6.383	5.43%
			Materials science, Biomaterials	Q1						Materials science, Biomaterials	Q1		
3	*J. Biomed. Mater. Res. Part A*	127	Engineering, Biomedical	Q1	3.231	10.38%	**3**	*Biofabrication*	34	Engineering, Biomedical	Q1	6.838	4.61%
			Materials science, Biomaterials	Q2						Materials science, Biomaterials	Q1		
4	*Acta Biomater*	125	Engineering, Biomedical	Q1	6.383	10.22%	**4**	*Tissue Eng*	25	Biotechnology & Applied microbiology	Q2	3.508	3.39%
										Cell Biology	Q2		
			Materials science, Biomaterials	Q1						Cell & Tissue Engineering	Q3		

5	*Adv. Healthc. Mater*	60	Engineering, Biomedical	Q1	5.609	4.91%	**5**	*Adv. Mater*	22	Chemistry, Multidisciplinary	Q1		2.99%
			Materials science, Biomaterials	Q1						Chemistry, Physical	Q1		
			Nanoscience & Nanotechnology	Q2						Materials science, Multidisciplinary	Q1		
										Nanoscience & Nanotechnology	Q1		
										Physics, Applied	Q1		
										Physics, Condensed matter	Q1		
6	*J. Mater. Sci.-Mater. Med*	56	Engineering, Biomedical	Q2	2.448	4.58%	**6**	*Biomacromolecules*	20	Biochemistry & Molecular biology	Q1	5.738	2.71%
			Materials science, Biomaterials	Q3						Chemistry, Organic	Q1		
										Polymer science	Q1		
7	*J. Mech. Behav. Biomed. Mater*	44	Engineering, Biomedical	Q1	3.239	3.60%	**7**	*Science*	19	Multidisciplinary sciences	Q1	41.058	2.58%
			Materials science, Biomaterials	Q2									
8	*J. Biomed. Mater. Res. Part B*	42	Engineering, Biomedical	Q1	3.373	3.43%	**8**	*J. Biomed. Mater. Res*	18	Engineering, Biomedical	Q1	3.652 (JCR 2004)	2.44%
			Materials science, Biomaterials	Q2						Materials science, Biomaterials	Q1		
9	*Ann. Biomed. Eng*	41	Engineering, Biomedical	Q1	3.405	3.35%	**9**	*J. Biomed. Mater. Res. Part A*	17	Engineering, Biomedical	Q1	3.231	2.31%
										Materials science, Biomaterials	Q2		
10	*Proc. Inst. Mech. Eng. Part H-J. Eng. Med*	29	Engineering, Biomedical	Q4	1.124	2.37%	**10**	*J. Mater. Sci.-Mater. Med*	16	Engineering, Biomedical	Q2	2.448	2.17%
										Materials science, Biomaterials	Q3		

3.1.5. Author analysis

Table 6 shows the 10 authors with the most occurrences and the 10 most cited authors. Among all the authors, the two most prominent are Dong-Woo Cho and Ali Khademhosseini. In addition to being the authors with more articles published about AM technologies for biomedical applications, they were also the most cited.

3.1.6. Research area analysis

According to the categories of the *Web of Science*, in all cases, as expected, articles studied were in the "Engineering, Biomedical" category, but in most cases, also in the "Materials Science, Biomaterials" category (see figure 5). In the case of cited documents, i.e. in the case of the knowledge used, the two predominant areas were the same (see figure 6). Therefore, the importance of Materials Sciences and Biomaterials for that field was noted.

> The institution that has published the most articles about AM technologies for biomedical engineering applications is the *Massachusetts Institute of Technology* (36 articles) and the institution that has been the most cited is *Harvard University* (72 articles)

Table 6. The 10 authors with the most occurrences and the 10 most cited authors

Research carried out in AM for BE (Who researching is)						Research used to develop research in AM for BE (Who knowledge comes from)				
#	Author	*h*-index*	# of articles	% of articles	Share of publications*	#	Cited author	*h*-index*	# of times cited	% of cites
1	Cho, Dong-Woo	37	35	2.86%	254/35	**1**	Khademhosseini, Ali	91	24	3.26%
2	Khademhosseini, Ali	91	19	1.55%	597/19	**2**	Cho, Dong-Woo	37	23	3.12%
3	Moroni, Lorenzo	26	16	1.31%	133/16	**3**	Langer, Robert	184	21	2.85%
4	Mano, Joao F	58	13	1.06%	395/13	**4**	Picart, Catherine	40	19	2.58%
5	Shim, Jin-Hyung	19	13	1.06	54/13	**5**	Dhert, Wouter J. A	44	16	2.17%
6	Fischer, Horst	33	12	0.98%	176/12	**6**	Mikos, AG	109	16	2.17%
7	Gbureck, Uwe	39	12	0.98%	122/12	**7**	Hutmacher, Dietmar Werner	21	15	2.04%
8	Hollister, Scott J	40	12	0.98%	118/12	**8**	Sun, Wei	105	15	2.04%
9	Hutmacher, Dietmar Werner	21	12	0.98%	43/12	**9**	Voegel, JC	68	15	2.04%
10	Reis, Rui L	66	12	0.98%	692/12	**10**	Malda, Jos	32	14	1.90%

*Data obtained on November 3[th], 2018

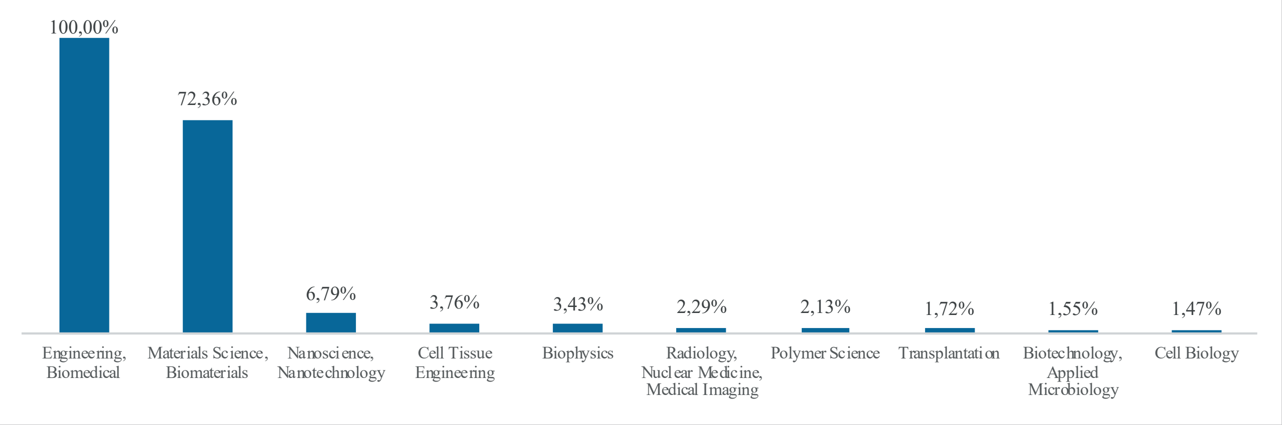

Figure 5. The 10 most frequent research areas in AM technologies for BE application articles

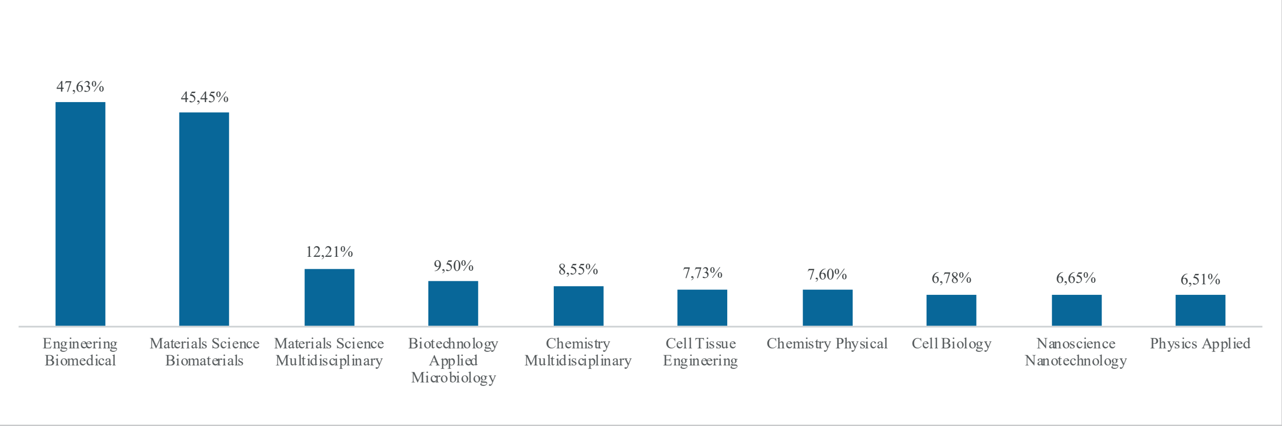

Figure 6. The 10 most frequent research areas in references used for AM technologies for BE application articles

3.1.7. Keyword analysis

The distance-based graph allows us to define the relationship forces of items, i.e., the closer they are the stronger their relationship. With regard to mapping keywords relating to the articles under study, the main hotspots that have a strong relationship between them are, on the one hand, “3D print” “Scaffold” “Additive manufacturing” “bone” and “rapid prototype”, along with “Tissue Engineering”, “3D bioprinter” and “hydrogel”, and on the other hand, “layer by layer” and “alginate” (see figure 7).

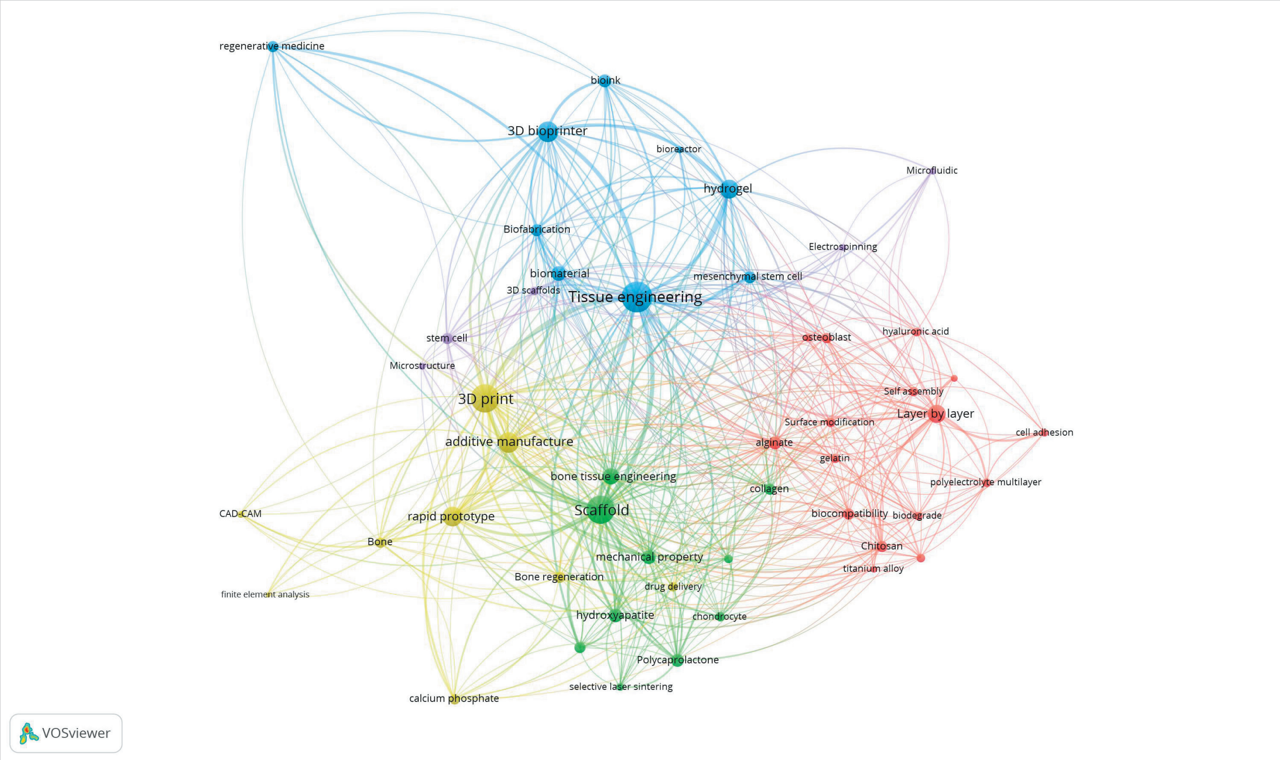

Figure 7. The top 50 keywords in AM technologies for BE application articles

As far as mapping keywords of the cited articles is concerned, the main points of knowledge are linked to "scaffold", "bone", "bone tissue engineering", "rapid prototype", "3D print" and "hydroxyapatite", and conversely "tissue engineering", "biomaterial", "hydrogel" and "bioprinter" (see figure 8).

The clustering process carried out on the map of study articles defines 5 clusters, the terms of which allow us to define the following research fields: "Tissue engineering and bioprinting", "Scaffold and bone tissue engineering", "3D print and rapid prototyping", "layer by layer - surface modification - alginate" and "microstructure and stem cell". Regarding the clusters defined in the keyword map of the cited articles, there are also 5 clusters that define the following research

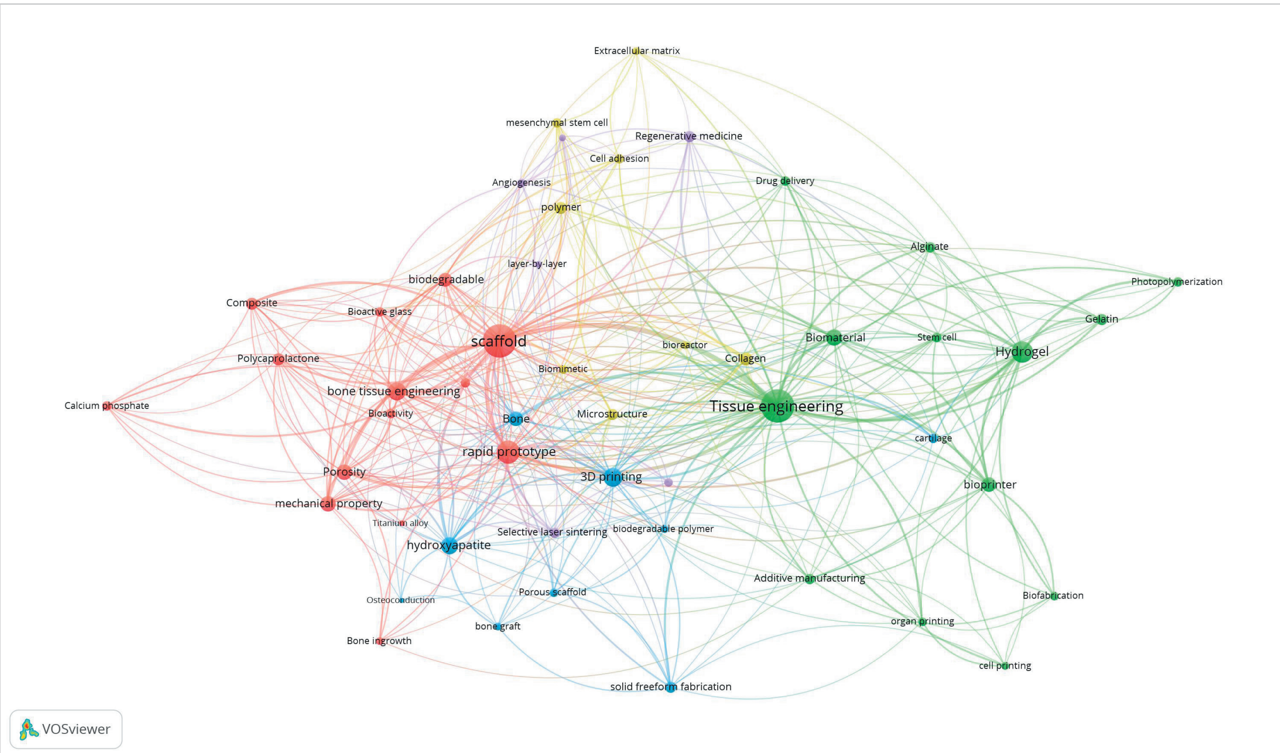

Figure 8. The top 50 keywords in references used for AM technologies for BE application articles

areas: "Scaffold and bone tissue engineering", "Tissue engineering and bioprinting", "3D print and bone", "Biomimetic and microstructure" and "Regenerative medicine".

3.2. Research impact

In this section, in order to appreciate the impact of these technologies, the impact that scientific publications had was determined from the results obtained from different impact indicator analyses. Moreover, the research impact measured and analyzed was varied: academic impact (from citation counts, *Mendeley* readers, and *Wikipedia* citations), and industrial and commercial impact (from *Google Patents* citations).

In addition, with the USA and China the countries with more publications in the field of study, the behavior of the impact of the research carried out by these countries was analyzed.

Tables 5 and table 6 contain the arithmetic mean, the geometric mean, the arithmetic mean of the log-transformed of the indicators analyzed, and the proportion of articles with at least one measure. In addition, where possible, 95% confidence intervals are given. They also contain the Mean Normalized Log-transformed Citation Scores (MNLCS)[2] and the Normalized Proportion Cited (EMNPC)[3] with confidence intervals, where possible.

3.2.1. Academic impact

Citation counts

First, it can be seen that the most cited articles, in general, are those that have been published earlier, i.e., those that have had the longest time to be cited (see table 7).

From the results obtained, it is observed that, on the one hand, practically all articles are cited at least once; and on the other hand, in general, the USA is cited above the world average, however, this does not occur with China.

For articles published from 2006 to 2015, the MNLCS values are higher than 1 for the USA, which indicates that the citation counts for the USA tend to be above the world average. However, for articles published in 2014 the confidence interval does not contain 1 so only in that case is the difference statistically significant, for the rest of the years the difference is not statistically significant. In the case of China, it is observed that, in general, Chinese articles are cited below the world average.

Finally, for articles published in the decade analyzed, when the non-zero proportion is not 1 for the World, the USA and China are above the world average for the proportion cited (except in the case of 2013 for the USA, and 2013 and 2015 for China), i.e. EMNPC values are higher than 1.

***Mendeley* reader counts**

Mendeley readership counts are useful indicators of academic impact and they can provide earlier evidence of impact than citations might (**Thelwall**, 2016; **Aduku**; **Thelwall**; **Kousha**, 2017).

In this case, the most read articles, in general, are not those that have been published earlier, i.e., there is no relation between the publication date and number of readers (see table 8).

Practically all articles have been gathered by *Mendeley* users. Likewise, it is observed that practically all articles analyzed from the USA and China have been gathered in *Mendeley* at least once.

Finally, the articles from USA are more read than the world average. The MNLCS value is higher than 1 for all analyzed years. Nevertheless, the same does not occur in the case of China, i.e. the research analyzed from China is less read than the world average, in general.

***Wikipedia* citation counts**

Wikipedia citations are a useful new source of evidence for scholarly impact; however, citations from the online encyclopaedia to academic studies may reflect the value of research for a more general public or education (**Thelwall**; **Kousha**, 2015a; **Kousha**; **Thelwall**, 2017a; **Thelwall**, 2018; **Thelwall**; **Sud**, 2018). Nonetheless, in this case, it is observed that practically no articles of the study were cited on *Wikipedia* (see table 9). The proportion of articles with at least 1 *Wikipedia* citation was a maximum of 3.6% in 2010. Moreover, no Chinese article were mentioned on *Wikipedia*.

3.2.2. Industrial and commercial impact

***Google Patents* citation counts**

Citations from patents to scientific articles could be used to assess the commercial value or technological benefits of the cited studies (**Thelwall**; **Kousha**, 2015a; **Thelwall**, 2018).

In this case, it can be observed that the most cited articles in patents, in general, are those that have been published earlier, i.e., those that have had the longest time to be cited (see table 10).

In this case, both countries, the USA and China, in general, are cited above the world average and their non-zero proportion is also above world average.

Table 7. Academic impact of AM technologies for biomedical engineering applications

Academic impact				
— Citation counts for individual sets of articles —				
Indicators	**Year**	**World**	**USA**	**China**
Arithmetic mean of raw data	2006	84.032258	**99.875000**	**103.000000**
	2007	68.187500	**84.666667**	66.000000
	2008	50.695652	**52.333333**	34.600000
	2009	64.578125	**113.105263**	51.571429
	2010	61.107143	**85.272727**	55.571429
	2011	43.296875	**51.608696**	43.750000
	2012	35.409091	**46.217391**	35.250000
	2013	34.820000	**52.562500**	24.437500
	2014	37.425926	**50.285714**	31.600000
	2015	23.411392	22.105263	21.148148
Geometric mean (95%CI) of raw data	2006	61.403058 (44.368132, 84.834296)	**84.802648 (61.030532, 117.685010)**	**99.969791 (62.821825, 158.740005)**
	2007	42.739649 (27.909845, 65.176656)	**58.212670 (27.134051, 123.622657)**	**54.181519 (-0.984488, 196295.414710)**
	2008	28.461897 (19.646144, 41.041910)	**42.873627 (25.735862, 70.996747)**	23.936505 (4.537577, 111.292673)
	2009	36.162970 (27.451244, 47.542211)	**48.330852 (23.943112, 96.563326)**	34.758256 (18.500242, 64.571129)
	2010	36.551322 (28.126404, 47.413178)	**44.843045 (27.646500, 72.362708)**	**39.525709 (16.090030, 95.098899)**
	2011	26.276796 (19.647951, 35.033773)	**34.471750 (21.387664, 55.202606)**	25.409614 (8.995830, 68.775868)
	2012	21.793240 (16.800286, 28.186710)	**24.017256 (14.035283, 40.626294)**	**22.547858 (11.089531, 44.866266)**
	2013	20.175256 (16.189655, 25.084959)	**24.344006 (14.872179, 39.468207)**	14.203120 (7.239744, 27.051219)
	2014	21.611618 (17.404608, 26.780287)	**32.456863 (22.840587, 45.951934)**	17.450977 (10.001326, 29.945229)
	2015	13.139339 (10.865472, 15.848963)	**13.469733 (9.939594, 18.139025)**	12.722162 (7.928466, 20.089597)
Mean (95%CI) of ln(1+raw data)	2006	4.133614 (3.814810, 4.452419)	**4.452050 (4.127627, 4.776473)**	**4.614821 (4.156095, 5.073548)**
	2007	3.778255 (3.364182, 4.192328)	**4.081136 (3.336981, 4.825290)**	**4.010628 (-4.166125, 12.187381)**
	2008	3.383098 (3.027529, 3.738667)	**3.781313 (3.286006, 4.276621)**	3.216333 (1.711557, 4.721109)
	2009	3.615313 (3.348192, 3.882434)	**3.898550 (3.216598, 4.580502)**	3.576781 (2.970427, 4.183135)
	2010	3.625709 (3.371645, 3.879772)	**3.825224 (3.355031, 4.295416)**	**3.701937 (2.838495, 4.565378)**
	2011	3.306036 (3.027616, 3.584457)	**3.568737 (3.108510, 4.028963)**	3.273728 (2.302168, 4.245288)
	2012	3.126464 (2.879215, 3.373713)	**3.219566 (2.710400, 3.728732)**	**3.159035 (2.492340, 3.825730)**
	2013	3.052833 (2.844308, 3.261359)	**3.232542 (2.764568, 3.700517)**	2.721501 (2.108969, 3.334032)
	2014	3.118464 (2.912601, 3.324327)	**3.510257 (3.171389, 3.849124)**	2.915117 (2.398016, 3.432219)
	2015	2.648961 (2.473633, 2.824289)	**2.672059 (2.392389, 2.951729)**	2.619012 (2.189245, 3.048780)
Proportion (95%CI) non-zero	2006	1.000000 (0.889745, 1.000000)	1.000000 (0.806392, 1.000000)	1.000000 (0.510109, 1.000000)
	2007	0.968750 (0.842557, 0.994462)	**1.000000 (0.700855, 1.000000)**	**1.000000 (0.342380, 1.000000)**
	2008	0.978261 (0.886647, 0.996152)	**1.000000 (0.700855, 1.000000)**	**1.000000 (0.565518, 1.000000)**
	2009	1.000000 (0.943376, 1.000000)	1.000000 (0.831821, 1.000000)	1.000000 (0.784689, 1.000000)
	2010	1.000000 (0.935806, 1.000000)	1.000000 (0.851345, 1.000000)	1.000000 (0.645670, 1.000000)
	2011	0.984375 (0.916659, 0.997236)	**1.000000 (0.856883, 1.000000)**	**1.000000 (0.675592, 1.000000)**
	2012	1.000000 (0.944997, 1.000000)	1.000000 (0.856883, 1.000000)	1.000000 (0.757506, 1.000000)
	2013	0.980000 (0.929988, 0.994498)	0.968750 (0.842557, 0.994462)	0.937500 (0.716713, 0.988881)
	2014	0.990741 (0.949407, 0.998364)	**1.000000 (0.901099, 1.000000)**	**1.000000 (0.838875, 1.000000)**
	2015	0.968354 (0.928067, 0.986409)	**0.982456 (0.907093, 0.996896)**	0.962963 (0.817165, 0.993432)
MNLCS - mean (95%CI) of world normalized ln(1+raw data)	2006	1.000000 (0.898357, 1.113144)	**1.077036 (0.971920, 1.194788)**	**1.116413 (1.010838, 1.235349)**
	2007	1.000000 (0.858399, 1.164959)	**1.080164 (0.881215, 1.305376)**	**1.061503 (0.705643, 1.443172)**
	2008	1.000000 (0.862575, 1.159320)	**1.117707 (0.955024, 1.305360)**	0.950706 (0.620988, 1.301663)
	2009	1.000000 (0.901516, 1.109242)	**1.078344 (0.887113, 1.281412)**	0.989342 (0.822578, 1.166968)
	2010	1.000000 (0.906364, 1.103309)	**1.055028 (0.915100, 1.205161)**	**1.021024 (0.818497, 1.233429)**
	2011	1.000000 (0.888473, 1.125527)	**1.079461 (0.924069, 1.250273)**	0.990227 (0.734631, 1.259970)
	2012	1.000000 (0.894934, 1.117401)	**1.029779 (0.858410, 1.214109)**	**1.010418 (0.806342, 1.227211)**
	2013	1.000000 (0.908632, 1.100556)	**1.058866 (0.898164, 1.229297)**	0.891467 (0.697145, 1.094147)
	2014	1.000000 (0.911568, 1.097011)	**1.125637 (1.001509, 1.259421)**	0.934793 (0.769841, 1.107764)
	2015	1.000000 (0.910488, 1.098312)	**1.008720 (0.889653, 1.136663)**	0.988694 (0.823503, 1.162586)
EMNPC (NPC) - world normalized proportion (95%CI) cited (non-zero)	2006	1.000000 (NaN[4], NaN)	1.000000 (NaN, NaN)	1.000000 (NaN, NaN)
	2007	1.000000 (0.940134, 1.063678)	**1.032258 (NaN, NaN)**	**1.032258 (NaN, NaN)**
	2008	1.000000 (0.958063, 1.043772)	**1.022222 (NaN, NaN)**	**1.022222 (NaN, NaN)**
	2009	1.000000 (NaN, NaN)	1.000000 (NaN, NaN)	1.000000 (NaN, NaN)
	2010	1.000000 (NaN, NaN)	1.000000 (NaN, NaN)	1.000000 (NaN, NaN)
	2011	1.000000 (0.969723, 1.031222)	**1.015873 (NaN, NaN)**	**1.015873 (NaN, NaN)**
	2012	1.000000 (NaN, NaN)	1.000000 (NaN, NaN)	1.000000 (NaN, NaN)
	2013	1.000000 (0.966373, 1.034797)	0.988520 (0.940399, 1.039104)	0.956633 (0.873188, 1.048051)
	2014	1.000000 (0.981974, 1.018356)	**1.009346 (NaN, NaN)**	**1.009346 (NaN, NaN)**
	2015	1.000000 (0.962948, 1.038478)	**1.014563 (0.978509, 1.051944)**	0.994432 (0.938128, 1.054116)

Table 8. *Mendeley* reader counts of AM technologies for biomedical engineering applications

— Mendeley reader counts —				
Indicators	**Year**	**World**	**USA**	**China**
Arithmetic mean of raw data	2006	80.322581	**105.375000**	**84.750000**
	2007	63.187500	**112.222222**	**80.500000**
	2008	56.782609	**80.666667**	30.400000
	2009	79.468750	**169.105263**	42.785714
	2010	85.464286	**127.454545**	48.428571
	2011	67.062500	**82.913043**	**72.375000**
	2012	61.439394	**96.260870**	56.750000
	2013	71.140000	**114.968750**	29.687500
	2014	86.990741	**131.142857**	64.500000
	2015	63.829114	63.105263	51.962963
Geometric mean (95%CI) of raw data	2006	42.858398 (25.962429, 70.342202)	65.098589 (31.233380, 134.543449)	70.485395 (22.480137, 216.637640)
	2007	40.531585 (26.858925, 60.914540)	**66.312377 (27.517542, 157.883125)**	**54.695601 (-0.999584, 7464696.637597)**
	2008	26.393798 (17.042271, 40.592335)	**60.056535 (31.823396, 112.574491)**	23.500815 (7.141632, 72.730911)
	2009	41.128847 (32.140176, 52.555532)	**71.156707 (38.024113, 132.419825)**	31.957020 (19.720930, 51.418747)
	2010	47.286862 (35.912207, 62.166666)	**64.483888 (39.317602, 105.358994)**	41.708099 (23.280220, 74.122123)
	2011	39.875029 (29.617857, 53.568415)	**53.910422 (35.071271, 82.588804)**	36.177941 (14.146939, 90.252718)
	2012	34.760151 (26.584395, 45.359123)	**41.650246 (22.265398, 77.186646)**	28.227489 (13.784274, 56.780729)
	2013	36.569170 (28.651956, 46.600318)	**52.448148 (33.476166, 81.860273)**	20.445194 (11.902626, 34.643623)
	2014	47.498319 (37.409307, 60.237423)	**78.744293 (51.824747, 119.382069)**	33.471535 (18.921628, 58.648074)
	2015	39.345145 (33.151499, 46.662059)	**43.719463 (34.858349, 54.770285)**	35.861180 (23.250475, 55.029691)
Mean (95%CI) of ln(1+raw data)	2006	3.780966 (3.294444, 4.267488)	**4.191147 (3.473003, 4.909292)**	**4.269493 (3.156155, 5.382831)**
	2007	3.726454 (3.327153, 4.125755)	**4.209344 (3.350519, 5.068169)**	**4.019901 (-7.785893, 15.825695)**
	2008	3.310317 (2.892717, 3.727916)	**4.111800 (3.491142, 4.732459)**	3.198706 (2.096991, 4.300422)
	2009	3.740733 (3.500746, 3.980719)	**4.278840 (3.664180, 4.893501)**	3.495204 (3.031144, 3.959264)
	2010	3.877160 (3.608542, 4.145777)	**4.181804 (3.696788, 4.666820)**	3.754389 (3.189662, 4.319115)
	2011	3.710519 (3.421583, 3.999455)	**4.005703 (3.585497, 4.425910)**	3.615716 (2.717798, 4.513633)
	2012	3.576834 (3.317250, 3.836418)	**3.753033 (3.146967, 4.359099)**	3.375110 (2.693564, 4.056655)
	2013	3.626184 (3.389528, 3.862839)	**3.978712 (3.540268, 4.417156)**	3.065501 (2.557431, 3.573570)
	2014	3.881529 (3.648300, 4.114758)	**4.378825 (3.966980, 4.790671)**	3.540134 (2.991806, 4.088462)
	2015	3.697471 (3.530806, 3.864136)	**3.800409 (3.579576, 4.021241)**	3.607159 (3.188436, 4.025882)
Proportion (95%CI) non-zero	2006	0.967742 (0.838059, 0.994283)	0.937500 (0.716713, 0.988881)	**1.000000 (0.510109, 1.000000)**
	2007	0.968750 (0.842557, 0.994462)	**1.000000 (0.700855, 1.000000)**	**1.000000 (0.342380, 1.000000)**
	2008	0.934783 (0.824973, 0.977572)	**1.000000 (0.700855, 1.000000)**	**1.000000 (0.565518, 1.000000)**
	2009	1.000000 (0.943376, 1.000000)	1.000000 (0.831821, 1.000000)	1.000000 (0.784689, 1.000000)
	2010	1.000000 (0.935806, 1.000000)	1.000000 (0.851345, 1.000000)	1.000000 (0.645670, 1.000000)
	2011	0.968750 (0.893027, 0.991388)	**1.000000 (0.856883, 1.000000)**	**1.000000 (0.675592, 1.000000)**
	2012	0.984848 (0.919041, 0.997320)	0.956522 (0.790088, 0.992283)	**1.000000 (0.757506, 1.000000)**
	2013	0.970000 (0.915481, 0.989745)	**1.000000 (0.892821, 1.000000)**	**1.000000 (0.806392, 1.000000)**
	2014	0.972222 (0.921497, 0.990509)	0.971429 (0.854669, 0.994939)	**1.000000 (0.838875, 1.000000)**
	2015	0.981013 (0.945669, 0.993522)	**1.000000 (0.936861, 1.000000)**	0.962963 (0.817165, 0.993432)
MNLCS - mean (95%CI) of world normalized ln(1+raw data)	2006	1.000000 (0.835602, 1.196743)	**1.108486 (0.895276, 1.358281)**	**1.129207 (0.907152, 1.389285)**
	2007	1.000000 (0.861350, 1.160968)	**1.129584 (0.904172, 1.381237)**	**1.078747 (0.566643, 1.615911)**
	2008	1.000000 (0.837112, 1.194584)	**1.242117 (1.032706, 1.491702)**	0.966284 (0.708469, 1.255351)
	2009	1.000000 (0.913956, 1.094145)	**1.143851 (0.975314, 1.321842)**	0.934364 (0.808333, 1.068117)
	2010	1.000000 (0.907374, 1.102081)	**1.078574 (0.942031, 1.225315)**	0.968335 (0.836317, 1.109509)
	2011	1.000000 (0.896467, 1.115490)	**1.079553 (0.947580, 1.224698)**	0.974450 (0.761796, 1.198994)
	2012	1.000000 (0.903185, 1.107193)	**1.049261 (0.873699, 1.235935)**	0.943603 (0.761772, 1.135425)
	2013	1.000000 (0.912532, 1.095852)	**1.097217 (0.964348, 1.239286)**	0.845379 (0.705984, 0.992006)
	2014	1.000000 (0.919201, 1.087901)	**1.128119 (1.008923, 1.255326)**	0.912046 (0.770583, 1.059987)
	2015	1.000000 (0.938192, 1.065879)	**1.027840 (0.955170, 1.104695)**	0.975575 (0.860030, 1.095092)
EMNPC (NPC) - world normalized proportion (95%CI) cited (non-zero)	2006	1.000000 (0.938248, 1.065816)	0.968750 (0.877548, 1.069431)	**1.033333 (NaN, NaN)**
	2007	1.000000 (0.940134, 1.063678)	**1.032258 (NaN, NaN)**	**1.032258 (NaN, NaN)**
	2008	1.000000 (0.906673, 1.102934)	**1.069767 (NaN, NaN)**	**1.069767 (NaN, NaN)**
	2009	1.000000 (NaN, NaN)	1.000000 (NaN, NaN)	1.000000 (NaN, NaN)
	2010	1.000000 (NaN, NaN)	1.000000 (NaN, NaN)	1.000000 (NaN, NaN)
	2011	1.000000 (0.947739, 1.055142)	**1.032258 (NaN, NaN)**	**1.032258 (NaN, NaN)**
	2012	1.000000 (0.970630, 1.030258)	0.971237 (0.910601, 1.035911)	**1.015385 (NaN, NaN)**
	2013	1.000000 (0.956586, 1.045384)	**1.030928 (NaN, NaN)**	**1.030928 (NaN, NaN)**
	2014	1.000000 (0.959774, 1.041912)	0.999184 (0.951089, 1.049710)	**1.028571 (NaN, NaN)**
	2015	1.000000 (0.972427, 1.028355)	**1.019355 (NaN, NaN)**	0.981601 (0.928647, 1.037574)

Table 9. *Wikipedia* citations counts of AM technologies for biomedical engineering applications

— *Wikipedia* citations counts —				
Indicators	**Year**	**World**	**USA**	**China**
Arithmetic mean (unique URLs[5])	2006	0.032258	0.000000	0.000000
	2007	0.000000	0.000000	0.000000
	2008	0.000000	0.000000	0.000000
	2009	0.015625	**0.052632**	0.000000
	2010	0.035714	**0.045455**	0.000000
	2011	0.015625	**0.043478**	0.000000
	2012	0.045455	**0.130435**	0.000000
	2013	0.020000	**0.031250**	0.000000
	2014	0.000000	0.000000	0.000000
	2015	0.012658	**0.035088**	0.000000
Geometric mean (95%CI) of unique URLs	2006	0.022611 (-0.022986, 0.070337)	0.000000 (0.000000, 0.000000)	0.000000 (0.000000, 0.000000)
	2007	0.000000 (0.000000, 0.000000)	0.000000 (0.000000, 0.000000)	0.000000 (0.000000, 0.000000)
	2008	0.000000 (0.000000, 0.000000)	0.000000 (0.000000, 0.000000)	0.000000 (0.000000, 0.000000)
	2009	0.010889 (-0.010772, 0.033025)	**0.037155 (-0.039335, 0.119735)**	0.000000 (0.000000, 0.000000)
	2010	0.025064 (-0.010228, 0.061615)	**0.032008 (-0.033455, 0.101905)**	0.000000 (0.000000, 0.000000)
	2011	0.010889 (-0.010772, 0.033025)	**0.030596 (-0.031732, 0.096935)**	0.000000 (0.000000, 0.000000)
	2012	0.021227 (-0.020785, 0.065041)	**0.062127 (-0.062457, 0.203267)**	0.000000 (0.000000, 0.000000)
	2013	0.013959 (-0.005627, 0.033932)	**0.021897 (-0.022275, 0.068065)**	0.000000 (0.000000, 0.000000)
	2014	0.000000 (0.000000, 0.000000)	0.000000 (0.000000, 0.000000)	0.000000 (0.000000, 0.000000)
	2015	0.008813 (-0.003465, 0.021242)	**0.024619 (-0.010056, 0.060508)**	0.000000 (0.000000, 0.000000)
Mean (95%CI) of log (1+unique URLs)	2006	0.022360 (-0.023254, 0.067973)	0.000000 (0.000000, 0.000000)	0.000000 (0.000000, 0.000000)
	2007	0.000000 (0.000000, 0.000000)	0.000000 (0.000000, 0.000000)	0.000000 (0.000000, 0.000000)
	2008	0.000000 (0.000000, 0.000000)	0.000000 (0.000000, 0.000000)	0.000000 (0.000000, 0.000000)
	2009	0.010830 (-0.010830, 0.032491)	**0.036481 (-0.040130, 0.113092)**	0.000000 (0.000000, 0.000000)
	2010	0.024755 (-0.010281, 0.059792)	**0.031507 (-0.034027, 0.097041)**	0.000000 (0.000000, 0.000000)
	2011	0.010830 (-0.010830, 0.032491)	**0.030137 (-0.032246, 0.092520)**	0.000000 (0.000000, 0.000000)
	2012	0.021004 (-0.021004, 0.063013)	**0.060274 (-0.064493, 0.185040)**	0.000000 (0.000000, 0.000000)
	2013	0.013863 (-0.005643, 0.033369)	**0.021661 (-0.022527, 0.065849)**	0.000000 (0.000000, 0.000000)
	2014	0.000000 (0.000000, 0.000000)	0.000000 (0.000000, 0.000000)	0.000000 (0.000000, 0.000000)
	2015	0.008774 (-0.003471, 0.021019)	**0.024321 (-0.010106, 0.058748)**	0.000000 (0.000000, 0.000000)
Proportion non-zero (95%CI)	2006	0.032258 (0.005717, 0.161941)	0.000000 (0.000000, 0.193608)	0.000000 (0.000000, 0.489891)
	2007	0.000000 (0.000000, 0.107179)	0.000000 (0.000000, 0.657620)	0.000000 (0.000000, 0.299145)
	2008	0.000000 (0.000000, 0.077074)	0.000000 (0.000000, 0.299145)	0.000000 (0.000000, 0.434482)
	2009	0.015625 (0.002764, 0.083341)	**0.052632 (0.009352, 0.246387)**	0.000000 (0.000000, 0.215311)
	2010	0.035714 (0.009849, 0.121188)	**0.045455 (0.008069, 0.217980)**	0.000000 (0.000000, 0.354330)
	2011	0.015625 (0.002764, 0.083341)	**0.043478 (0.007717, 0.209912)**	0.000000 (0.000000, 0.324408)
	2012	0.015152 (0.002680, 0.080959)	**0.043478 (0.007717, 0.209912)**	0.000000 (0.000000, 0.242494)
	2013	0.020000 (0.005502, 0.070012)	**0.031250 (0.005538, 0.157443)**	0.000000 (0.000000, 0.193608)
	2014	0.000000 (0.000000, 0.034347)	0.000000 (0.000000, 0.098901)	0.000000 (0.000000, 0.161125)
	2015	0.012658 (0.003478, 0.044973)	**0.035088 (0.009676, 0.119208)**	0.000000 (0.000000, 0.124555)
MNLCS - mean (95%CI) of world normalized log (1_unique URLs)	2006	1.000000 (NaN, NaN)	0.000000 (NaN, NaN)	0.000000 (NaN, NaN)
	2007	NaN (NaN, NaN)	NaN (NaN, NaN)	NaN (NaN, NaN)
	2008	NaN (NaN, NaN)	NaN (NaN, NaN)	NaN (NaN, NaN)
	2009	1.000000 (NaN, NaN)	**3.368421 (NaN, NaN)**	0.000000 (NaN, NaN)
	2010	1.000000 (NaN, NaN)	**1.272727 (NaN, NaN)**	0.000000 (NaN, NaN)
	2011	1.000000 (NaN, NaN)	**2.782609 (NaN, NaN)**	0.000000 (NaN, NaN)
	2012	1.000000 (NaN, NaN)	**2.869565 (NaN, NaN)**	0.000000 (NaN, NaN)
	2013	1.000000 (NaN, NaN)	**1.562500 (NaN, NaN)**	0.000000 (NaN, NaN)
	2014	NaN (NaN, NaN)	NaN (NaN, NaN)	NaN (NaN, NaN)
	2015	1.000000 (NaN, NaN)	**2.771930 (NaN, NaN)**	0.000000 (NaN, NaN)
EMNPC - world normalized proportion non-zero (95%CI) [ie risk ratio]	2006	1.000000 (0.109949, 9.095124)	0.000000 (0.000000, 0.124555)	0.000000 (0.000000, 0.124555)
	2007	0.000000 (NaN, NaN)	0.000000 (NaN, NaN)	0.000000 (NaN, NaN)
	2008	0.000000 (NaN, NaN)	0.000000 (NaN, NaN)	0.000000 (NaN, NaN)
	2009	1.000000 (0.106833, 9.360444)	**3.368421 (0.371563, 30.536600)**	0.000000 (0.000000, 0.000000)
	2010	1.000000 (0.180240, 5.548168)	**1.272727 (0.178693, 9.064912)**	0.000000 (0.000000, 0.000000)
	2011	1.000000 (0.106833, 9.360444)	**2.782609 (0.304509, 25.427506)**	0.000000 (0.000000, 0.000000)
	2012	1.000000 (0.106746, 9.368058)	**2.869565 (0.313896, 26.232896)**	0.000000 (0.000000, 0.000000)
	2013	1.000000 (0.177108, 5.646260)	**1.562500 (0.214718, 11.370277)**	0.000000 (0.000000, 0.000000)
	2014	0.000000 (NaN, NaN)	0.000000 (NaN, NaN)	0.000000 (NaN, NaN)
	2015	1.000000 (0.175675, 5.692336)	**2.771930 (0.493049, 15.583837)**	0.000000 (0.000000, 0.000000)

Table 10. Industrial and commercial impact of AM technologies for biomedical engineering applications

Industrial and commercial impact				
		— *Google Patents* citation counts —		
Indicators	**Year**	**World**	**USA**	**China**
Arithmetic mean (unique domains)	2006	0.580645	**0.687500**	**1.000000**
	2007	0.500000	**0.666667**	0.500000
	2008	0.304348	**0.444444**	**0.400000**
	2009	0.468750	**0.578947**	**0.571429**
	2010	0.428571	0.409091	**0.714286**
	2011	0.375000	**0.391304**	**0.625000**
	2012	0.257576	**0.260870**	**0.500000**
	2013	0.240000	**0.406250**	0.125000
	2014	0.259259	**0.342857**	0.250000
	2015	0.170886	**0.228070**	**0.259259**
Geometric mean (95%CI) of unique domains	2006	0.495518 (0.316637, 0.698702)	**0.610490 (0.349650, 0.921742)**	**1.000000 (1.000000, 1.000000)**
	2007	0.414214 (0.245567, 0.605694)	**0.587401 (0.215598, 1.072923)**	0.414214 (-0.982723, 114.760560)
	2008	0.234860 (0.121781, 0.359338)	**0.360790 (0.027130, 0.802838)**	**0.319508 (-0.176956, 1.115441)**
	2009	0.383910 (0.268399, 0.509941)	**0.493759 (0.260997, 0.769486)**	**0.485994 (0.209963, 0.824997)**
	2010	0.345900 (0.225848, 0.477710)	0.327849 (0.137548, 0.549986)	**0.640671 (0.19950, 1.244095)**
	2011	0.296840 (0.191693, 0.411264)	**0.311579 (0.129684, 0.522761)**	**0.542211 (0.141819, 1.083004)**
	2012	0.195468 (0.108874, 0.288825)	**0.198201 (0.047594, 0.370459)**	**0.414214 (0.123763, 0.779735)**
	2013	0.180993 (0.112768, 0.253400)	**0.325237 (0.169832, 0.501285)**	0.090508 (-0.038661, 0.237032)
	2014	0.196864 (0.128596, 0.269262)	**0.268266 (0.130368, 0.422986)**	0.189207 (0.029811, 0.373275)
	2015	0.125750 (0.080280, 0.173133)	**0.171267 (0.082832, 0.266925)**	**0.196864 (0.058642, 0.353132)**
Mean (95%CI) of log(1+unique domains)	2006	0.402473 (0.275081, 0.529864)	**0.476539 (0.299845, 0.653232)**	**0.693147 (0.693147, 0.693147)**
	2007	0.346574 (0.219591, 0.473556)	**0.462098 (0.195236, 0.728960)**	0.346574 (-4.058377, 4.751524)
	2008	0.210958 (0.114918, 0.306998)	**0.308065 (0.026769, 0.589362)**	**0.277259 (-0.194745, 0.749263)**
	2009	0.324913 (0.237755, 0.412070)	**0.401296 (0.231902, 0.570689)**	**0.396084 (0.190590, 0.601579)**
	2010	0.297063 (0.203633, 0.390493)	0.283560 (0.128875, 0.438246)	**0.495105 (0.181908, 0.808302)**
	2011	0.259930 (0.175375, 0.344485)	**0.271232 (0.121938, 0.420525)**	**0.433217 (0.132623, 0.733811)**
	2012	0.178538 (0.103345, 0.253731)	**0.180821 (0.046496, 0.315146)**	**0.346574 (0.116683, 0.576465)**
	2013	0.166355 (0.106851, 0.225860)	**0.281591 (0.156860, 0.406322)**	0.086643 (-0.039429, 0.212715)
	2014	0.179705 (0.120974, 0.238435)	**0.237650 (0.122543, 0.352758)**	0.173287 (0.029375, 0.317198)
	2015	0.118449 (0.077220, 0.159678)	**0.158086 (0.079580, 0.236593)**	**0.179705 (0.056987, 0.302422)**
Proportion non-zero (95%CI)	2006	0.580645 (0.407663, 0.735845)	**0.687500 (0.444044, 0.858354)**	**1.000000 (0.510109, 1.000000)**
	2007	0.500000 (0.336309, 0.663691)	**0.666667 (0.354202, 0.879416)**	0.500000 (0.094531, 0.905469)
	2008	0.304348 (0.190798, 0.448056)	**0.444444 (0.188779, 0.733349)**	**0.400000 (0.117621, 0.769276)**
	2009	0.468750 (0.351760, 0.589279)	**0.578947 (0.362759, 0.768581)**	**0.571429 (0.325906, 0.786192)**
	2010	0.428571 (0.307690, 0.558624)	0.409091 (0.232558, 0.612652)	**0.714286 (0.358934, 0.917781)**
	2011	0.375000 (0.266660, 0.497496)	**0.391304 (0.221576, 0.592145)**	**0.625000 (0.305742, 0.863156)**
	2012	0.257576 (0.167488, 0.374331)	**0.260870 (0.125486, 0.464700)**	**0.500000 (0.253782, 0.746218)**
	2013	0.240000 (0.166913, 0.332323)	**0.406250 (0.255196, 0.577400)**	0.125000 (0.034977, 0.360228)
	2014	0.259259 (0.185891, 0.349165)	**0.342857 (0.208317, 0.508481)**	0.250000 (0.111862, 0.468701)
	2015	0.170886 (0.120183, 0.237213)	**0.228070 (0.138419, 0.352060)**	**0.259259 (0.131704, 0.446786)**
MNLCS - mean (95%CI) of world normalized log (1_unique domains)	2006	1.000000 (0.632776, 1.580339)	**1.184028 (0.711693, 1.914321)**	**1.722222 (1.308160, 2.519795)**
	2007	1.000000 (0.584017, 1.712279)	**1.333333 (0.616767, 2.463397)**	1.000000 (-1.077876, 3.387999)
	2008	1.000000 (0.496709, 2.013251)	**1.460317 (0.286993, 3.397228)**	**1.314286 (-0.317905, 3.633703)**
	2009	1.000000 (0.679000, 1.472754)	**1.235088 (0.703875, 1.957830)**	**1.219048 (0.610937, 2.016201)**
	2010	1.000000 (0.631677, 1.583088)	0.954545 (0.435792, 1.678302)	**1.666667 (0.772978, 2.918297)**
	2011	1.000000 (0.620921, 1.610510)	**1.043478 (0.468033, 1.865901)**	**1.666667 (0.666941, 3.060869)**
	2012	1.000000 (0.528419, 1.892436)	**1.012788 (0.276594, 2.185739)**	**1.941176 (0.730814, 3.988658)**
	2013	1.000000 (0.589018, 1.697742)	**1.692708 (0.898465, 2.972352)**	0.520833 (-0.194141, 1.388639)
	2014	1.000000 (0.619412, 1.614436)	**1.322449 (0.664615, 2.289534)**	0.964286 (0.202781.,1.951286)
	2015	1.000000 (0.594978, 1.680734)	**1.334633 (0.647040, 2.390200)**	**1.517147 (0.505898, 2.946691)**
EMNPC - world normalized proportion non-zero (95%CI) [i.e. risk ratio]	2006	1.000000 (0.664172, 1.505635)	**1.184028 (0.776782, 1.804782)**	**1.722222 (NaN, NaN)**
	2007	1.000000 (0.621941, 1.607871)	**1.333333 (0.787758, 2.256756)**	1.000000 (0.419890, 2.381578)
	2008	1.000000 (0.547518, 1.826422)	**1.460317 (0.669484, 3.185330)**	**1.314286 (0.495971, 3.482756)**
	2009	1.000000 (0.695506, 1.437803)	**1.235088 (0.791688, 1.926821)**	**1.219048 (0.744264, 1.996708)**
	2010	1.000000 (0.657052, 1.521950)	0.954545 (0.543139, 1.677576)	**1.666667 (1.023382, 2.714312)**
	2011	1.000000 (0.644078, 1.552606)	**1.043478 (0.585395, 1.860019)**	**1.666667 (0.950797, 2.921527)**
	2012	1.000000 (0.56666, 1.764722)	**1.012788 (0.471267, 2.176556)**	**1.941176 (1.005908, 3.746036)**
	2013	1.000000 (0.614726, 1.626742)	**1.692708 (0.994474, 2.881182)**	0.520833 (0.158530, 1.711138)
	2014	1.000000 (0.640527, 1.561214)	**1.322449 (0.766984, 2.280193)**	0.964286 (0.442831, 2.099777)
	2015	1.000000 (0.618556, 1.616668)	**1.334633 (0.749760, 2.375753)**	**1.517147 (0.755935, 3.044883)**

4. Discussion

The findings from this work suggest that AM technologies for biomedical engineering applications are emerging technologies, i.e. they are at an early stage of development, which agrees with the results obtained by other studies for additive manufacturing technologies (**Rodríguez-Salvador**; **Río-Belver**; **Garechana-Anacabe**, 2017; **Zarrabeitia-Bilbao** *et al.*, 2019).

Within this scenario, the USA and China are undoubtedly the central characters in scientific production in this field. In this case, the USA shows the supremacy also demonstrated in other studies related to both research areas, additive manufacturing, and medicine; however, in the case of China it seems that this position is due to the area of the technology and not to the medicine. While in other studies related to the technology, both countries are among the first positions, in the case of China, in other studies related to medicine it does not appear in the first positions of the countries with more publications (**López-Muñoz** *et al.*, 2003; **López-Illescas**; **De-Moya-Anegón**; **Moed**, 2009; **Filser**; **Da-Silva**; **De-Oliveira**, 2017; **Rodríguez-Salvador**; **Río-Belver**; **Garechana-Anacabe**, 2017; **Caviggioli**; **Ughetto**, 2019; **Muhuri**; **Shukla**; **Abraham**, 2019).

The top publishing and cited institutions, as expected, are universities. However, the presence of certain laboratories or medical centers is omitted. Due to this, it would be interesting, for future works, to include an analysis of the departments (**Filser**; **Da-Silva**; **De-Oliveira**, 2017) which were involved in the published articles and analyze if there are more medical or more technical departments.

The findings from this work suggest that AM technologies for biomedical engineering applications are emerging technologies, i.e. they are at an early stage of development

The findings from academic impact and industrial and commercial impact indicators suggest that AM technologies for biomedical engineering application research, in general, produces good results, and, consequently, fine quality research is performed.

In the case of citation counts for individual sets of articles, this emphasizes that the proportion of articles with at least 1 citation $(\sum_{year\ 2006}^{year\ 2015} Proportion\ non-zero/10)$ is practically 100% (98.7%).

For *Mendeley* readers count it is observed that the proportion of articles with at least 1 *Mendeley* reader is 97.5%, while the proportion with at least one *Mendeley* reader varied from 40.7% in humanities to 81% in psychology (72.4% for biomedical research and 71.6% for engineering and technology) for articles from 2010 to 2012 in *PubMed* and *Web of Science* (**Haustein** *et al.*, 2014). There is a high level of interest among researchers in biomedical engineering applications.

In the case of *Google Patents* citation counts, the proportion of articles with at least 1 *Google Patents* citation is 35.9%, while the coverage in applied science and engineering varies for 1.9% in mechanical engineering to 10.1% in biomedical engineering for articles from 1996 to 2012 in *Scopus* (**Kousha**; **Thelwall**, 2017b). Therefore, we can say that a high rate of transfer between science and technology is taking place.

As for *Wikipedia* citation counts, the proportion of articles with at least 1 *Wikipedia* citation is only 1.5%, whereas the proportion with at least one *Wikipedia* citation varied from 1.4% in Computer Science to 10.7% in History for articles from 2005 to 2012 in *Scopus* (**Kousha**; **Thelwall**, 2017a). More time is required for new research and its applications to be broadly transferred to the academic field.

4.1. Limitations and other considerations

Finally, the present study, like all bibliometric/webometric analyses, has its inherent methodological limitations. Reliability of bibliometric data can be affected by the bibliometric database coverage (*Web of Science*). The impact indicators used show academic, and industrial and commercial impact, and have been used as a proxy for quality. However, estimates of quality based on these variables can be misleading because work may be cited for a variety of reasons, not all of which may reflect quality (**Gunashekar** *et al.*, 2015).

The USA shows the supremacy also demonstrated in other studies related to both research areas, additive manufacturing, and medicine; however, in the case of China it seems that this position is due to the area of the technology and not to the medicine

Hence, despite the fact that bibliometric/webometric analysis has been used increasingly as a tool within the scientific community (**Ellegaard**, 2018) and bibliometric/webometric methods offer a practical and impartial way to estimate publication profiles of scientific researchers, it would also be interesting to complete the results obtained with other methods, such as expert opinions and panels (**Koskinen** *et al.*, 2008).

5. Conclusions and future lines of research

This research contributes to the diffusion of technologies to society, providing key elements to scientific and technological policy makers. Usually main productivity impact studies come from firms and follow a variety of methodological approaches. This paper addressing trends and the scientific impact of additive manufacturing technologies for biomedical engineering applications provides evidence on the generation and impact of scientific production from bibliometric data and suggests only one methodological approach for every study, which may be extended to other fields.

Additive manufacturing technologies have been identified as revolutionary because of their power to change, among other things, productive systems, skills and well-being; and they will have major implications for society, in general; and for policy makers, in particular.

> Additive manufacturing technologies have been identified as revolutionary because of their power to change, among other things, productive systems, skills and well-being; and they will have major implications for society, in general; and for policy makers, in particular

In general, in AM technologies for BE applications is worth noting the clear agreement between where knowledge comes from and who is researching it (countries and institutions), except for the case of China, who, despite extensive research activity, would appear to have contributed relatively little to that field to date.

The greatest research areas from where the knowledge comes and research areas developed, are in both cases "Engineering, Biomedical" and "Materials Science, Biomaterials". It can also be deduced that the different areas of knowledge are following the same paths, for both where the knowledge comes from and where it goes. In addition, the fields of research have evolved very little, in general, inferring that they cover the same topics.

With respect to scientific journals, the most prolific journals and the most cited journals are in upper quartile rankings, which demonstrates the quality of the articles being published in the area.

Another important point to highlight is that the USA, apart from being the central character in scientific production, produces scientific studies into AM technologies for biomedical engineering applications that have higher academic, industrial, and commercial impact than the world average. This is not the case for China, the second most productive country in the area for academic impact but with merely good results in terms of industrial and commercial impact.

Finally, future work related with this study could take many forms, given the diversity of the current situation for additive manufacturing and informetrics. It would be interesting to analyze specific AM technologies and their behavior in different biomedical engineering applications. Further research should also use other primary search engines (like *Scopus*) and other scientific impact indicators. New scientific impact indicators could be *Google Books* citations and citations from the Grey Literature (academic impact); Syllabus mentions (educational impact); Clinical Trials or Guidelines (medical impact); and Blog citations (public engagement impact). Finally, it would also be interesting to expand this study to include other processes and technologies.

> The most prolific journals and the most cited journals are in upper quartile rankings, which demonstrates the quality of the articles being published in the area

6. Notes

1. A top technician was identified through *Addimat* (the Spanish *Association of Additive Manufacturing Technologies and 3D*, *http://www.addimat.es*). At the time of furnishing assistance, the expert selected was a qualified engineer from *Optimus3D* (*http://optimus3d.es*), a company that provides comprehensive engineering and part manufacturing solutions, using different additive manufacturing technologies, both in plastic materials or resins, as well as metal.

2. MNLCS is the average number of log-transformed citations for the group, divided by the average number of log-transformed citations for the corresponding world set (**Thelwall**, 2016).

3. EMNPC is the proportion of articles cited for the group, divided by the corresponding world proportion of cited articles for the same field and year (**Thelwall**, 2016).

4. NaN (Not a Number) in the sample confidence limits mean that these are impossible to calculate and are effectively infinite.

5. Even though normally unique domains value is best information value (to avoid counting multiple similar pages in a single website), in the case of *Wikipedia* URLs value is better (**Kousha**; **Thelwall**, 2017a).

7. Appendix

Search query for Additive Manufacturing for Biomedical Engineering Applications adapted to the Web of Science Core Collection database

Equation (1) [World]	(TS=((((3D OR "3 D" OR 3-D OR "3 dimension*" OR 3-dimension* OR "three* dimension*" OR three-d OR "three d" OR desktop* OR additive* OR freeform) NEAR/1 (print* OR bioprint* OR bio-print* OR "bio print*" OR fabricat* OR biofabricat* OR bio-fabricat OR "bio fabricat" OR manufactur* OR biomanufactur* OR bio-manufactur* OR "bio manufactur*")) OR ((rapid) NEAR/1 (prototype* OR bioprototyp* OR bio-prototyp* OR "bio prototyp*")) OR "layer by layer" OR layer-by-layer) NOT (stereoscopic* OR "oxidation product*" OR "streaming interactive" OR "non halogen" OR non-halogen OR "media access control" OR "multi-wafer 3D CAM cell" OR nanoweb OR "nano web" OR nano-web OR nanofiber* OR nanofibre* OR "nano fiber*" OR "nano fibre*" OR "nanometer fiber*" OR "nanometer fibre*" OR "nanometre fiber*" OR "nanometre fibre*" OR ((food* OR feed* OR liquid*) NEAR/2 (additive*)) OR "seed culture" OR antibacteria* OR 3-sigma OR "three sigma" OR ((rheolog*) NEAR/1 (additive*)) OR ((vibration) NEAR/1 (isolator*)) OR toilet OR paper OR transistor OR "solar cell" OR "light emitting" or diode OR spectophotom* OR spectroscop*)) AND (SO="Annual Review of Biomedical Engineering" OR SO="Biomaterials" OR SO="Acta Biomaterialia" OR SO="Artificial Cells Nanomedicine and Biotechnology" OR SO="Biofabrication" OR SO="Advanced Healthcare Materials" OR SO="-Medical Image Analysis" OR SO="European Cells & Materials" OR SO="Journal of Tissue Engineering and Regenerative Medicine" OR SO="IEEE Transactions on Medical Imaging" OR SO="Clinical Oral Implants Research" OR SO="IEEE Transactions on Biomedical Engineering" OR SO="Journal of NeuroEngineering and Rehabilitation" OR SO="Journal of Neural Engineering" OR SO="Organogenesis" OR SO="IEEE Transactions on Neural Systems and Rehabilitation Engineering" OR SO="Biomechanics and Modeling in Mechanobiology" OR SO="Annals of Biomedical Engineering" OR SO="Journal of Biomedical Materials Research Part B-Applied Biomaterials" OR SO="Journal of the Mechanical Behavior of Biomedical Materials" OR SO="Journal of Biomedical Materials Research Part A" OR SO="IEEE Transactions on Biomedical Circuits and Systems" OR SO="Regenerative Medicine" OR SO="Physics in Medicine and Biology" OR SO="Journal of Biomechanics" OR SO="Computer Methods and Programs in Biomedicine" OR SO="Biomedical Materials" OR SO="Artificial Organs" OR SO="Journal of Materials Science-Materials in Medicine" OR SO="Journal of Biomaterials Applications" OR SO="Lasers in Medical Science" OR SO="Expert Review of Medical Devices" OR SO="Biomedical Signal Processing and Control" OR SO="International Journal for Numerical Methods in Biomedical Engineering" OR SO="Asaio Journal" OR SO="Biomedical Microdevices" OR SO="Physiological Measurement" OR SO="Journal of Biomechanical Engineering-Transactions of the ASME" OR SO="Artificial Intelligence in Medicine" OR SO="Medical & Biological Engineering & Computing" OR SO="Computer Methods in Biomechanics and Biomedical Engineering" OR SO="Journal of Biomaterials Science-Polymer Edition" OR SO="Clinical Biomechanics" OR SO="International Journal of Computer Assisted Radiology and Surgery" OR SO="Computers in Biology and Medicine" OR SO="Medical Engineering & Physics" OR SO="Ultrasonic Imaging" OR SO="Computerized Medical Imaging and Graphics" OR SO="Biomedical Engineering Online" OR SO="Pace-Pacing and Clinical Electrophysiology" OR SO="-Journal of Artificial Organs" OR SO="Cell and Tissue Banking" OR SO="Australasian Physical & Engineering Sciences in Medicine" OR SO="International Journal of Artificial Organs" OR SO="Tissue Engineering and Regenerative Medicine" OR SO="Biorheology" OR SO="Cardiovascular Engineering and Technology" OR SO="Journal of Applied Biomechanics" OR SO="Biocybernetics and Biomedical Engineering" OR SO="Proceedings of the Institution of Mechanical Engineers Part H-Journal of Engineering in Medicine" OR SO="Journal of Medical and Biological Engineering" OR SO="Applied Bionics and Biomechanics" OR SO="Journal of Mechanics in Medicine and Biology" OR SO="Biomedical Engineering-Biomedizinische Technik" OR SO="Acta of Bioengineering and Biomechanics" OR SO="Sports Biomechanics" OR SO="Bioinspired Biomimetic and Nanobiomaterials" OR SO="IRBM" OR SO="Technology and Health Care" OR SO="Bio-Medical Materials and Engineering" OR SO="IEEE Pulse" OR SO="Journal of Hard Tissue Biology" OR SO="Journal of Medical Devices-Transactions of the ASME" OR SO="Isokinetics and Exercise Science" OR SO="IEEE Journal of Translational Engineering in Health and Medicine-JTEHM" OR SO="artifici" OR SO="Regenerative Therapy" OR SO="Nature Biomedical Engineering"))
Equation (2) [USA]	Equation (1) AND (AD=USA)
Equation (3) [China]	Equation (1) AND (AD=China)
Source	*Web of Science*
Databases	Core Collection
Timespan (1)	From 2000 to 2017
Timespan (2)	From 2006 to 2015
Document type	Articles
Date of the search	October 01, 2018
Results [equation (1) + timespan (1)]	1223 articles
Results [equation (1) + timespan (2)]	31 articles (in 2006), 32 articles (in 2007), 46 articles (in 2008), 64 articles (in 2009), 56 articles (in 2010), 64 articles (in 2011), 66 articles (in 2012), 100 articles (in 2013), 108 articles (in 2014), 158 articles (in 2015)
Results [equation (2) + timespan (2)]	16 articles (in 2006), 9 articles (in 2007), 9 articles (in 2008), 19 articles (in 2009), 22 articles (in 2010), 23 articles (in 2011), 23 articles (in 2012), 32 articles (in 2013), 35 articles (in 2014), 57 articles (in 2015)
Results [equation (3) + timespan (2)]	4 articles (in 2006), 2 articles (in 2007), 5 articles (in 2008), 14 articles (in 2009), 7 articles (in 2010), 8 articles (in 2011), 12 articles (in 2012), 16 articles (in 2013), 20 articles (in 2014), 27 articles (in 2015)

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