



## Original article

## Mapping of stem cell research in India during 2009–2014: A bibliometric analysis

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## ABSTRACT

**Introduction:** Stem cell is a miracle for treatment of all diseases including anomalies for its multi-potency nature of cell differentiation. There are several articles published on stem cell research and its applications. In this study, we analyze the stem cell research articles from January 2009 to December 2014, indexed in Scopus database.

**Aim:** To find out the status and number of published stem cell articles with bibliometric analysis indexed in the Scopus database in Indian scenario.

**Material and methods:** In this retrospective study, the number of publications on stem cell research, citation, distributions of journals of Scopus database were analyzed. Bibliometric indicators including total articles, independent articles, collaborative articles, first author articles and corresponding author articles were analyzed to compare publications between different countries and organizations. All the data and information were retrieved from the Scopusdata base on 27 October 2015 for a period of 2009 to 2014.

**Results and discussion:** The number of articles on stem cell research increased year by year from 2009 to 2014. Similarly, from total articles, the number of original articles is more as compared to other articles. It is found that the articles from the medicine subjects are more than the other subjects. A total number of 221 publications are cited by numerous authors in the field of stem cell. It is found that the Indian authors published these documents with the collaboration of other authors staying abroad. According to our study, *Cell Adhesion and Migration* journal published more articles in comparison to other journals. The impact of top articles changed from year to year.

**Conclusions:** The comprehensive analysis of highly cited articles in the stem cell field could identify milestones and important contributors, giving a historic perspective on scientific progress.

## 1. INTRODUCTION

Research on stem cell is a biomedical field of great expectations. It was 1949 when scientist John Hammond discovered the method to maintain mouse embryos in culture *in vitro*. Since, research with stem cells has developed to the point where it holds very hopeful perspectives for the treatment of thus far incurable diseases. At present, research is mainly oriented towards developing new therapies for hematological, cardiovascular, neurodegenerative and genetic diseases, as well as cancer and diabetes, among others.<sup>1–4</sup> Its intrinsic nature makes stem cell research transcend to other fields as diverse as politics, ethics, culture, and law, placing it in the arena of social controversy. The use of bibliometric studies to comprehend and analyze scientific domains,<sup>5</sup> together with the development and fine tuning of new techniques and tools, facilitates decision-making in areas of scientific policy and reflects the ‘state of the art’ of research at a given time. These processes, necessary for the evaluation of science<sup>6,7</sup> are a responsibility that no country can elude<sup>8</sup> the evident connections between advancement through research activity, economic growth, progress and the enhanced well-being of society.<sup>9</sup> The number of scientific disciplines interrelated by stem cell research lends it an interesting yet complicated characters.<sup>10</sup> Its interdisciplinarity presents a great challenge when delimiting and analyzing its thematic composition, demanding a very precise analysis. Precisely to face this challenge, bibliometrics has complementary tools that more recently include social network analysis<sup>11</sup> and the visualization of scientific domains.<sup>12–14</sup>

When searching for reliable information, studies of this nature have traditionally used bibliographic databases as the most usual source.<sup>15</sup> As it is not designed for this purpose, the information they offer has demonstrated its bibliometric potential. However, they present limitations when resolving specific matters, for example the precise definition and delimitation of a topic. It is therefore essential to reveal the semantic structure established among documents by means of the bibliographic information contained in a database.

## 2. AIM

To find out the status and number of published stem cell articles with bibliometric analysis indexed in Scopus database in Indian scenario.

## 3. MATERIAL AND METHODS

Data used in this retrospective study were retrieved from the Scopus database on 27 October 2015 for a period of 2009 to 2014. The database was searched under the keywords ‘stem cell,’ ‘pluripotency’ and ‘totipotency’ in terms of topic (title, abstract, author keywords, and Key Words Plus) within the publication year with a limit of 2009 to 2014. Key

Words Plus supplied additional search terms extracted from the titles of articles cited by authors in their bibliographies, database and substantially augmented title word and author keyword indexing.<sup>16</sup> Non-article-type documents such as reviews, meeting abstracts, editorial materials, proceeding papers, letters, book chapters, news items, corrections and notes were also included. The final filter was the front page, in which only the articles having the search keywords in their first page including article title, abstract, and author keywords were retained.<sup>17</sup> The number of citations of an article in a single year, for example 2012, was referred to as the C2012 and the total number of citations since publication up to 2012 was referred to as the TC2012.<sup>18–19</sup> The collaboration type was determined by the address of the authors. Collaboration could be classified as either a single-country article, in which all authors’ address were from the same country, or an international collaborative article, which was co-authored by researchers from multiple countries.<sup>20</sup> The records were downloaded and reorganized using Microsoft Excel 2010. In the Scopus database, the corresponding author was designated as the ‘reprint’ author; this study instead used the term ‘corresponding author.’ In a single author article where authorship was unspecified, the single author was both first author and corresponding author. Similarly, for a single institution article, the institution was classified as the first author’s institution and the corresponding author’s institution.

## 4. RESULTS

After retrieving the data i.e. numbers of articles published in the field of stem cell were documented from the year 2009 to 2014. It is revealed from the analysis that in each year the articles on stem cell research were published and the maximum numbers of articles are published particularly in the year 2013. It is documented in the Table 1. In total 221 numbers of articles were published during the studied period. The average growth percentage of the published documents is 20.79 (Table 1).

It is observed that documents on stem cell research were 7 types (Table 2). Among the 7 varieties of articles the original article i.e. full length articles were 186 (Table 2). It is

**Table 1. Year wise distribution of published documents.**

| Year  | Number of documents | Percentage | Growth percentage                 |
|-------|---------------------|------------|-----------------------------------|
| 2009  | 19                  | 8.61%      |                                   |
| 2010  | 30                  | 13.57%     | 57.89%                            |
| 2011  | 33                  | 14.93%     | 9.09%                             |
| 2012  | 44                  | 19.91%     | 33.33%                            |
| 2013  | 50                  | 22.62%     | 13.64%                            |
| 2014  | 45                  | 20.36%     | –10.00%                           |
| Total | 221                 | 100        | Average growth percentage = 20.79 |

**Table 2. Different types of published documents.**

| Type             | Number of documents | Percentage |
|------------------|---------------------|------------|
| Article          | 186                 | 84.06%     |
| Review           | 29                  | 13.12%     |
| Conference paper | 2                   | 0.91%      |
| Book chapter     | 1                   | 0.45%      |
| Article in press | 1                   | 0.45%      |
| Letter           | 1                   | 0.45%      |
| Short survey     | 1                   | 0.45%      |
| Total            | 221                 | 99.99%     |

**Table 3. Distribution of documents into different subjects.**

| Subject  | Number of documents |
|--|---------------------|
| Medicine   | 143                 |
| Biochemistry, genetics and molecular biology                               | 136                 |
| Engineering  | 27                  |
| Materials science  | 17                  |
| Pharmacology, toxicology and pharmaceuticals                               | 16                  |
| Agricultural and biological sciences                                       | 14                  |
| Chemical engineering   | 14                  |
| Neuroscience   | 13                  |
| Immunology and microbiology  | 9                   |
| Chemistry  | 4                   |
| Physics and astronomy  | 3                   |
| Veterinary   | 3                   |
| Nursing and social sciences  | 2                   |
| Dentistry, Environmental Science, Health Professions and Multidisciplinary | 1                   |

revealed that the original articles are 84% and rest articles are 16% (Table 2). The documents are from different area of the science. There are 143 articles published from the field of medicine, which is the highest number from the other area. Whereas, it is found that only 1 document is published in each field of dentistry, environmental science, health profession and multidisciplinary (Table 3). Different articles are cited with number of publications. In our study, it is revealed that 1 article is cited 121 times whereas 47 articles have no citations (Table 4). All articles are published by the Indian researchers but few researchers from other countries are also collaborative authors. Among the collaborative authors, USA was the highest number of publications i.e. 23 (Table 5). All these Indian research papers on stem cell are published through different sources. *Cell Adhesion and Migration* is the highest preferred journal with more than 48% of publications and *PLOS ONE* is in the second position with 12 nos of publications, where as 20 journals having 2 publications each (Table 6). There are many Indian

**Table 4. Indian research papers cited by other authors.**

| Number of articles | Frequency of citation | Number of articles           | Frequency of citation |
|--------------------|-----------------------|------------------------------|-----------------------|
| 47                 | 0                     | 3                            | 26                    |
| 23                 | 1                     | 1                            | 27                    |
| 17                 | 2                     | 4                            | 28                    |
| 16                 | 3                     | 2                            | 31                    |
| 13                 | 4                     | 1                            | 33                    |
| 10                 | 5                     | 2                            | 34                    |
| 9                  | 6                     | 1                            | 36                    |
| 5                  | 7                     | 1                            | 37                    |
| 11                 | 8                     | 1                            | 38                    |
| 6                  | 9                     | 1                            | 41                    |
| 3                  | 10                    | 1                            | 48                    |
| 3                  | 11                    | 1                            | 51                    |
| 6                  | 12                    | 1                            | 53                    |
| 6                  | 13                    | 1                            | 54                    |
| 2                  | 14                    | 1                            | 55                    |
| 1                  | 15                    | 1                            | 56                    |
| 3                  | 16                    | 1                            | 58                    |
| 2                  | 17                    | 1                            | 61                    |
| 1                  | 19                    | 1                            | 63                    |
| 2                  | 20                    | 1                            | 94                    |
| 1                  | 21                    | 1                            | 114                   |
| 3                  | 22                    | 1                            | 121                   |
| 2                  | 25                    | Total no. of documents = 221 |                       |

**Table 5. Geographical distribution of authors.**

| Name of the country  | Number of authors |
|--|-------------------|
| India  | 221               |
| USA  | 23                |
| Malaysia   | 9                 |
| South Korea  | 5                 |
| Germany  | 4                 |
| Singapore  | 4                 |
| Australia, Denmark and Saudi Arabia                                    | 3                 |
| Japan, Mexico and Spain  | 2                 |
| Belgium, Canada, Iran, Italy, Slovenia, Switzerland and United Kingdom | 1                 |

researchers publish 221 papers in different journals. Among them Mohanty occupies the top position with 11 nos of publications to his credit. Gupta, Verma and Bhone are combine in second position with 10 numbers of publications to justify their performance and 13 researchers have 1 document each (Table 7).

**Table 6. Documents published in different sources.**

| Name of the source   | Number of documents | Cumulative number of documents | Percentage | Cumulative percentage |
|--|---------------------|--------------------------------|------------|-----------------------|
| PLOS ONE   | 12                  | 12                             | 5.42%      | 5.42%                 |
| Stem Cells and Development   | 8                   | 20                             | 3.61%      | 9.03%                 |
| Cytherapy  | 7                   | 27                             | 3.16%      | 12.19%                |
| Cell and Tissue Research   | 7                   | 34                             | 3.16%      | 15.35%                |
| Stem Cell Research and Therapy                                       | 4                   | 38                             | 1.80%      | 17.15%                |
| BMJ Case Reports   | 4                   | 42                             | 1.80%      | 18.95%                |
| Neurology India  | 4                   | 46                             | 1.80%      | 20.75%                |
| Cell Biology International   | 4                   | 50                             | 1.80%      | 22.55%                |
| Cytotechnology   | 3                   | 53                             | 1.36%      | 23.91%                |
| Cell Transplantation   | 3                   | 56                             | 1.36%      | 25.27%                |
| Biochemical and Biophysical Research Communications                  | 3                   | 59                             | 1.36%      | 26.63%                |
| International Journal of Stem Cells                                  | 3                   | 62                             | 1.36%      | 27.99%                |
| International Wound Journal  | 3                   | 65                             | 1.36%      | 29.35%                |
| Journal of Stem Cells  | 3                   | 68                             | 1.36%      | 30.71%                |
| Stem Cells International   | 3                   | 71                             | 1.36%      | 32.07%                |
| Trends in Biomaterials and Artificial Organs                         | 3                   | 74                             | 1.36%      | 33.43%                |
| Hepatology International   | 2                   | 76                             | 0.91%      | 34.34%                |
| Cancer Research  | 2                   | 78                             | 0.91%      | 35.25%                |
| Human Cell   | 2                   | 80                             | 0.91%      | 36.16%                |
| International Journal of Pharmacy and Technology                     | 2                   | 82                             | 0.91%      | 37.07%                |
| Cell Biochemistry and Function                                       | 2                   | 84                             | 0.91%      | 37.98%                |
| Cell Proliferation   | 2                   | 86                             | 0.91%      | 38.89%                |
| International Journal of Pharmaceutical Sciences Review and Research | 2                   | 88                             | 0.91%      | 39.80%                |
| Journal of Tissue Engineering and Regenerative Medicine              | 2                   | 90                             | 0.91%      | 40.71%                |
| Journal of Translational Medicine                                    | 2                   | 92                             | 0.91%      | 41.62%                |
| Journal of the Indian Medical Association                            | 2                   | 94                             | 0.91%      | 42.53%                |
| Nanomedicine   | 2                   | 96                             | 0.91%      | 43.44%                |
| Current Stem Cell Research and Therapy                               | 2                   | 98                             | 0.91%      | 44.35%                |
| Phytomedicine  | 2                   | 100                            | 0.91%      | 45.26%                |
| Biomedical Journal   | 2                   | 102                            | 0.91%      | 46.17%                |
| Research Journal of Pharmaceutical Biological and Chemical Sciences  | 2                   | 104                            | 0.91%      | 47.08%                |
| Biomaterials   | 2                   | 106                            | 0.91%      | 47.99%                |
| Journal of Cellular Biochemistry                                     | 2                   | 108                            | 0.91%      | 48.90%                |
| Stem Cells and Cloning Advances and Applications                     | 2                   | 110                            | 0.91%      | 49.81%                |
| International Journal of Pharmacy and Bio Sciences                   | 2                   | 112                            | 0.91%      | 50.72%                |
| Journal of Stem Cells and Regenerative Medicine                      | 2                   | 114                            | 0.91%      | 51.63%                |
| Cell Adhesion and Migration  | 107                 | 221                            | 48.40%     | 100%                  |

**Table 7. Number of documents produced by each author.**

| Cumulative percentage | Number of documents | Name of the author | Number of documents |
|-----------------------|---------------------|--------------------|---------------------|
|                       | 11                  | Bajaj M            | 2                   |
|                       | 10                  | Dhanasekaran M     | 2                   |
|                       | 10                  | Hardikar AA        | 2                   |
|                       | 10                  | Balaraju S         | 2                   |
|                       | 9                   | Mandal BB          | 2                   |
|                       | 9                   | Dixit A            | 2                   |
|                       | 8                   | Mohapatra PC       | 2                   |
|                       | 8                   | Chullikana A       | 2                   |
|                       | 7                   | Murthy TVRK        | 2                   |
|                       | 7                   | Lissa RP           | 2                   |
|                       | 7                   | Nath A             | 2                   |
|                       | 7                   | Pande G            | 2                   |
|                       | 7                   | Panilaitis B       | 2                   |
|                       | 7                   | Paspala SAB        | 2                   |
|                       | 5                   | Phadnis SM         | 2                   |
|                       | 5                   | Poliseti N         | 2                   |
|                       | 5                   | Poojitha R         | 2                   |
|                       | 5                   | Das B              | 2                   |
|                       | 5                   | Chopra G           | 2                   |
|                       | 5                   | Prasad K           | 2                   |
|                       | 5                   | Kirkland MA        | 2                   |
|                       | 5                   | Rallapalli S       | 2                   |
|                       | 5                   | Ramakrishna S      | 2                   |
|                       | 4                   | Ramakrishnan M     | 2                   |
|                       | 4                   | Ramesh T           | 2                   |
|                       | 4                   | Routray P          | 2                   |
|                       | 4                   | Roy P              | 2                   |
|                       | 4                   | Roy S              | 2                   |
|                       | 4                   | Sachdeva N         | 2                   |
|                       | 4                   | Sangeetha VM       | 2                   |
|                       | 4                   | Chelluri LK        | 2                   |
|                       | 4                   | Sarkar C           | 2                   |
|                       | 4                   | Seetharam RN       | 2                   |
|                       | 4                   | Kumar A            | 2                   |
|                       | 4                   | Bhansali A         | 2                   |
|                       | 4                   | Jindal N           | 2                   |
|                       | 4                   | Sharma MC          | 2                   |
|                       | 4                   | Sharma RR          | 2                   |
|                       | 4                   | Singh R            | 2                   |
|                       | 4                   | Bhartiya D         | 2                   |
|                       | 4                   | Srivastava A       | 2                   |
|                       | 3                   | Srivastava S       | 2                   |
|                       | 3                   | Airan B            | 2                   |
|                       | 3                   | Suri A             | 2                   |
|                       | 3                   | Suri V             | 2                   |
|                       | 3                   | Surolia A          | 2                   |
|                       | 3                   | Mathapati S        | 2                   |
|                       | 3                   | Kumar SR           | 2                   |
|                       | 3                   | Hinge A            | 2                   |
|                       | 3                   | Thej C             | 2                   |

**Table 7. No of documents produced by each author.**

| Cumulative percentage | Number of documents | Name of the author | Number of documents |
|-----------------------|---------------------|--------------------|---------------------|
| Al-Nbaheen M          | 3                   | Thrichelvam ST     | 2                   |
| Aldahmash A           | 3                   | Tiwari A           | 2                   |
| Gangenhalli G         | 3                   | Dubey PK           | 2                   |
| Gokulchandran N       | 3                   | Mathew SA          | 2                   |
| Chandra T             | 3                   | Jacob VC           | 2                   |
| Pal R                 | 3                   | Bansal A           | 2                   |
| Bhonde RR             | 3                   | Kumar AA           | 2                   |
| Pereira JA            | 3                   | Vemuganti GK       | 2                   |
| Kinjavdekar P         | 3                   | Maiwall R          | 2                   |
| Kulkarni P            | 3                   | Mishra R           | 2                   |
| Potdar PD             | 3                   | Gottipamula S      | 2                   |
| Seth T                | 3                   | Vidyasekar P       | 2                   |
| Sharma A              | 3                   | Gupta V            | 2                   |
| Sharma M              | 3                   | Viswanathan C      | 2                   |
| Dutta RK              | 3                   | Walia R            | 2                   |
| Basak P               | 3                   | Yadav PK           | 2                   |
| Taru Sharma G         | 3                   | Sarang S           | 2                   |
| Chaudhuri S           | 3                   | Bhaskaran S        | 1                   |
| Chatterjee S          | 3                   | Bhatia A           | 1                   |
| Behari M              | 3                   | Bhatia R           | 1                   |
| Vishnubalaji R        | 3                   | Bhatnagar S        | 1                   |
| Ghaskadbi SM          | 2                   | Bhattacharya AK    | 1                   |
| Kanmani A             | 2                   | Bhuvanlakshmi GB   | 1                   |
| Kannan S              | 2                   | Biju H             | 1                   |
| Gil ES                | 2                   | Binas B            | 1                   |
| Habeeb MA             | 2                   | Boccaccini AR      | 1                   |
| Kaplan DL             | 2                   | Bodakhe S          | 1                   |
| Badhe P               | 2                   | Bokara KK          | 1                   |
| Campos-Neto A         | 2                   | Borena BM          | 1                   |
| Jain KG               | 2                   | Boroujeni ME       | 1                   |

## 5. DISCUSSION

In 2000, the Japanese government released a report that had been on hold for a longer period of time. The report endorsed the use of human stem cells in research-work.<sup>21</sup> The draft report outlined a process for both publicly and privately funded scientists to follow in deriving and working with stem cells. However, the number of stem cell research collaboration in the UK and USA has not been affected by the different national stem cell policies or regulatory mechanisms that motivate international stem cell research including other countries with which the USA and UK are most often collaborated.<sup>22</sup>

Professor Shinya Yamanaka of Kyoto University of Japan and the Gladstone Institutes, USA received the Nobel Prize in physiology or medicine in 2012 for the discovery that mature cells can be reprogrammed to become pluripotent. In addition, Yamanaka has published 57 pluripotent stem cell ar-

ticles of which 4 articles ranked in the top 10 for TC2012 and C2012, respectively, including the top ranked article entitled Induction of pluripotent stem cells from mouse embryonic and adult fibroblast cultures by defined factors<sup>23</sup> and second ranked article entitled Induction of pluripotent stem cells from adult human fibroblasts by defined factors.<sup>24</sup> A steep slope could be found with these two distinguished patterns of citations per year. It has been noticed that in the highest percentile, the top 0.1% of authors, a significant percentage have won the Nobel Prize or eventually proceeded to win the award in later years.<sup>25</sup> Nobel Prizes are the gold standard of quality in scientific achievement in the fields where they are given.<sup>26</sup> Furthermore, a high correlation between the bibliometric indicators and the number of Nobel Prize achievements was found in peace, economics, chemistry, medicine/physiology and physics.<sup>27,28</sup> This bibliometric investigation of articles on pluripotent stem cell-related research has revealed some interesting findings. In total, 221 articles were published in Scopus indexed journal of 2009–2014 with keyword ‘stem cell,’ ‘pluripotent’ and ‘totipotency.’ Articles were published in 37 journal categories in the science edition till 2014. *Stem Cells* and *PLOS ONE* were the most common journals in pluripotent stem cell research. There was a sharp increase in articles annually after 2012. Articles without the required search words on their front page could be still found in Scopus which is designed for researchers to find literature but not for bibliometric study. The citation lives of the top articles in total citations as well as in publication year and recent year showed that the impact of top articles in a research field might alter according to novelty and not only time. In general, the so-called ‘classic’ articles had low citations in their publication year. The countries like G7 (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States) were part of the top ten countries in terms of publication. It was noted that the USA, as a country, contributed the most independent and internationally collaborative articles, as well as the most first and corresponding author articles. Institutionally, Harvard University published the most inter-institutional articles and overall articles, while Kyoto University published the most first and corresponding author articles. The papers of the Nobel Prize winner in 2012, Prof. Shinya Yamanaka, who published four articles ranked among the top ten in terms of total citations and citations in the most recent year, have followed a distinguished pattern with steep slopes indicating rapidly increasing citation counts. Studies on induced pluripotent stem cells and embryonic stem cells have been found to be the most popular research focus in recent years in pluripotent stem cell research. As seen by the popularity of stem cell research in various countries and the acknowledgment of the potential of pluripotent stem cells to aid in patient specific therapies in our ever increasing elderly population, regenerative medicine will continue to progress with the advent of new research findings. With utologous hematopoietic stem cell transplantation, the palifermin decreased the incidence of severe oral mucositis (grade 3–4 WHO) by 19% (44% vs. 63%), however it did not contribute to the du-



ration of oral mucositis and total parenteral nutrition use. There were no differences in opioid use, incidence of fever of unknown origin, severe infection, engraftment and gastrointestinal hemorrhage between groups. Five-year overall survival was better in patients treated with palifermin. Only in one patient generalized, itching rash was observed after palifermin administration.<sup>29</sup> In another study, it was revealed that the divergences are attributed to differences in cell preparations, the large number of stem cell types under investigation in different clinical settings, timing, methods of cell administration and characteristics of patients.<sup>30</sup>

## 6. CONCLUSIONS

The impact of top articles changed from year to year with their citation. Top cited articles in previous publication years were not the same as recent years. ‘Induced pluripotent stem cell(s)’ and ‘embryonic stem cell(s)’ were the most used author keywords in stem cell research. In addition, the winner of the Nobel Prize in physiology or medicine in 2012, Prof. Shinya Yamanaka, published four of the top ten most frequently cited articles.

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