A SCIENTOMETRIC ANALYSIS OF GLOBAL RESEARCH TRENDS IN BIOMATERIALS

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Abstract

The paper analyses the results of total publication of the world in Biomaterials subject field as reflected in Thomson Reuters Web of Science database during the period of 1999 to 2013. The study has used various Scientometric indicators like R^2 Value, Annual Growth Rate, Activity Index (AI), Attractive Index (AAI), Publication Efficiency Index (PEI) and Relative Citation Impact (RCI). The present study compares the top ten countries' publications and their citations performance to the world average within their period cited earlier.

Keywords: Activity Index, Attractive Index, Biomaterials, Publication Efficiency Index, Relative Citation Impact, Scientometric Analyses, Scientometric Indicators.

1. INTRODUCTION

The biomaterials are basically materials which are utilized and acclimatized for a medical purpose. The biomaterials can have a benevolent function, being used in a proactive or used in heart valve and used for a more interactive purpose such as hydroxyl-apatite coated in different organs, implanted in the human body. The biomaterials can be used in dental surgery, dental application and also in drug relief in a routine life. The blog, 'Environment' (2014) defines biomaterials as "biomaterial is any material, natural or man-made, that comprises whole or part of a living structure or biomedical device which performs, augments, or replaces a natural function".

The biomaterials can be used in Bone plates, Artificial ligaments, Bone cement, and tendons, Joint restoration, Blood vessel prosthesis implantation, cochlear implant replacements, heart valves blockage treatment, skin repair devices (Ex. Micro-Plasma Device), contact lenses and dental implants for tooth fixation. Considering the importance of biomaterials and its application in various fields, the present study is carried out for using various Scientometric indicators for the period of 1999 to 2013.

2. OBJECTIVES

The objectives of the study are to perform a Scientometric analysis of all Bio Materials publications in the world. The specific objectives of the study are to find out;

1) the growth of publications and citations of Biomaterials research;
2) country wise distribution of publications and to calculate activity index;
3) most productive institutions;
4) highly preferred journals in the field of Biomaterials and
5) to calculate publication efficiency index for the study.

3. MATERIALS AND METHOD

The study involves scientific output of Biomaterials in terms of research publications. The data was using by 'Web of Science' for the period of fifteen years, i.e. 1999 to 2013. The keyword used for the search was "**WC= (Biomaterials) AND PY= (1999-2013)**" for measuring the research output on Biomaterials. 'Biomaterials' included research specific publications related to Engineering, Biophysics, Chemistry, Polymer Science, Dentistry oral Surgery Medicine, Biochemistry Molecular Biology, Biotechnology, Applied Microbiology, Energy Fuels, Robotics, etc,. The total number of publications of "Biomaterials" showed 47,622 records.

The Scientometric indicators are mainly proposed to recognize, compare and assessment appropriate characteristics of input and output of scientific productivity and research in more objectives that is quantitative fashion (Sangam, et. all. 2008). To evaluate publications and citation efficiency the study used Scientometric indicators.

The R^2 value can be mathematically derived from the given below formula

$$R^2 = 1 - \frac{SSE}{SS_{yy}}$$

R^2 is the coefficient of determination that shows the relation between dependent variable and the other independent variables.

Activity Index (AI), the indicator compares a country's research recital with that of the world performance (Chen and Guan 2011; Hu and Rousseau 2009). The Activity Index is also

called as relative performance indictor, which considered publications size of the evaluated country in the field of Biomaterials.

Mathematically, the Activity Index is (AI^t_i) for the i^{th} country in the t^{th} year during the considered period and it can be describing as follows:

$$AI^t_i = \frac{\left(P^t_i / \sum P\right)}{\left(TP^t / \sum TP\right)}$$

$\mathbf{P^t_i}$ is the Biomaterials research publication by the $\mathbf{i^{th}}$ country in the t^{th} year; $\mathbf{\Sigma P}$ is the Biomaterials publications by the i^{th} country during the period; $\mathbf{TP^t}$ is the total Biomaterials publication output by the world in the t^{th} year; $\mathbf{\Sigma TP}$ is the total Biomaterials research publications by the world during the period. If **AI**=1, it indicates that the country's research attempt in a particular field match up specifically to the world's average. If AI>1, as the result shows that the country used to spend more force and funds to the specified field than the world average, or if AI<1, this reflects a specialization by this country in the field under study (Hu and Rousseau 2009; Chen and Guan 2011).

The Attractive Index (AAI) is used to characterize the relative impact of a country's research output in a subject field as reflected by the citations they received during the period (Chen and Guan 2011; Hu and Rousseau 2009). Mathematically, the Attractive Index for (AAI^t_i) is defined as follows:

$$AAI^t_i = \frac{\left(C^t_i / \sum C\right)}{\left(TC^t / \sum TC\right)}$$

$\mathbf{C^t_i}$ is the Biomaterials publications citations by the i^{th} country in the t^{th} year; ΣC is the Biomaterials research citation by the i^{th} country during the period; here TC^t is the total Biomaterials citations by the world in the t^{th} year; and ΣTC is the total Biomaterials citations by the world during 1999 to 2013. If AAI=1, the indicator used that the particular country's relative citation impact in the subject field match up specifically to the world average. If AAI >1, indicates that the country's relative citation impact in that field is higher than the world average and if AAI<1, it results that the country's relative citation impact in the field is lower than the world average (Hu and Rousseau 2009; Chen and Guan 2011).

The Publication Efficiency Index (PEI) is an indicator to find out if the impact of publication output by the top ten contributing countries in Biomaterials research corresponds with the

country's research output during 1999 to 2013. Mathematically, the publication efficiency index (PEI^t_i) as follows;

$$PEI^t_i = \frac{\left(C^{t+2}_i / \sum C \right)}{\left(P^t_i / \sum P \right)}$$

C^{t+2}_i is the citations by the i^{th} country, y in the $(t + 2)^{th}$ year; ΣC is the citations by the i^{th} country during the taken citation period; P^t_i is the research publications by the ith country in the t^{th} year; ΣP is the total research output by the i^{th} country during the period of 1999-2013. It is attained through isolating the percentage of citations "returns" by the percentage of publications "efforts". If PEI >1(Publication Efficiency Index is greater than One) , It indicates that the impact of total research publication in a given subject field by a particular country is more than the research attempt devoted to it during the period, the paper has considered.

Relative Citations Impact (RCI) is a measure of citations impact of the research output by a country compared to the world average. This is determined on the basis of average citations per paper for the relative to the average citation per paper for the world output (Gupta & Dhawan, 2006, p.33).

$$\text{Relative Citations Impact} = \frac{Average\ Citation\ Per\ Paper\ for\ the\ Country\ output}{Average\ Citations\ Per\ Paper\ for\ the\ World\ Output}$$

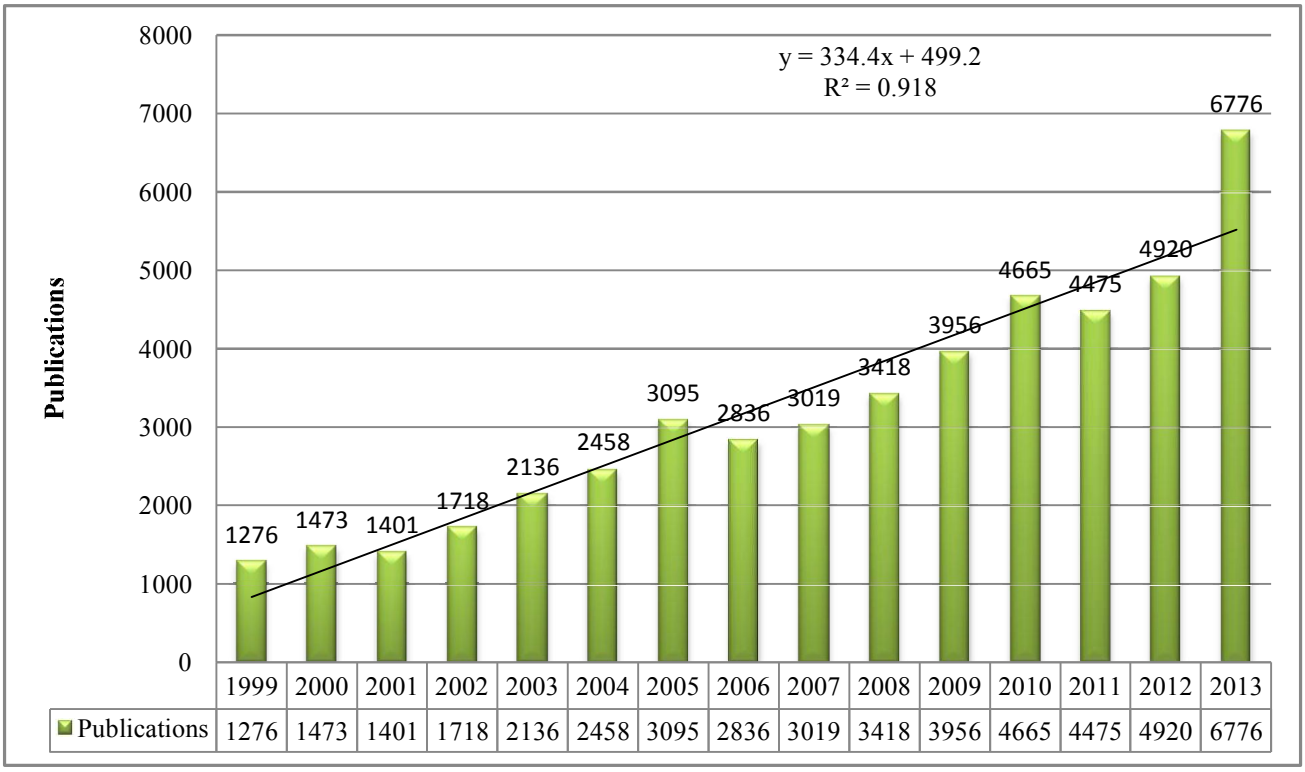
The RCI compares a country's citation rate (the citation per year) for a particular field to the world wide citation rate for that field. A Relative Citation Impact greater than 1 shows that the country's rate for the field is higher than the world's and is viewed by some as a reliable indicators of the quality of the average paper. This latter measure takes into account the size of the particular country productiveness relative to that in other countries (National Research Council, 2000).

4. RESULTS AND ANALYSIS

The total number of publications extracted in the field of Biomaterials is 47,622 during 1999-2013 as reflected in Web of Science database and 9, 50,044; citations were received for 47,622 total publications.

During the period, the exponential growth pattern was reflected by the value of R^2 from WoS (R^2= 0.918). The result confirms the fast growth of publications in Biomaterials research during 1999-2013.

Figure 1: Growth of Publications in Biomaterials research (1999-2013)



4.1 Publications and Citations trend of different Countries

Table 1 show the publications output of top seventeen countries which have contributed at least 1000 publications or above. Among the different countries, USA topped the list with 12,025 publications and its share is 25.251 % of the total publications, h-Index of 184 (which is highest among the countries) in Biomaterials. China ranked second in terms of number of publications (7,494) with the citations of 1,19,506 and 15.95 Average Citation per Paper (ACP) but it's ACP is too low compared to other countries. Singapore ranked first in terms of ACP with 36.53% but ranked last in the table in terms of total publications (1040). Japan with 5595 publications to its credit, ranked third in terms of publications (5,595) and citations (1,02,637), whereas, Germany with 3337 and UK with 3091 publications ranked third to fifth respectively. It is surprising to note that though the publications output of some countries (such as Netherlands, Switzerland and Singapore) are less but their ACP is high compared to that of top countries producing total number of publications.

Singapore has the highest RCI (Relative Citation Impact) with 1.822, Netherlands with 1.486, Switzerland with 1.467, USA with 1.436, Canada and UK with 1.130, Germany with 1.112 ranked first to sixth respectively. The RCI of other countries is presented in table 1.

Table 1: Performance of the Top Countries

Sl. No	Countries	Total Publications	Total Citations	Average Citations Per Publication	H-Index	Percentage	RCI
1	USA	12025	328255	27.30	184	25.251	1.436
2	China	7494	119506	15.95	113	15.739	0.839
3	Japan	5595	102637	18.34	111	11.749	0.965
4	Germany	3337	70502	21.13	99	7.007	1.112
5	UK	3091	66361	21.47	100	6.491	1.130
6	South Korea	2483	51609	20.78	95	5.214	1.094
7	Italy	2128	40265	18.92	80	4.469	0.996
8	Canada	1881	40404	21.48	82	3.950	1.130
9	France	1849	38024	20.56	79	3.883	1.082
11	India	1656	21398	12.92	57	3.477	0.680
11	Taiwan	1393	25451	18.27	67	2.925	0.961
12	Spain	1345	21531	16.01	65	2.822	0.842
13	Netherlands	1272	35924	28.24	90	2.671	1.486
14	Australia	1132	23164	20.46	67	2.377	1.077
15	Brazil	1067	14573	13.66	49	2.241	0.719
16	Switzerland	1053	29367	27.89	81	2.209	1.467
17	Singapore	1040	36013	34.63	87	2.184	1.822
Total		47622	905044	19.00			

(*1000 $\geq$ and above contribution of total publications)* Relative Citation Impact (RCI)

4.2 Growth Rate of Publications in the field of Biomaterials

The table 2 shows the growth rate of publications in the field of Biomaterials. It reveals that the total of 47,622 publications were published during the 1999 - 2013 which received 9, 05,044 citations. The highest numbers of publications i.e. 6, 724 were published in the year 2013. The highest number of citations were received i.e. 94,668 for the year 2005. It appears that the annual growth during the period is inconsistent. The Annual Growth Rate is fluctuant during the study period. The present study contradicts the results of Kademani et. al (2011) i.e. " The quantity and quality of research always go hand in hand as average citations per year is decreasing. The older publications received more citations than the publications published recently".

Table 2: Growth Rate of publications in the field of Biomaterials

Publications Year	Total Publications	Annual Growth Rate (%)	Total Citations	Average Citations Per Paper
1999	1276	-	55,139	43.21
2000	1473	15.44	57,970	39.36
2001	1401	-4.89	54,987	39.25
2002	1718	22.63	65,787	38.29
2003	2136	24.33	74,192	34.73
2004	2458	15.07	77,159	31.39
2005	3019	22.82	94,668	30.59
2006	2836	-6.06	79,218	27.93
2007	3019	6.45	73,519	24.35
2008	3418	13.22	68,869	20.16
2009	3955	15.71	68,568	17.34
2010	4665	17.95	64,117	13.74
2011	4474	-4.09	42,071	9.41
2012	4890	9.30	21,968	4.49
2013	6724	37.51	68,12	1.01
Total Citations			9,05,044	

4.3 Activity Index (AI) of different countries

Table 3 gives the Activity Index of different countries in Biomaterials research. Though India is placed tenth position in terms of total publications it has the highest mean AI i.e. 1.854, followed by China (1.800 AI), Germany (1.575 AI), USA with 1.524(AI), Canada (1.507 and France (1.465) ranked second to sixth respectively. This indicates that all these countries' Average AI is greater than 1 (AI > 1) indicating an active and specialized focus on Biomaterials research. This means top ten countries average corresponds to that of world's average.

Table 3: Activity Index (AI) of Top Ten Countries in Biomaterials

Years	USA	China	Japan	Germany	UK	South Korea	Italy	Canada	France	India
1999	0.227	0.023	0.220	0.139	0.282	0.076	0.228	0.243	0.365	0.076
2000	0.331	0.067	0.439	0.276	0.357	0.152	0.437	0.329	0.503	0.146
2001	0.309	0.072	0.407	0.324	0.459	0.185	0.365	0.309	0.392	0.154
2002	0.378	0.135	0.548	0.389	0.461	0.309	0.520	0.504	0.524	0.186
2003	0.508	0.304	0.936	0.451	0.584	0.524	0.577	0.474	0.475	0.269
2004	0.682	0.390	1.093	0.601	0.960	0.842	0.812	0.615	0.754	0.227
2005	0.964	0.852	1.282	1.084	0.991	1.159	1.063	1.260	0.924	0.362
2006	0.952	0.676	1.356	0.851	1.000	1.061	0.719	0.931	1.024	0.495
2007	1.170	0.928	1.228	1.142	1.157	0.879	1.097	1.143	0.963	0.811
2008	1.427	1.401	1.205	1.498	1.492	1.326	1.493	1.195	1.394	1.264
2009	1.930	2.231	1.630	1.750	1.731	1.787	1.886	1.683	1.495	2.383
2010	2.861	3.085	2.165	2.949	2.520	2.836	2.631	3.198	2.354	2.762
2011	3.256	3.857	2.254	3.013	2.552	3.268	2.887	3.111	2.675	3.787
2012	3.403	4.699	2.369	3.738	2.815	4.134	3.179	3.343	3.052	4.495
2013	4.466	8.287	3.008	5.413	4.226	5.742	4.192	4.266	5.087	10.390
Mean	1.524	1.800	1.343	1.575	1.439	1.619	1.472	1.507	1.465	1.854

*(see also table 1)*Countries listed with top 10 priority in publications.

4.4 Attractive Index (AAI) of different countries

Table 4 indicates the Attractive Index of top ten countries. India scored highest Attractive Index that is 3.434 in the year 2013 followed by China with 2.617 in the same year. Both India and China have recorded Attractive Index greater than 1 during 2007 to 2013. Whereas USA, Japan, UK, Canada and France recorded less than 1 Attractive Index during the period of 2008 to 2010, which are not corresponding to the world's average. The AAI of China and India seems to be performing better than other countries. Fluctuant trend of AAI was observed for Germany, South Korea and Italy.

Table 4: Attractive Index (AAI) Top Countries in Biomaterials

Years	USA	China	Japan	Germany	UK	South Korea	Italy	Canada	France	India	Total Citations
1999	1.217	0.138	1.303	0.546	1.225	0.681	1.194	1.380	1.669	0.332	51,063
2000	1.244	0.291	1.161	0.895	1.173	0.916	0.968	1.106	1.777	0.306	55,649
2001	1.011	0.398	1.367	0.909	1.308	0.547	1.121	1.135	1.080	0.402	48,791
2002	0.953	0.541	1.323	0.996	1.135	0.924	1.149	1.039	1.135	0.509	59,164
2003	0.974	0.725	1.524	0.936	0.818	1.044	0.853	0.723	1.050	0.685	67,586
2004	0.950	0.764	1.086	1.042	1.213	1.391	1.018	0.967	0.697	0.328	70,282
2005	1.023	0.869	1.042	1.349	0.895	1.011	1.109	1.318	0.836	0.489	90,743
2006	1.018	0.828	1.051	1.049	1.268	1.014	0.880	1.034	1.130	0.592	75,655
2007	1.060	1.028	0.884	1.168	1.018	0.893	0.837	1.093	0.928	1.148	71,607
2008	0.982	1.228	0.729	0.939	0.996	0.958	1.150	0.750	0.926	1.497	66,135
2009	0.926	1.654	0.706	0.908	0.917	1.039	0.887	0.740	0.653	1.967	68,247
2010	0.910	1.598	0.610	1.096	0.665	1.148	1.013	0.968	0.821	1.865	65,746
2011	0.950	2.026	0.540	0.989	0.622	1.178	0.917	0.923	0.799	2.084	47,756
2012	0.806	2.251	0.516	0.832	0.579	1.176	0.921	0.819	0.653	2.199	27,268
2013	0.661	2.617	0.425	0.811	0.7415	1.036	0.905	0.581	0.888	3.434	13,404
MEAN	**0.979**	**1.130**	**0.951**	**0.964**	**0.972**	**0.997**	**0.995**	**0.972**	**1.003**	**1.189**	
MEDIAN	**0.974**	**0.869**	**1.042**	**0.939**	**0.996**	**1.014**	**0.968**	**0.968**	**0.926**	**0.685**	
											8,78,970

4. 5 Publication Efficiency Index (PEI) of different countries

Table 5 depicts the Publication Efficiency Index (PEI) of top ten countries. The results demonstrate the impact of research publications in Biomaterials in these countries. This means that for those nine countries, the research performance is more than the research effort devoted to it during 1999 - 2012. South Korea scored the highest PEI i.e 3.639 and 3.574 in 1999 and 2000 respectively in the Biomaterials research. The top countries' PEI score is

greater than one for the period 1999 to 2006 but it is lesser than one during 2009 to 2013. No country displays good performance during 2009 to 2013. All ten countries seem to display regular decreasing trends during the study period 1999-2013.

Table 5: Publication Efficiency Index (PEI) of Top Ten Countries

Years	Total Publications	Total Citations	USA	China	Japan	Germany	UK	South Korea	Italy	Canada	France	India
1999	1276	56592	2.191	2.403	2.419	1.604	1.773	3.639	2.139	2.319	1.867	1.776
2000	1473	59710	2.229	2.566	1.567	1.927	1.948	3.574	1.315	1.991	2.097	1.241
2001	1401	56634	1.941	3.271	1.993	1.662	1.691	1.752	1.823	2.177	1.634	1.548
2002	1718	67925	1.870	2.975	1.792	1.898	1.824	2.221	1.639	1.531	1.607	2.025
2003	2136	77033	1.826	2.271	1.549	1.976	1.332	1.897	1.406	1.453	2.103	2.422
2004	2458	80188	1.596	2.244	1.139	1.988	1.448	1.894	1.438	1.803	1.061	1.657
2005	3095	98980	1.659	1.594	1.271	1.945	1.412	1.364	1.631	1.635	1.415	2.109
2006	2836	83363	1.443	1.653	1.046	1.664	1.711	1.289	1.651	1.499	1.489	1.612
2007	3019	77958	1.216	1.488	0.967	1.373	1.182	1.364	1.025	1.285	1.296	1.901
2008	3418	74118	1.013	1.292	0.891	0.923	0.984	1.064	1.135	0.925	0.979	1.746
2009	3956	75123	0.825	1.274	0.745	0.891	0.911	0.999	0.809	0.756	0.750	1.418
2010	4665	72488	0.655	1.068	0.581	0.766	0.544	0.834	0.794	0.624	0.719	1.393
2011	4475	50017	0.484	0.872	0.398	0.545	0.405	0.598	0.527	0.492	0.495	0.913
2012	4920	29969	0.248	0.501	0.228	0.233	0.215	0.297	0.303	0.256	0.224	0.511
2013	6776	14497	0.082	0.175	0.078	0.083	0.097	0.100	0.120	0.076	0.097	0.183
Total	**47622**	**974595**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1.000**

4.6 Prolific Authors in Biomaterials Research

A total of 86,084 authors contributed to 47,622 papers in WoS during the period 1999-2013. The ratio of number of articles is 86,084: 47,622 or 1: 0.68. Table 7 shows the most productive (42) authors with their respective authorship score (greater than or equals to 100) in the field of Biomaterials. All the forty two most productive authors contributed on an average of 11.96% of total publications during the period. Zhang, Y. From Beijing Union Medical College, Hosp, Dept Orthopedic, Beijing (China) has the highest publications (263 publications), followed by Nakamura, T. from Hokkaido University, Faculty of Pharmaceutics Science, Lab Mol Design Pharmaceutics, Kita Ku, Sapporo, Hokkaido (Japan) has 238 Publications. It is also revealed from the study that among the top forty two authors, 15 authors belong to China, which is predominantly high compared to other countries, followed by seven authors belong to Japan, Six authors from South Korea, five authors belong to the USA and two author belongs to Portugal and Spain, one author from Netherlands, Singapore, Italy, UK and Finland respectively.

Table 7: Prolific Authors in the field of Biomaterials

Sl. No	Author	Total Publications	Name of the Institution	Country	H-Index
1	Zhang, Y.	263	Beijing Union Medical College, Hosp, Dept Orthopedic, Beijing	China	38
2	Nakamura, T.	238	Hokkaido University, Faculty of Pharmaceutics Science, Lab Mol Design Pharmaceutics, Kita Ku, Sapporo, Hokkaido	Japan	50
3	Reis, R. L.	220	University Minho, European Inst Excellence Tissue Engineering & Regenerat, Dept Polymer Engineering, Research Group Biomaterials Biodegradables & Biomimet 3Bs, Caldas Das Taipas, Guimaraes	Portugal	35
4	Jansen, J. A.	212	Radboud University Nijmegen, Med Centre, Dept Biomaterials, NL-6525 EX Nijmegen	Netherlands	44
5	Wang, Y.	201	Academy of Mil Med Science, Dept Adv Interdisciplinary Studies, Inst Basic Med Science, Beijing	China	29
6	Wang, J.	193	Peking University School & Hosp Stomatol, Dept Prosthodont, Beijing	China	26
7	Liu, Y.	192	Nanyang Technology University, School Civil & Environmental Engineering, Division of Environmental & Water Resources Engineering, Singapore	Singapore	28
8	Kokubo, T.	181	Chubu University, Dept Biomed Sci, College of Life & Hlth Sci, Kasugai, Aichi	Japan	50
9	Kaplan, D. L.	155	Tufts University, Dept Biomed Engn, Medford, MA	USA	43
10	Mikos, A. G.	148	Tufts University, Dept Biomed Engn, Medford, MA USA	USA	54
11	Zhang, X. D.	146	Sichuan University, Natl Engn Res Ctr Biomat, Chengdu,	China	23
12	Li, Y.	136	Chongqing University, Minist Educ, Key Lab Biorheol Sci & Technol, Chongqing	China	21
13	Lee, J.H.	134	Dankook University, Inst Tissue Regenerat Engn ITREN, Cheonan	South Korea	27
14	Knowles, J. C.	131	Dankook University, Grad Sch, Dept Nanobiomed Sci, Cheonan,	South Korea	35
15	Tabata, Y.	130	Kyoto University, Inst Frontier Med Sci, Dept Biomat, Kyoto	Japan	31
16	Zhang, L.	128	Tianjin University, Sch Chem Engn & Technol, Tianjin,	China	22
17	Tagami, J.	127	Tokyo Med & Dent University, Dept Restorat Sci, Bunkyo Ku, Tokyo	Japan	20
18	Chang, J.	123	Chinese Academy of Science, Shanghai Inst Ceram, State Key Lab High Performance Ceram & Superfine, Shanghai,	China	26
19	Kim, S.H.	122	Korea Institute of Science & Technology, Biomed Res Inst, Ctr Theragnosis, Seoul	South Korea	29
20	Lee, Y. K.	121	Yonsei University, Dept & Res Inst Dent Biomat & Bioengn, Coll Dent, Seoul	South Korea	18
21	Ishihara, K.	119	Univ Tokyo, School of Engineering, Dept Mat Engn, Bunkyo Ku, Tokyo	Japan	31
22	Kim, H.W.	118	Dankook Univ, Inst Tissue Regenerat Engineering ITREN, Cheonan	South Korea	34
23	Bonfield, W.	115	Ato Cap Ltd, London W1T 4TP,	UK	36
24	Li, J.	114	Chinese Academy of Science, Lanzhou Inst Chem Phys, State Key Lab Solid Lubricat, Lanzhou	China	25
25	Miyazaki, T.	114	Kyushu Inst Technol, Grad Sch Life Sci & Syst Engn, Kitakyushu, Fukuoka,	Japan	20
26	Ambrosio, L.	113	CNR, Inst Composite & Biomed Mat, I-80125 Naples	Italy	27
27	Pashley, D. H.	113	Georgia Regents University, Coll Dent Med, Dept Oral Biol, Augusta, GA	USA	35
28	Tay, F. R.	112	Georgia Regents University, Coll Dent Med, Dept Oral Biol, Augusta, GA	USA	35
29	Li, H.	111	Zhejiang University, School of Med, Affiliated Hosp 2, Dept Orthoped Surg, Hangzhou, Zhejiang	China	22
30	Li, L.	111	Harbin Engineering University, Ctr Biomed Mat & Engn, Harbin	China	16
31	Langer, R.	109	MIT, Dept Chemical Engineering, Cambridge, MA	USA	47
32	Zhuo R. X.	109	Wuhan University, Dept Chem, Minist Educ, Key Lab Biomed Polymers, Wuhan	China	25
33	Okano, T.	107	Tokyo Women's Medical University, Inst Adv Biomed Engn & Sci, TWIns, Shinjuku Ku, Tokyo	Japan	35
34	Planell, J. A.	107	Inst Bioengn Catalonia IBEC, Barcelona	Spain	29

35	Wang, W.	105	Xiamen University, Fuzhou Gen Hosp, Dept Digest Dis, Fuzhou	China	23
36	Wang, Y. J.	105	Sichuan University, West China Med School, West China Hosp, State Key Lab Biotherapy, Chengdu	China	21
37	Cui, F. Z.	104	Tsinghua University, Dept Mat Sci & Engn, State Key Lab New Ceram & Fine Proc, Beijing	China	27
38	Mano J. F.	104	University of Minho, European Inst Excellence Tissue Engn & Regenerat, Dept Polymer Engn, Res Grp Biomat Biodegradables & Biomimet 3Bs, Caldas Das Taipas, Guimaraes	Portugal	27
39	Vallet-Regi, M.	104	University of Complutense Madrid, Fac Farm, Dept Quim Inorgan & Bioinorgan, Madrid	Spain	34
40	Zhang, J.	101	Shaanxi Normal University, Coll Food Engn & Nutr Sci, Xian,	China	18
41	Kim, J. H.	100	Konkuk University, Dept Anim Biotechnol, Seoul	South Korea	21
42	Vallittu, P. K.	100	University Turku, Inst Dent, Dept Biomat Sci, FIN- Turku	Finland	22

*≥100 publications by the authors

4.7 Institutions' Productivity

Table 9 presents the list of 21 Institutions which have contributed at least ≥ 300 publications on Biomaterials during 1999 to 2013. The total publications count of top twenty one institutions is 9,298 (19.52%). Chinese Academy of Science, Zhejiang (China) has the highest publications (974) among the different institutions, followed by Kyoto University, Kyoto (Japan) has 654 publications, Seoul National University, Seoul (South Korea) with 614 publications, National University of Singapore, Singapore with 578 publications and Sichuan University, Sichuan (China) with 577 publications ranked second to fifth respectively. The study reveals that the institutions from China dominate among the other institutions (5 institutions) considered for the study, followed by four institutions from Japan, four institutions from USA, two institutions from Singapore, one institution from South Korea, Taiwan, Brazil and Portugal respectively appeared in the list of top twenty one institutions in the field of Biomaterials.

Table 9: Institutions Productivity

Sl. No	Name of the Institution	Country	Total Publications	Total Citations	H-index
1	Chinese Academy of Sciences, Beijing	China	974	17,150	60
2	Kyoto University, Kyoto	Japan	654	16,516	66
3	Seoul National University, Seoul	South Korea	614	14,348	57
4	National University of Singapore, Singapore	Singapore	578	25,013	79
5	Sichuan University, Sichuan	China	577	7,289	40
6	Tokyo Medical Dental University, Tokyo	Japan	521	8,744	48
7	Harvard University, Cambridge	USA	463	16,052	64
8	Zhejiang University, Zhejiang	China	463	8,841	46
9	Massachusetts Institute of Technology, Cambridge	USA	397	16,931	68
10	Nanyang Technological University , Nanyang Ave	Singapore	391	6,979	44
11	National Taiwan University, Taipei City	Taiwan	384	5,934	38
12	Shanghai Jiao Tong University, Shanghai	China	380	5,112	35

13	University of Toronto, Toronto	Canada	375	9,846	52
14	University of Washington, Washington	USA	336	10,700	56
15	University College London, London	UK	329	7,771	47
16	University of Michigan, Ann Arbor	USA	317	16,522	66
17	Hokkaido University, Hokkaido	Japan	313	6,931	43
18	Universidade De Sao Paulo, Sao Paulo	Brazil	312	4,820	36
19	Universidade Do Minho, Braga	Portugal	311	6,601	39
20	Osaka University, Osaka Prefecture	Japan	306	4,277	32
21	Wuhan University, Wuhan, Hubei	China	303	4,907	35
			9298		

*≥ 300 and above publications

4.8 Preferred Sources of Publications

The distribution of Biomaterials publications were spread over 51 sources of publications. The table10 shows top nineteen journals which have produced 1% or more than 1% of total publications during the period 1999 to 2013. The Journal, *Biomaterials* (UK) has 9923 publications and topped the list, followed by *Journal of Biomedical Materials Research Part A* (USA) with 4504 publications, *Colloids and Surfaces B Biointerfaces* (Netherlands) with 4486 publications, *Journal of Materials Science Materials In Medicine* (Netherlands) with 3554 publications and *ACTA biomaterialia* (UK) with 2821 publications topped the list and ranked second to fifth respectively. The study also reveals that among the top nineteen sources of publications, eight journals are published form UK, Five from Netharlands, Three from USA and one from Germany, Switzerland, Japan respectively in the list.

Table 10: Preferred Sources of Publications

Sl. No	Source Title	Country	Total Publications	Percentage
1	*Biomaterials*	UK	9923	20.867
2	*Journal of Biomedical Materials Research Part A*	USA	4504	9.472
3	*Colloids and Surfaces B Biointerfaces*	Netharlands	4486	9.434
4	*Journal of Materials Science Materials In Medicine*	Netharlands	3544	7.453
5	*ACTA Biomaterialia*	UK	2821	5.932
6	*Journal of Biomedical Materials Research Part B Applied Biomaterials*	USA	2479	5.213
7	*Dental Materials*	UK	2177	4.578
8	*Journal of Biomaterials Science Polymer Edition*	UK	1686	3.546
9	*Journal of Biomedical Materials Research*	USA	1641	3.451
10	*Materials Science Engineering C Materials For Biological Applications*	Netharlands	1625	3.417
11	*Macromolecular Bioscience*	Germany	1583	3.329
12	*Key Engineering Materials*	Switzerland	1509	3.173

13	*Dental Materials Journal*	Japan	1224	2.574
14	*Journal of the Mechanical Behavior of Biomedical Materials*	Netharlands	904	1.901
15	*Journal of Materials Chemistry B*	UK	717	1.508
16	*Biomedical Materials*	UK	664	1.396
17	*Bio Medical Materials and Engineering*	Netharlands	654	1.375
18	*Journal of Bioactive and Compatible Polymers*	UK	556	1.169
19	*Journal of Biomaterials Applications*	UK	529	1.112

(≥ 1% of Total Publications)

5. CONCLUSION

Among the different countries, USA topped the list with 12,025 publications and its share is 25.251 % of the total publications with the h-Index of 184 (which is highest among the countries) in the field of Biomaterials. Though the publications output of some countries are less but their ACP is high compared to that of top countries producing number of publications. The older publications received more citations than the publications published recently.

It is also revealed from the study that among the top forty two authors, fifteen authors belong to China, which is predominantly high compared to other countries. Chinese Academy of Science, Zhejiang (China) has the highest publications (974) among the different organizations, followed by Kyoto University, Kyoto (Japan) with 654 publications.

The study reveals that the Institutions from China dominate among the other institutions (5 institutions) considered for the study, followed by four institutions from Japan, three institutions from USA, two institutions from Singapore and UK respectively appeared in the list of top twenty one Institutions.

Biomaterials (UK) has 9923 publications and topped the list among the different sources, followed by *Journal of Biomedical Materials Research Part A* (USA) with 4504 publications, *Colloids and Surfaces Biointerfaces* (Netherlands) with 4486 publications ranked second to third respectively.

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