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Investigating the Process of Producing Scientific Clinical Research about Zirconia Implants: A Bibliometric Visual Mapping Approach

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ABSTRACT

Nowadays, implants are considered the most suitable alternatives to restoration of lost organs owing to their good mechanical properties and smooth surface, which are similar to those of bone tissue. One of the newest types of implants is zirconia implant, which reduces the possibility of infection due to its one-piece design. Zirconia implants proved to be biocompatible and less prone to corrosion than their traditional titanium counterparts, making them a beneficial option for dental implantation. Another reason why zirconia implants are superior to titanium ones is their better compatibility with soft tissues and greater durability against pressure and tension. Zirconia implants generate less stimulation of the soft tissues, hence lower levels of irritation and inflammation. As a result, zirconia implants are less likely to cause irritation or inflammation. In this research, articles published within the time period of 1980-2022 were examined and processed using VOSviewer software. The total number of articles examined was 3122, 47.6 % of which were published within the last five years. The results revealed that a majority of the articles were from America and Germany. India had the highest Compound Annual Growth Rate (CAGR) of 40 %, followed by Brazil and Spain with the CAGRs of 28 % and 25 %, respectively. Moreover, developing countries such as Poland, Taiwan, Iran, and Egypt have recently started their research activities in this field.

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1. INTRODUCTION

In numerous clinical cases such as dentistry and bone repair, there is a requirement to produce and reconstruct bone which would be best accomplished through spontaneous bone growth and repair. However, in most cases, the tissue cannot be transformed into the shape needed for successful bone regeneration. Therefore, the focus has been shifted to the application of implants [1].

One of the modern sciences that has made significant progress in recent years and has been able to reduce human concerns about tooth loss to a great extent is dental implantation. Despite the wide applications of titanium implants technology in this field. The prolonged stabilization period required for this type of implant and two-stage implantation procedure which takes a considerable duration of time (3-6 months) to create an integrated space with the bone can result in bone resorption. From a surgical perspective, implanting this type of implant in cases where the jaw bone is atrophied is also quite difficult [2-4].

Recently, use of zirconia implants has been highly

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recommended due to their biological compatibility with the bone tissues as well as their one-stage implantation process [5]. In addition, zirconia implants have high resistance that enables them to withstand quite high pressures. One of the main reasons behind the popularity of zirconia implants is their high durability and strength. In addition, due to the one-piece design of the zirconia implants, the possibility of infection and further problems related to the connection of the abutment to the implant is significantly reduced. In the two-piece designs that are commonly found in titanium implants, there is a possibility of bacteria infiltration and accumulation at the connection site of the abutment to the implant which in turn increases the risk of infection. Additionally, there is a possibility of abutment loosening due to severe jaw pressure, a problem that is resolved with the one-piece design of zirconia implants [6,7].

Zirconia is a crystalline form of an intermediate metal called zirconium, and zirconia implants are often known as metal-free implants [8]. Due to the increasing concerns about the presence of mercury in titanium implants, patients prefer to use metal-free implants. Research has shown that ceramic zirconia implants easily integrate with the bone, hence no signs of inflammation [9-11]. Other researchers also reported that zirconium is an ideal element for use in dental implants [12,13]. Zirconia implants have a very high success rate owing to their biocompatibility. Integration of the bone with this type of implant is quite satisfactory. For this reason, the implant is characterized by the strength similar to that of natural teeth [14].

In addition to the advantages mentioned earlier, it is important to be aware of the fracture potential in zirconia crown prostheses used in artificial teeth. Factors that cause fracture include the design errors, excessive force, surface cracks, and weak tooth foundations. To prevent fracture, it is essential to use appropriate prosthesis materials of high quality and adhere to the standards designated to the design and implementation of zirconia crown prostheses. Additionally, it is critical to evaluate the patient's oral and dental conditions before beginning treatment to identify and address any issues that may increase the risk of fracture. By taking these precautions, dental practitioners can ensure the longevity and effectiveness of zirconia crown prostheses for their patients [15,16].

Zirconia is a highly versatile material that can be used in a variety of dental implant applications. To cater to specific biological and mechanical requirements, different types of zirconia can be utilized for monolithic implants. High-translucent zirconia, for instance, is preferred for anterior teeth, where translucency is crucial for a natural-looking appearance. This type of zirconia offers outstanding optical properties that make it suitable for single-unit implants, implant-supported bridges, and implant-supported dentures. On the contrary, medium-translucent zirconia is best suited for posterior teeth and implant-supported restorations where both strength and durability are of utmost importance. Its good mechanical properties make it ideal for implant-supported bridges and full-arch restorations. When extreme loads are expected (as in bruxism or clenching cases), high-strength zirconia is preferred. This type of zirconia boasts excellent mechanical properties, including high flexural strength and fracture toughness, making it an ideal choice for implant-supported restorations in high-stress areas. In recent years, bioactive zirconia has emerged as a new type of zirconia that promotes osseointegration and bone regeneration. This type of zirconia is coated with a bioactive material that contributes to bone growth and attachment, making it an excellent choice for cases involving bone loss or regeneration. Overall, selection of zirconia for monolithic implants will depend on a range of factors, including the patient's clinical requirements, aesthetic preferences, and mechanical demands for restoration. By carefully choosing the right type of zirconia, dental practitioners achieve optimal results and enhance patient outcomes [17-21]. Given the aforementioned points, investigating the achievements and research in the realm of zirconia dental implants gains significance that is carried out through a scientific method known as scientometric.

With the continuous growth and advancement in science, there have been changes in scientific fields, and the scope of these changes is extending day by day. These changes have caused outdated scientific realities to lose their prevalence to the extent that Thomas Kuhn interprets this change and evolution in science and technology as a scientific revolution [22]. One of the areas that have emerged in recent decades as a result of these scientific changes and developments is the field of scientometrics. Simply put, scientometrics is the method for measuring science which includes all quantitative methods and models related to the production and dissemination of knowledge and technology. Scientometrics provides quantitative and comparative evaluations of the knowledge progress among researchers, groups, institutions, and countries and helps gain a better understanding of the construction of scientific research through the analysis of the quantitative aspects of scientific productions and application of such information [22,23].

Nowadays, scientometrics is one of the most common methods for evaluating scientific activities and research management. The rapid development of information in scientometrics, on the one hand, and the changes in this field as a research area, on the other hand, led to its confrontations with huge amount of information [23]. Under such circumstances, tracking subjects, identifying vocabulary and concepts, and understanding the structural relationships between these concepts become challenging. Additionally, scientometric methods have drawn interest in various fields. Given that changes in various scientific fields are inevitable, they also cause

differences in vocabulary, content, and meaning [24]. Therefore, creating a picture of the status of research conducted in this field and drawing a conceptual structure based on co-occurrence analysis as a model are necessary. Co-occurrence analysis is an efficient content analysis method based on the co-occurrence of vocabulary in texts and documents. One of its main applications is to create a network of conceptual documents for better analysis and evaluation of a scientific field [25].

A research was conducted on the scientific trends and clinical research on zirconia dental implants using the Web of Science database. The results of this article show that the number of such studies on the zirconia dental implants have significantly increased in recent years. It can also be concluded that use of zirconia dental implants can be an alternative method to metallic dental implants [26].

With an increase in the number of published articles on the dental implants, more advancements and trends have emerged in vital research areas. In this regard, the main objective of this research is to investigate the progress and trends concerning the applications of zirconia dental implants, identify the leading countries in this regard, and finally predict the future changes in this research field.

2. MATERIALS AND METHODS

Some articles about zirconia implants were found in Scopus from 1980 to 2022 using the following keywords: TITLE-ABS-KEY (zircon) OR TITLE-ABS-KEY (zirconium) OR TITLE-ABS-KEY (zirconia) AND TITLE-ABS-KEY (oral implant) OR TITLE-ABS-KEY (dental implants) OR TITLE-ABS-KEY (dental implant) OR TITLE-ABS-KEY (oral implants) OR TITLE-ABS-KEY (dental implantation) OR TITLE-ABS-KEY (dental implantology) OR TITLE-ABS-KEY (implant dentistry) OR TITLE-ABS-KEY (osseointegrated dental implantation) OR TITLE-ABS-KEY (osseointegrated). The article information, including its year of publication, title, authors, keywords, abstract, and downloaded source affiliations, were processed using the VOSviewer software. This process is illustrated in Figure 1.

3. RESULTS AND DISCUSSION

Figure 2a shows the number of published articles from 1980 to 2022. The total number of published articles was 3122, 79.5 % of which (2483 articles) were published in the past ten years and 47.6 % (1489 articles) in the past five years. The highest number of published articles was in 2022 and 2021, with 351 (11.2 %) and 338 (10.8 %) articles, respectively. Evidently, the trend of articles about the zirconia implants has increased over time, and most of the articles have been published in recent years. Figure 2b shows the top 10 journals with the highest number of publications related to zirconia implants. Journal of Prosthetic Dentistry (6.8 %, n = 213) and Clinical Oral Implants Research (6.5 %, n = 205) had the highest number of published articles. Among the top 10 journals that have published articles about zirconia dental implants, Dental Materials journal with an IF of 5.304 has published 2.2 % of the total articles in this field.

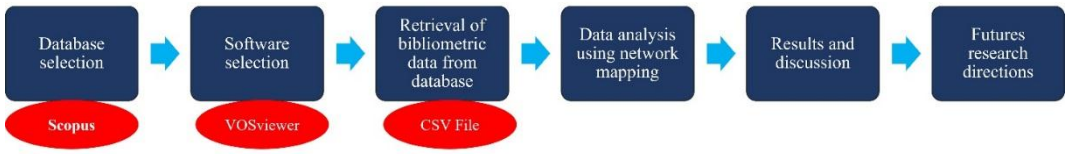

Figure 1. Stages of conducting research

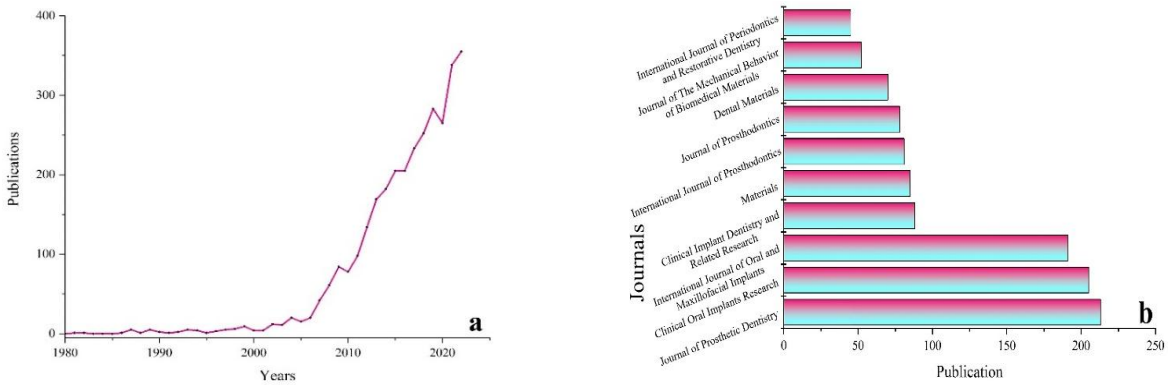

Figure 2. Published articles on zirconia implants: (a) by year of publication, and (b) by publication in journals

Figure 3 shows the annual number of articles on zirconia implants in top 10 countries with the highest number of articles in Scopus database. Initially, Japan had the highest number of articles but over time, the United States and Germany competed closely from 1980 to 2022. In some years, the United States had more articles while in others, Germany surpassed the USA. However, the United States surpassed Germany in 2020 with the highest number of articles about zirconia implants.

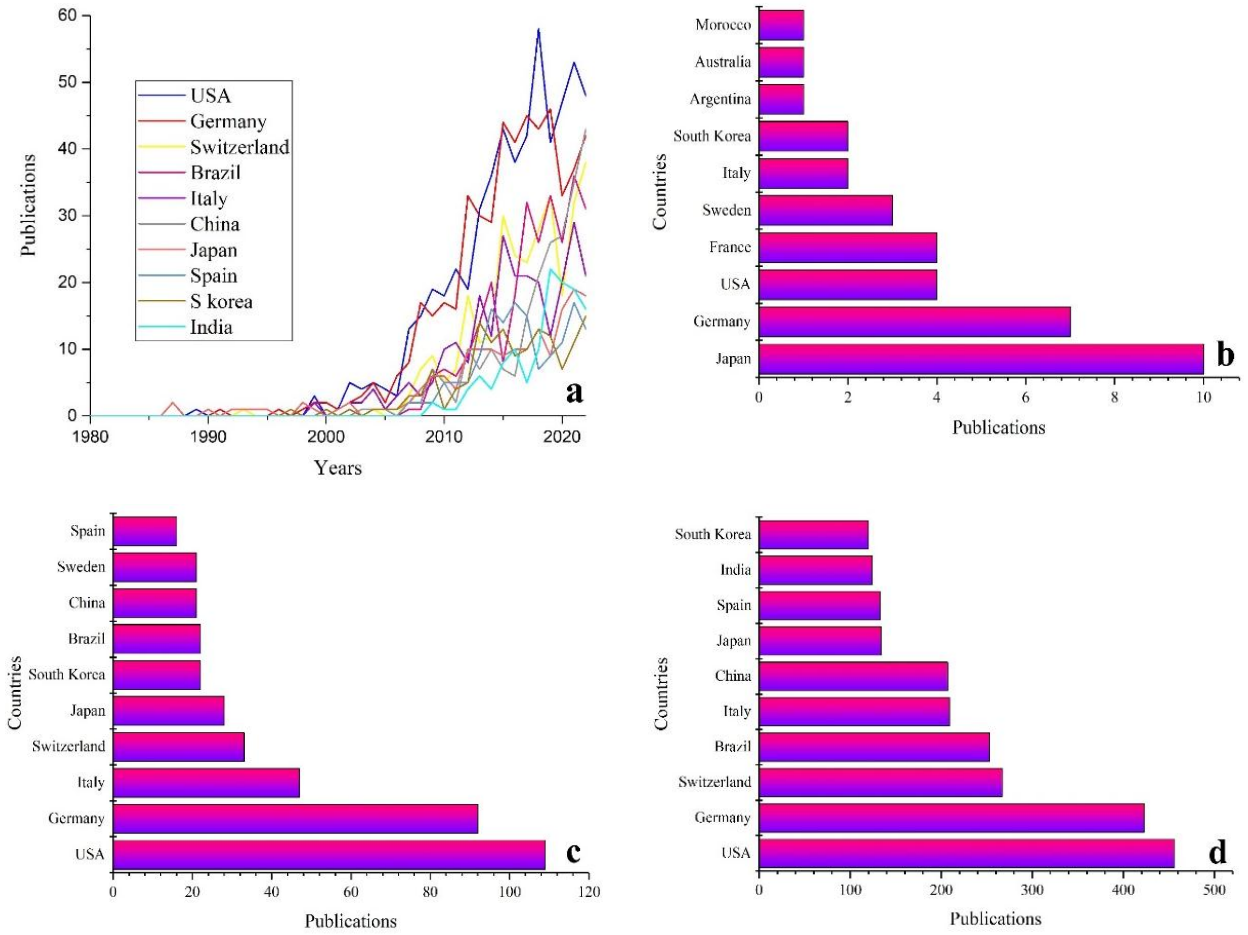

Figure 3. Articles on zirconia implants in the top 10 countries: (a) 1980-2022, (b) 1980-2000, (c) 2001-2011, and (d) 2012-2022

Figure 4 shows Compounded Annual Growth Rate (CAGR) [27,28] from 2010 to 2019 of the top 10 countries in the field of zirconia implants. India had the highest growth rate of over 40 % in the past 10 years. Research on zirconia implants in India began in the early 2009 that was further expanded with the support of the Saveetha Institute of Medical and Technical Sciences and later the Saveetha Dental College and Hospitals.

After India, Brazil, and Spain had the second and third highest growth rates of 28 % and 25 %, respectively, while the United States followed a declining trend with the CAGR of 16 %. In order to examine the relationship between the leading countries in the field of zirconia implants, VOSviewer software and Scopus data were used. Out of a total of 154 countries, 30 countries have 20 or more articles, as shown in Figure 5. The thickness of the lines is indicative the degree of cooperation among

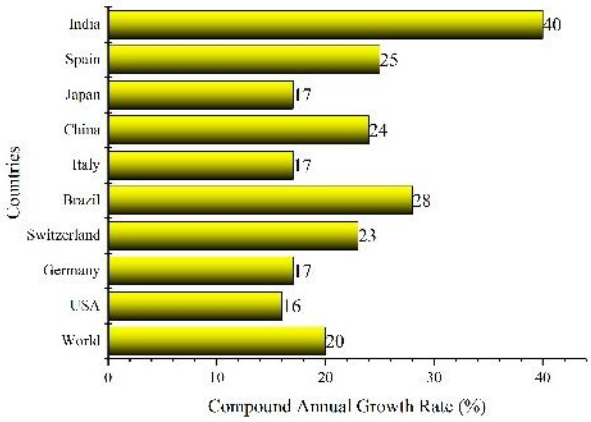

Figure 4. The compounded annual growth rate (CAGR) of the top 10 countries in the field of zirconia implants

the countries, and the size of the circles indicates the number of articles. Additionally, the more yellow the color, the higher the number of articles for that country. As evident, the United States and Germany have more publications and cooperation with each other than other countries. Of note, Poland, Taiwan, Iran, and Egypt have recently started their activities in this field.

Figure 6 depicts a map of the relationships and collaborations among individuals in the field of zirconia implants. The total number of authors was 8,917, 29 of whom have published at least 15 articles. The largest network of connections belongs to "Sailer i" with 14 researchers and "Kohal r.j" and "Spies b.c" with 13 researchers.

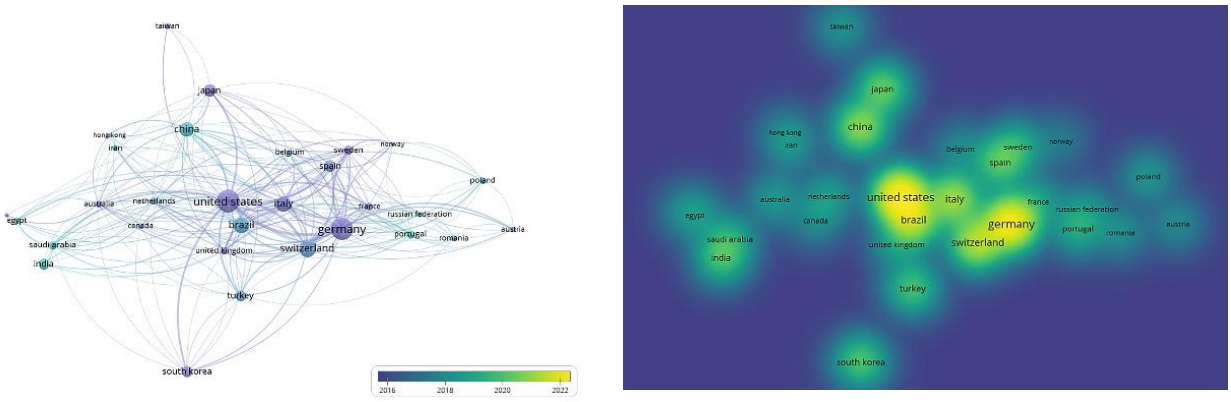

Figure 5. Map of active countries in the field of zirconia implants and their research relationships with each other

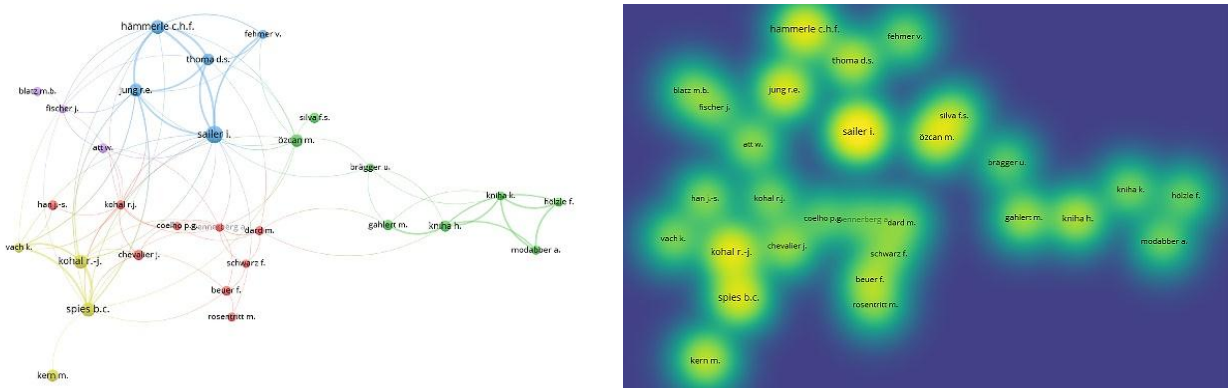

Figure 6. Map of active individuals in the field of zirconia implants and their research collaborations with each other

Figure 7 shows the research trend using words related to zirconia implants. Out of a total of 11,994 words, only 23 words have been repeated at least 500 times. The increase in the distance between two words implies that they are less likely to occur together.

On the contrary, the decrease in the distance between two words shows that they are more likely to occur together, and the size of the circle is indicative of the frequency. According to this figure, the words "Zirconium," "Human," and "Zirconium oxide" have the highest frequency of occurrence.

Figure 8 demonstrates the communication network of authors based on Citation/Document and Citation/Author. As shown in Figure 8a, out of a total of 3122 published articles, only 20 articles about zirconia implants had more than 250 citations, with "Piconi c" having 9 connections and "hisburgues m" having 7 connections with other authors with the highest communication network.

According to Figure 8b, out of a total of 8917 authors, 33 authors had at least 10 published articles in this field with 500 citations. Among them, "kohal r.j" had the highest communication network with 32 connections followed by "hammerle c.h.f" and "junge r.e" with 31 connections with other authors.

Figure 9 shows the active research centers in the field of zirconia implants. As shown, University of Buenos Aires, Hiroshima University, and Pitie-Salpetriere University Hospital were among the first centers to initiate research in this area. From 2001 to 2011, University of Freiburg and University of Zurich were also active. Since 2012, University of Zurich has continued to grow and has taken the lead along with University of Bern, surpassing the other centers.

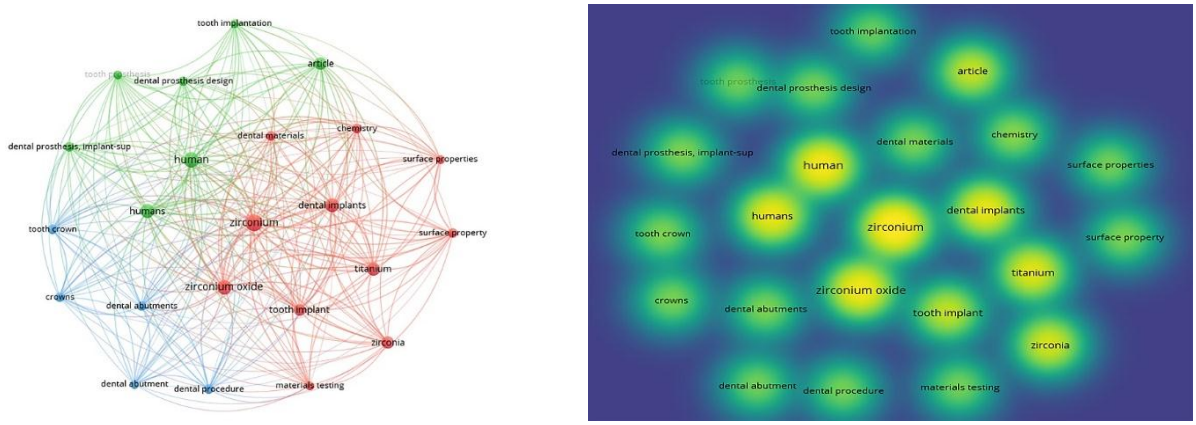

Figure 7. Map of frequently used words in the field of zirconia implants

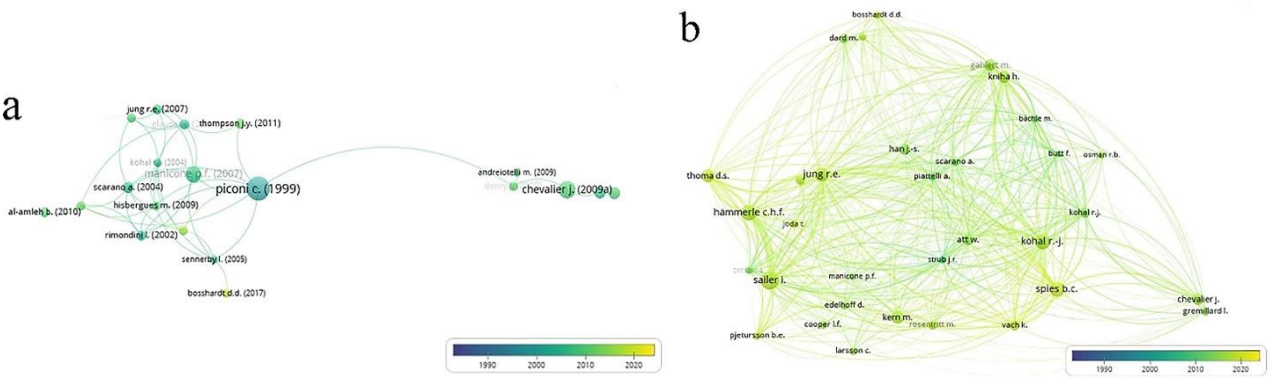

Figure 8. The communication network of authors based on (a) Citation/Document and (b) Citation/Author

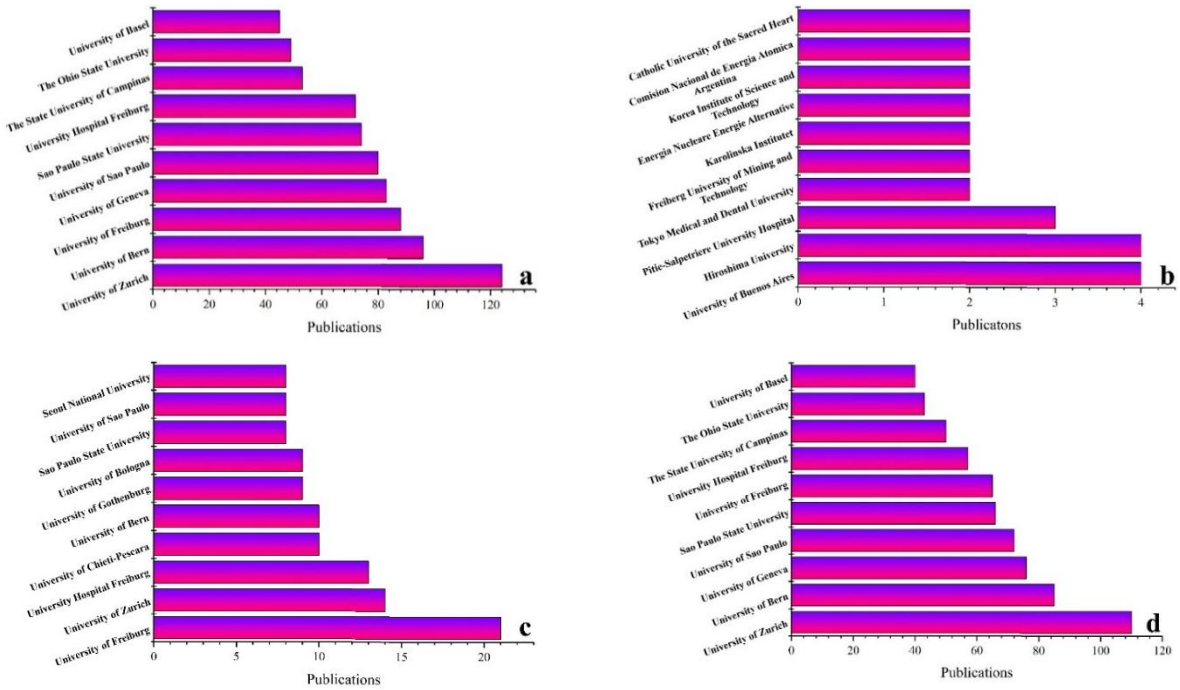

Figure 9. Active research centers in the field of zirconia implants: (a) 1980-2022, (b) 1980-2000, (c) 2001-2011, and (d) 2012-2022

Undoubtedly, future studies on zirconium implants is essential for further advancements in and understanding their potential applications. Conducting long-term clinical studies are also necessary to evaluate the lifespan and effectiveness of zirconium implants. The current research monitored patients over several years and assessed the success rate of their implants. Additionally, further research on the antibacterial properties of zirconium implants can lead to the development of even more effective coatings that reduce the infection risk.

While zirconium implants are generally well-tolerated by the body, further research can help identify the potential biocompatibility issues that may arise in some patients. This research can also ensure the development of more biocompatible materials and designs. In addition, research on the potential of zirconium implants to facilitate bone regeneration paves the way for the scientific creation of implants that strengthen bone restoration and repair, which can be useful in cases of bone loss or severe damage. Since zirconium implants gain increasing popularity due to their aesthetic properties, further research ensures the development of implants with a more natural and durable appearance.

Overall, future research on zirconium implants explores even more effective and versatile implant options that can improve the patient's achievements and life quality.

4. CONCLUSIONS

1. Further exploration in the field of implant innovation is of high importance for the future development of body health. For this reason, more attention has been drawn to zirconia implants over time. Research has shown that from 2000 to 2022, the United States and then Germany were the two leading countries in publishing articles about zirconia implants.
2. India had the highest growth rate in publishing articles with the CAGR of 40 % while the CAGR of the United States was 16 %.
3. Recently, some developing countries including Poland, Taiwan, Iran, and Egypt have started their research activities for further development of zirconia implants.

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