A Bibliometric Analysis and Visualisation of Research Trends in Corrosion of Titanium Implants

Raman Kumar[a]

[a] Department of Mechanical Engineering, Chandigarh University, Gharuan, Punjab, India. 140413

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Abstract: Corrosion of medical implants is a serious issue in the medical sector. The bibliometric analysis had been conducted to understand the active authors, organizations, journals, and countries involved in the research domain of "corrosion of Titanium implants". All published articles related to "corrosion of Titanium implants" from "Scopus", were analyzed using the VOS viewer to develop analysis tables and visualization maps. This article had set the objective to consolidate the scientific literature regarding "corrosion of Titanium implants" and also to find out the trends related to the same. The most active journals in this research domain were Material Science and Engineering C and Biomaterials. The most active country was the United States of America. The leading organizations engaged in the research regarding the Corrosion of Titanium implants were the Sao Paulo State University of Brazil. The most active authors who had made valuable contributions related to corrosion of Titanium implants were Jacob J.J and Zhang X.

Keywords: Titanium-implants, Corrosion, Material engineering, Bibliometric analysis, VOS viewer,

1. Introduction

Medical implants are manmade medical devices for replacing missing or damaged biological structures. Most of the innovations and advances in material engineering and surface engineering play a key role in developing modern implants (Ralls et al., 2020). Various types of implants had been used in modern medicine and include sensory implants, neurological implants, cardiovascular implants, orthopedic implants, contraceptive implants, and cosmetic implants. Some latest developments related to implants include bioactive glass/ bioglass coating, surface texturing, and additive manufacturing to improve the quality, life, and performance of implants (Singha, Singh and Sidhu, 2020).

Different types of metals and materials are used to create implants and the most popularly used metals and alloys for bio-implants are stainless steel, cobalt-chromium alloy, and Titanium (Novikova, 2011) (Priyanka et al., 2014). Corrosion of material of implants is a major challenge in implantation(Shaw, 2008). The major remedial measures against corrosion of implants are to bulk alloy stainless steel with Titanium and Nitrogen; bioceramic coating etc(Kamachimudali, Sridhar and Raj, 2003). The issue of corrosion of bio-implants (made of uncoated stainless steel) due to simulated body fluids of the human body is an important issue addressed in all bio implantations and Titanium Nitride coating by using physical vapor deposition method was found effective against corrosion of implantations (Iqbal et al., 2013).

There are several methods to defend corrosion of Titanium-based implants, modifying Titanium implant by electro-polymerized of 4-allyl-2-methoxyphenol (Eugenol) using direct current lower than 3.5 volts (AlMashhadani and Saleh, 2020); electrochemical deposition of hydroxyapatite post-anodizing (Almashhadani and Saleh, 2019); Plasma-sprayed, reinforced coating for improved corrosion resistance and surface Properties of Titanium-based Implants (Bansal, Singh and Sidhu, 2021); zeolite coatings against corrosion of titanium alloy biomedical implants (Bedi et al., 2009); usage of Chemical Mechanical Surface Nano-Structuring (CMNS) implementation on Titanium Based Implants (Beers, Sur and Basim, 2020); Corrosion Resistance of Boron Nitride Coated Titanium Dental Implants (Çakal et al., 2019); sol-gel coating on Titanium implants (Catauro et al., 2014);

This bibliometric analysis will be a useful platform for future researchers by realizing the top researchers, organizations, and countries involved in research regarding the corrosion of bio-implants. This article is arranged into four sections. The first section is the introduction, followed by the discussion of the methodology by which the research was conducted. The third section deals with results and discussion. The fourth section deals with the conclusion. The following research objectives and research questions were framed for conducting bibliometric analysis systematically.

1.1 Research Objectives

a) To consolidate the literature regarding corrosion of Titanium implants
b) To find out the trends related to research in corrosion of Titanium implants

1.2 Research Questions

a) Who are the active researchers working on the corrosion of Titanium implants?

b) Which are the main organizations and countries working on the corrosion of Titanium implants?
c) Which are the main journals related to corrosion of Titanium implants?

2. Research Methodology

Scopus files had been used for this article. For the article selection, the Boolean used was TITLE-ABS (Titanium implant corrosion) on 04/03/2021. All the tables in this paper were created by using Microsoft Excel and VOS Viewer. Grammarly was used for spelling and grammar checks. Mendeley was used for article review and citation. This paper had been inspired by bibliometric analysis in its presentation style, analysis, and methodology from the works (Farhat et al., 2013; Liao et al., 2016; Kolkailah et al., 2019; Rodríguez-Padial et al., 2019; Tran et al., 2019; Ullah et al., 2019; Shahid et al., 2020).

3. Results and discussion

3.1 Results

This first round of search produced an outcome of 2118 documents, in nineteen languages, out of which 1193 documents were in English. The classification of document categories is shown in Figure 1. For improving the quality of the analysis, we had selected only the peer-reviewed articles and all other documents had not been considered. Thus after using filters "Article" and "English" the second round search produced an outcome of 1405 English articles (both open access and others) and had been used to conduct bibliometric analysis and visualization using VOS Viewer. The English research articles in this domain since 1964 had been shown in Figure 2.

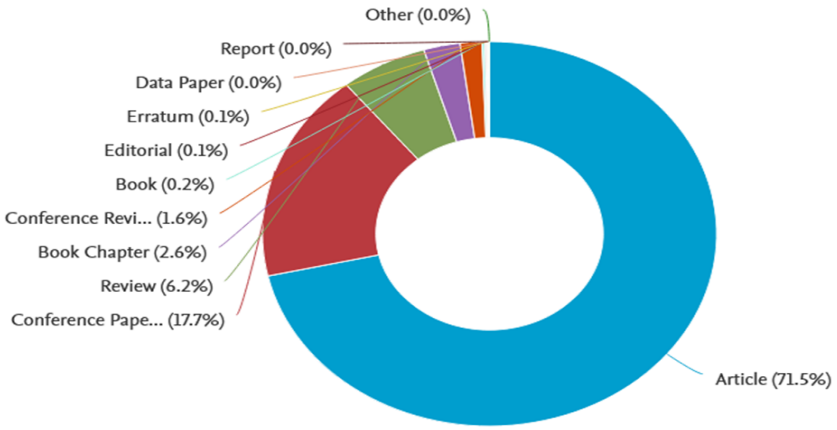

Figure 1: Classification of the documents on "Corrosion of Titanium implants", Source: www.scopus.com

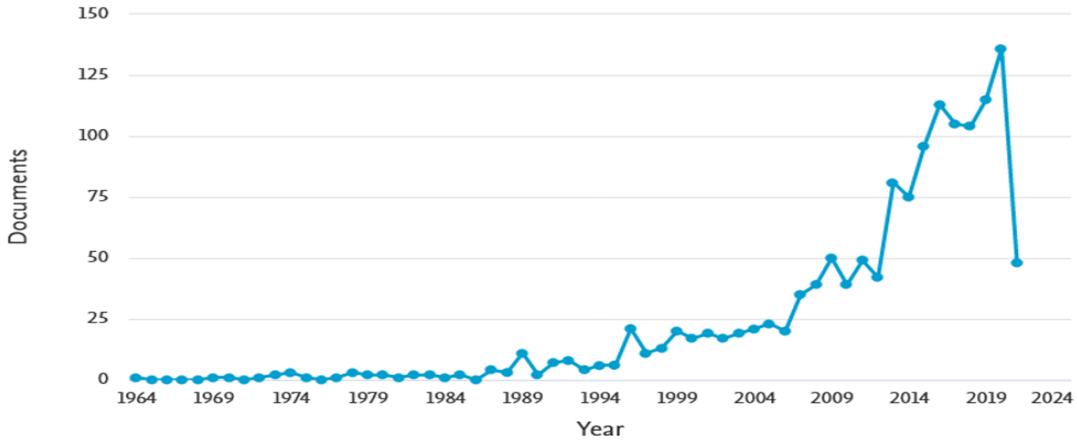

Figure 2: Period wise publication of articles, Source: WWW.scopus.com

Co-authorship analysis of top authors had been shown in figure 3. For a better presentation of the analysis, the parameters used were the minimum number of documents of an author as nine and the minimum number of citations of authors as one. This combination plotted the map of 31 authors, in seven clusters. The overlay visualization map of co-authorship analysis plotted in Figure 3, points out the major researchers with their strong co-authorship linkages and clusters involved.

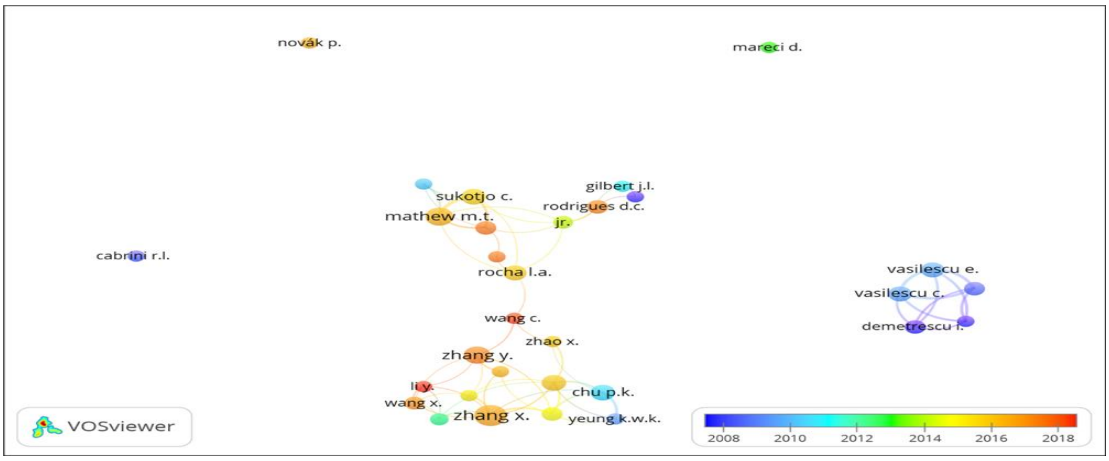

Figure 3: Co-authorship analysis on basis of authors

The citation analysis of top authors had been shown in table 1, along with co-authorship links. For the citation analysis, the parameters used were the minimum number of documents of an author as one and the minimum citations of an author as one.

Table 1: Highlights of most active authors

Description	Authors	Documents	Citations	Average citations per documents	Link strength
Authors with the highest publication and co-authorship links	Zhang X.	31	1042	33.6	199
Authors with the highest citations	Jacobs J.J	09	2144	238.2	31

In Co-occurrence analysis, we had used all keyword analyses, by keeping the minimum number of occurrences of a keyword as 100. This combination plotted the map of 43 thresholds, in two clusters. The overlay visualization of co-occurrence analysis of keywords has been shown in Figure 4.

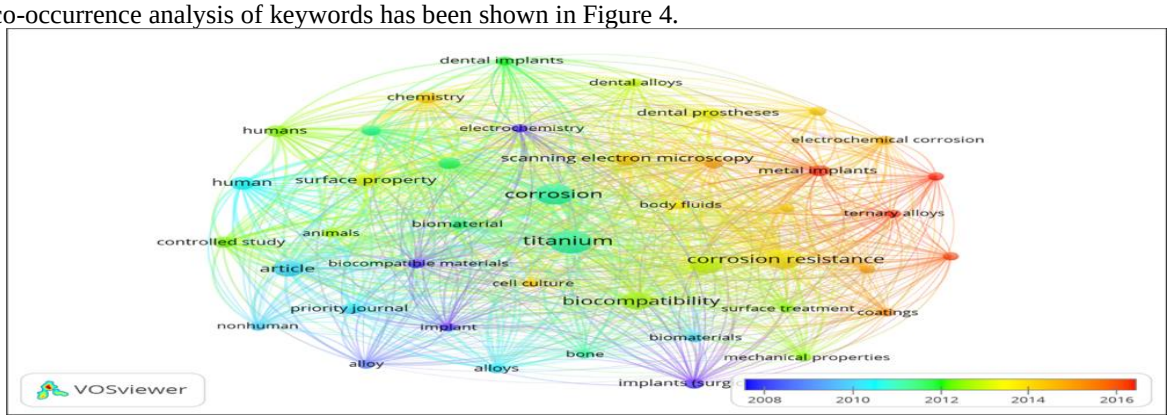

Figure 4: Co-occurrence analysis on basis of all keywords

The leading organizations engaged in research on “Corrosion of Titanium implants” had been found out by the volume of publications and citation analysis, the parameters used are the minimum number of documents of an organization as one and the minimum number of citations of organizations as one. The leading organization in the research regarding “Corrosion of Titanium implants”, with the highest number of publications and citations, was the Sao Paulo State University of Brazil. (Refer to table 2).

Table 2: Highlights of the most active organization

Organizations	Country	Documents	Citations	Average Citations per document
Sao Paulo State University	Brazil	52	1049	20.1

Co-authorship analysis of the countries engaged in the research on "Corrosion of Titanium implants" had been shown in Figure 5. The overlay visualization map of co-authorship analysis plotted in Figure 5, points out the main countries with their strong co-authorship linkages and clusters involved.

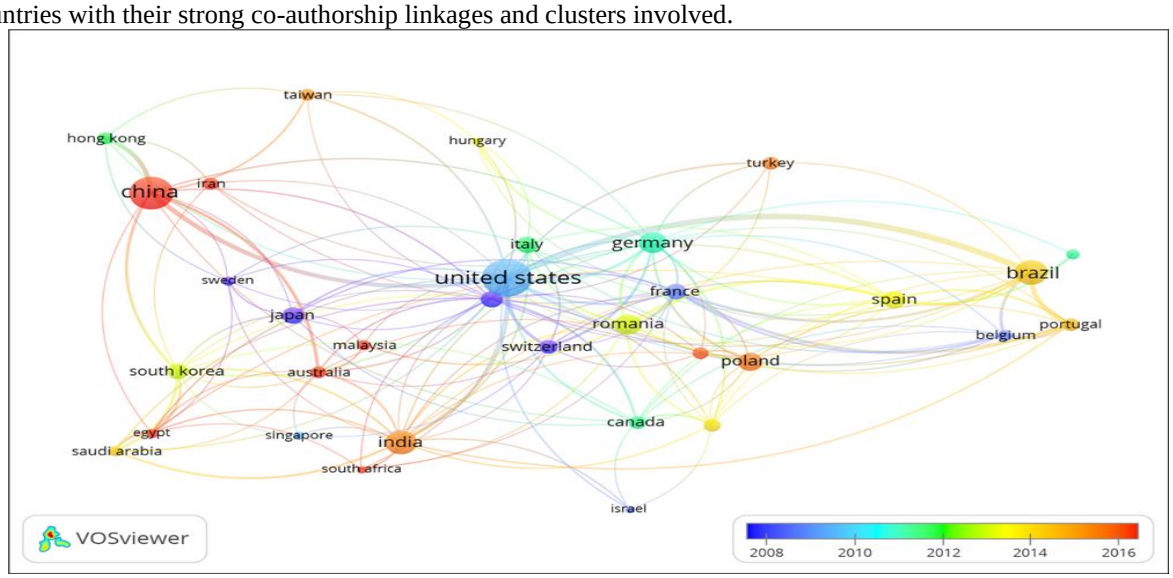

Figure 5: Co-authorship analysis on basis of countries

The citation analysis of top countries had been shown in table 3, along with co-authorship links. For the citation analysis, the parameters used were the minimum number of documents of a country as one and the minimum citations of the country as one.

Table 3: Highlights of Active Countries

Description	Country	Documents	Citations	Link strength
The country with the highest publication, citations, and co-authorship links	United States of America	269	10513	147

The most active country in this research domain was the United States of America, with the highest number of publications, and citations.

Link analysis and citation analysis were used to identify the most active journal in this research domain. We have taken the parameters of the minimum number of documents of a journal as one and the minimum number of citations of a journal as one for the link analysis and citation analysis. Highlights of the most active and relevant journals related to "Corrosion of Titanium implants" are shown in table 4. Table 4 shows the journal activity of this research domain through parameters of publication volume, citations, and co-authorship linkages.

Table 4: Analysis of journal activity

Description	Journal details	Documents	Citations	Average citations per documents
Journal with the highest publications	Material Science and Engineering C	65	1569	176
Journal with the highest citation and co-authorship links	Biomaterials	29	4169	267

From the above discussion regarding the bibliometric patterns in the research regarding Corrosion of Titanium implants, this research had observed a gradual increase in research interest regarding Corrosion of Titanium implants from the starting of the millennium and the momentum is going on positively. This points out the relevance and potential of this research domain (Refer to Figure 2). The most active authors in this research domain were Jacob J.J and Zhang X. with the highest citations; publication and co-authorship links respectively (Refer to table 1). The overlay analysis of top countries researching corrosion of Titanium implants indicates that the United States of America was the leading country relating to the highest number of publications, citations, and co-authorship links (Refer to figure 5). The top journal of this research domain was identified as the Material Science and Engineering C and Biomaterials. From these wide sources of information, researchers can focus on top journals where they can identify the most relevant and highly cited articles regarding the Corrosion of Titanium implants.

4. Conclusion

Corrosion of Titanium implants was an interesting research domain and the most active journal related to this research domain were Material Science and Engineering C and Biomaterials. The most active country was the United States of America. The leading organization engaged in the research regarding the Corrosion of Titanium implants was the Sao Paulo State University of Brazil. The most active authors who had made valuable contributions related to corrosion of Titanium implants were Jacob J.J and Zhang X. This research domain offers a new avenue for researchers and future research can be on innovations in the Corrosion of Titanium implants.

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