ORIGINAL RESEARCH

A 10-year Scientometric Study of the Emerging Patterns and Spatial–Temporal Trends of Probiotics in Dentistry

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Abstract

Aim: To perform a bibliometric analysis of the scientific production related to the use of probiotics in oral health.

Materials and methods: A retrospective, descriptive, observational study with a scientometric approach was conducted. Metadata from scientific articles were retrieved from the Web of Science (WoS) Core Collection and analyzed using Medical Subject Headings (MeSH) and Emtree terms. The search strategy included the terms related to probiotics and oral health, and articles published between 2013 and 2022 were analyzed. Different scientometric indicators were used to analyze the production, impact, and network collaboration.

Results: A total of 485 articles were retrieved from 241 sources, with an average annual growth rate of 10.72%. The manuscripts received an average citation per doc of 15.2. Authors collaborated on an average of 5.76 coauthors per paper. The number of articles published increased progressively from 2013 to 2022. The year 2022 had the highest number of articles published (90), while in 2013 only 36 articles were published. There was a progressive decrease in the average number of citations per article, from 32.44 in 2013 to 2.41 in 2022.

Conclusion: The production of articles on probiotics in dentistry has grown steadily, with an annual growth rate of 10.72%. The most productive countries were the United States, Italy, and China. The importance of international scientific collaborations and the need for more research in this field is emphasized.

Clinical significance: The findings of this study may help researchers identify areas that require further study and lead to more rapid and efficient advances in the use of probiotics to improve oral health. Its clinical importance lies in its value and ability to inform and guide future research to advance this field of science.

Keywords: Evolution, Oral health, Probiotics, Scientometric analysis.

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Introduction

Probiotics are live microorganisms that produce favorable effects for human health if they are consumed in adequate amounts, and therefore, in recent decades, they have been included in several food products.[1,2] Their effects are produced because they can antagonize pathogenic microorganisms by competing for binding sites, their production of bacteriocins that eliminate pathogenic bacteria, the production of mucin, the modulation of cellular mechanisms of proliferation and apoptosis, and the modulation of the immune system.[3–5] In a probiotic product, the use of microorganisms must be justified based on experiments and scientific evidence. In addition, the strains must be identified genetically and phenotypically, in a quantity and dose equivalent to that used in clinical studies.[6]

The oral cavity harbors a diverse range of flora. Numerous studies have demonstrated the beneficial effects of various probiotics in combating oral pathogens, suggesting their potential role in the treatment or prevention of dental caries, periodontal disease, and other related pathologies. However, it is worth noting that some trials have yielded contradictory results.[3]

The oral environment is inhabited by complex communities of microorganisms, which are in equilibrium when the individual is healthy.[7] *Streptococcus mutans* and *Lactobacilli* are microorganisms associated with dental caries, as well as *Porphyromonas gingivalis*, *Tannerella forsythia*, and *Treponema denticola* are associated with periodontal disease. Poor oral hygiene, biofilm accumulation, and carious lesions lead to a permanent intake of microorganisms from dysbiotic microbiota that can affect airway health in older adults.[2,7] Certain studies indicate that various clinical trials have found probiotics to be effective in reducing caries development in schoolchildren and preschoolers at high risk of caries. This effect

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is observed following the prolonged consumption of products fortified with probiotics, such as milk.[2,8]

The literature shows that in *in vitro* and preclinical *in vivo* studies, probiotics exhibit preferential growth over pathogenic microbes by the production of bacteriocins, as well as a greater potential for colonization and adherence, as well as a modulation of the immune response favorable to the host.[3,4,9] For instance, in clinical studies, probiotics can decrease alveolar bone loss and loss of clinical attachment level. In the treatment of periodontitis experimentally induced in animal biomodels, improvements in microbiological and immunological balance were observed.[9]

Probiotics have been shown to exert beneficial effects against halitosis, a condition characterized by an unpleasant odor during an individual's exhalation. This condition can be attributed to a variety of factors including reduced salivary flow, oral diseases, alcohol consumption, medication use, and drug intake.[10]

Bibliometric analyses play a crucial role in identifying the key characteristics of research and pinpointing areas of high interest and potential within a given field. Despite the existence of some bibliometric studies that assess scientific output related to the use of probiotics in oral health, there is still much to explore.[11,12] Thus, the aim of this study was to conduct a 10-year scientometric exploration to analyze the evolution, emerging patterns, and spatiotemporal trends of scientific research on the use of probiotics in oral health.

Materials and Methods

Study Design

A retrospective, descriptive, observational, retrospective study with a scientometric approach was performed. The metadata of the scientific articles was retrieved from the Web of Science (WoS) Core Collection database. Medical Subject Headings (MeSH) terms and Emtree terms were used. Articles published from 2013 to 2022 were analyzed.

Search Strategy

In the current study, articles relevant to the topic were analyzed. There were no language restrictions in the WoS. The metadata of the selected articles, totaling 485 manuscripts, were exported in plain text format on 11 March 2023. This format facilitates subsequent data analysis and integration within the utilized software.

The following search strategy was used: Searches for terms in the title, abstract, author keywords (TS) – "probiotic agent" or "probiotic" or "symbiotic" or "lactobacill" or "beneficial bacteria" or "good bacteria" or "live cultures" orR "friendly bacteria" or "probiotic strains" or "probiotic microorganisms" or "gut-friendly bacteria" or "health-promoting bacteria" or "beneficial microflora" or "*Lactobacillus acidophilus*" or "*Bifidobacterium bifidum*" or "*Lactobacillus rhamnosus* GG" or "*Lactobacillus reuteri*" or "*Streptococcus thermophilus*" or "*Bifidobacterium lactis* BB-12" or "*Lactobacillus casei* Shirota" or "*Lactobacillus plantarum* 299v" or "*Lactobacillus fermentum*" or "*Bifidobacterium animalis* subsp. *lactis* DN-173 010" or "*Saccharomyces boulardii*" or "*Lactobacillus plantarum*" or "*Lactobacillus casei*" or "*Bifidobacterium lactis*" or "*Lactobacillus reuteri*" or "*Lactobacillus fermentum*" or "*Bacillus coagulans*" or "*Enterococcus faecium*" or "*Pediococcus acidilactici*" or "*Escherichia coli* Nissle 1917" OR "*Propionibacterium freudenreichii*") and TS – "oral health" or "dental health" or "oral hygiene" or "dental hygiene" or "dental care" or "mouth health" or "dental wellness" or "oral wellness" or "teeth health" or "mouth care" or "dental maintenance". Refined by using the publication years in the range of 2013–2022.

Bibliometric Indicators

A variety of scientometric indicators were employed in this study to scrutinize production, impact, and collaborative networks. These encompassed the H index, annual growth rate, Lotka's law, Bradford's law, and Sankey diagrams. In addition, visualization tools, and citation maps were utilized to discern the collaborative networks among authors and countries. These comprehensive metrics facilitated a thorough examination of the progression and trends in this research field, providing a nuanced understanding of its evolution.

Data Analysis

The collected data underwent processing using Bibliometrix 3.0 and R, version 4.2.3, facilitating a meticulous and comprehensive analysis of the acquired information. Additionally, CiteSpace 6.2 R2, a tool specialized in scientometric analysis, was employed. This enabled the detection of patterns of collaboration, thematic trends, and cocitation relationships among the articles, thereby providing a holistic view of the research landscape.

Results

A total of 241 sources were examined, leading to the creation of 485 documents. An average annual growth rate of 10.72% was observed and the average age of the documents was 4.28 years. Each document received an average of 15.2 citations and 17,697 references were recorded. In addition, 1,220 additional keywords and 1,120 author keywords were used in the content of the documents. A total of 2,346 authors were found, of which only 9 papers were written by a single author. Collaboration between authors resulted in an average of 5.76 coauthors per paper, with 24.95% of these collaborations being international. The documents analyzed included different types, such as articles, reviews, and corrections, among others (Table 1).

According to Bradford's law, the sources of information are distributed in three zones. Most of the articles were sourced from the top five publications, highlighting the significance of *BMC Oral Health*, *Caries Research*, *Probiotics and Antimicrobial Proteins*, *Microorganisms*, and *Clinical Oral Investigations* in the realm of oral health. This indicates that these sources are considered the most important and relevant in the field (Fig. 1). According to Lotka's law, it was observed that most of the manuscripts (87.3%) were written by a single author, compared to 9.1% of papers that were written by two authors. The University of Rochester leads the list with 27 articles, followed closely by Prince Songkla University with 26. Seoul National University has 18 articles, while the University of Otago and the University of Copenhagen have 17 and 16 articles, respectively (Fig. 2). Among the most outstanding journals are Caries Research and Acta Odontologica Scandinavica, with H-indexes of 11 and 7, respectively.

The field of oral health has experienced a notable increase in article production in the last years such as *BMC Oral Health*, *Caries Research*, *Probiotics and Antimicrobial Proteins*, *Microorganisms*, and *Clinical Oral Investigations*, pointing toward an upward trend. This trend is particularly pronounced in the last few years. Moreover, Seoul National University has emerged as a prominent affiliation in

Table 1: Scholarly output

Description	*Results*
Timespan	2013–2022
Sources (journals, books, etc.)	241
Documents	485
Annual growth rate (%)	10.72
Document average age	4.28
Average citations per document	15.2
References	17,697
Document contents	
Keywords plus (ID)	1,220
Author's keywords (DE)	1,120
Authors	
Authors	2,346
Authors of single-authored documents	9
Authors collaboration	
Single-authored documents	9
Coauthors per document	5.76
International coauthorships (%)	24.95
Document types	
Article	380
Article; early access	3
Article; proceedings paper	4
Correction	1
Editorial material	1
Review	95
Review; early access	1

dental research, with a consistent rise in article output, culminating in 18 publications in both 2021 and 2022 (Fig. 3).

The region with the highest frequency of production was the United States with 160 publications, followed by Italy with 132, and China with 129. Brazil, Saudi Arabia, Germany, and Spain also contributed significantly to the field, with lower frequencies of 59, 58, 54, and 53 articles, respectively. Different collaborative networks between countries were observed, mainly between Australia, Brazil, China, and France, among others. Australia is the country that has collaborated the most with New Zealand, with a total of four collaborations, followed by Denmark, Egypt, and Greece with two each. Finally, the map indicates that many countries have only

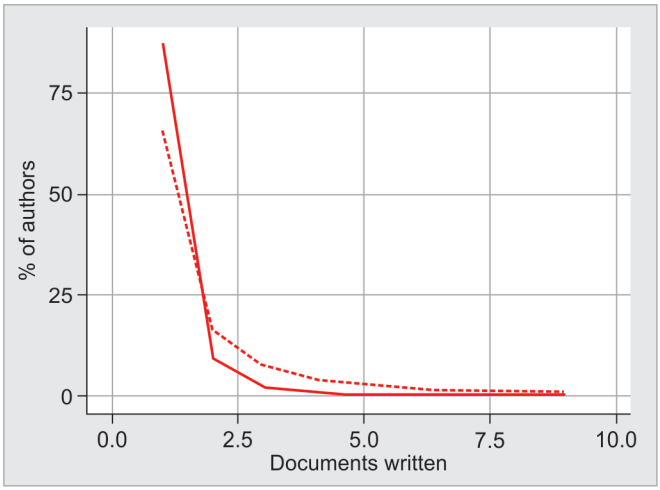


Fig. 2: Analysis of the distribution of scientific publications

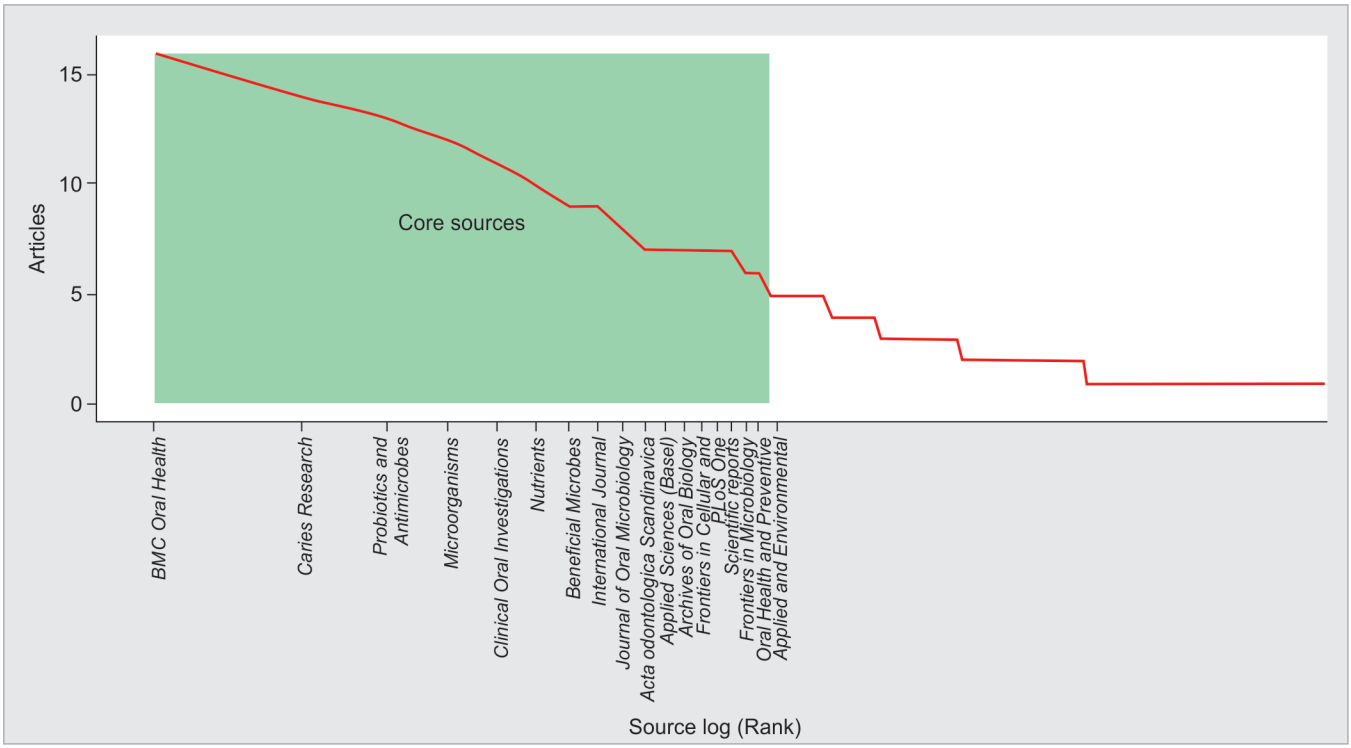


Fig. 1: Analysis of the impact and distribution of scientific publications

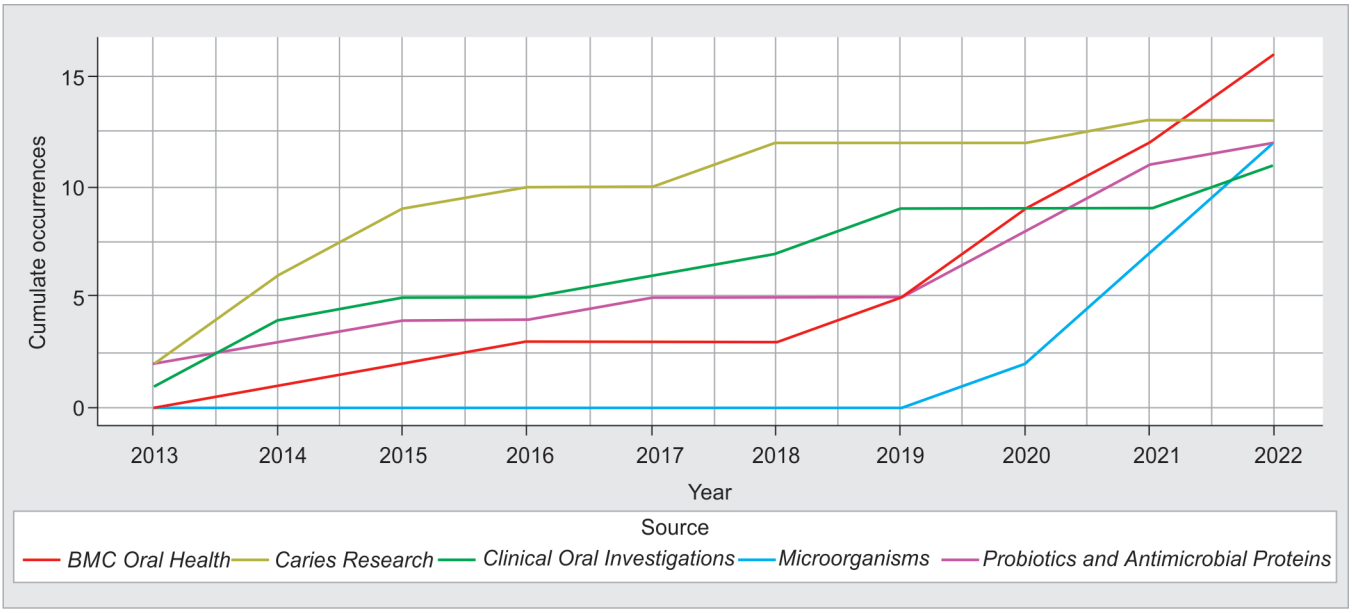


Fig. 3: Scientific production over time

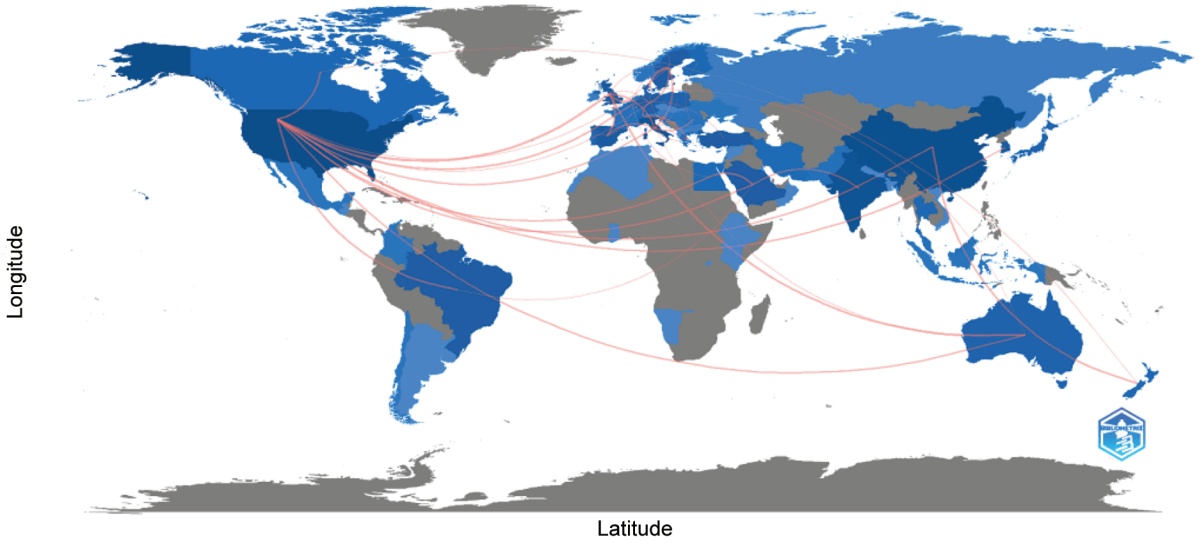


Fig. 4: Scientific production and collaboration by country

collaborated once with other countries, highlighting the need for more international scientific collaborations (Fig. 4).

The dual map overlay provided a visual representation of the thematic distribution of scientific publications on probiotics in oral health. The journals, primarily located on the left side of the map, represent the thematic areas and are predominantly cited by the journals on the right. The colored pathways serve as indicators of the significance of the references, the flow of information, and the linkage between the two knowledge domains. Two principal citation paths were identified. The lead-colored path in cluster 9, encompassing dentistry, dermatology, and surgery, suggested that studies were frequently published in journals belonging to cluster 8, which includes molecular biology and genetics. This highlights the interdisciplinary nature of the research in this field (Fig. 5).

The Time zone visualization according to source and author, evidenced the temporal distribution of scientific publications according to time. It was found that the journals *BMC Oral Health*, *Nutrients*, *Journal of Periodontology*, and *Periodontology 2000* condensed the patterns and trends in the year 2013. However, only in the year 2020 was the journal Biomed Res Int found to condense the highest number of publications in this area. Finally, in the years between 2017 and 2020, little activity was observed (Fig. 6).

Discussion

Probiotics are microorganisms that generate great health benefits for people when consumed in adequate amounts.[13] In recent years, their use has generated interest in the global population, which has led to increased commercialization due to their high demand.[14]

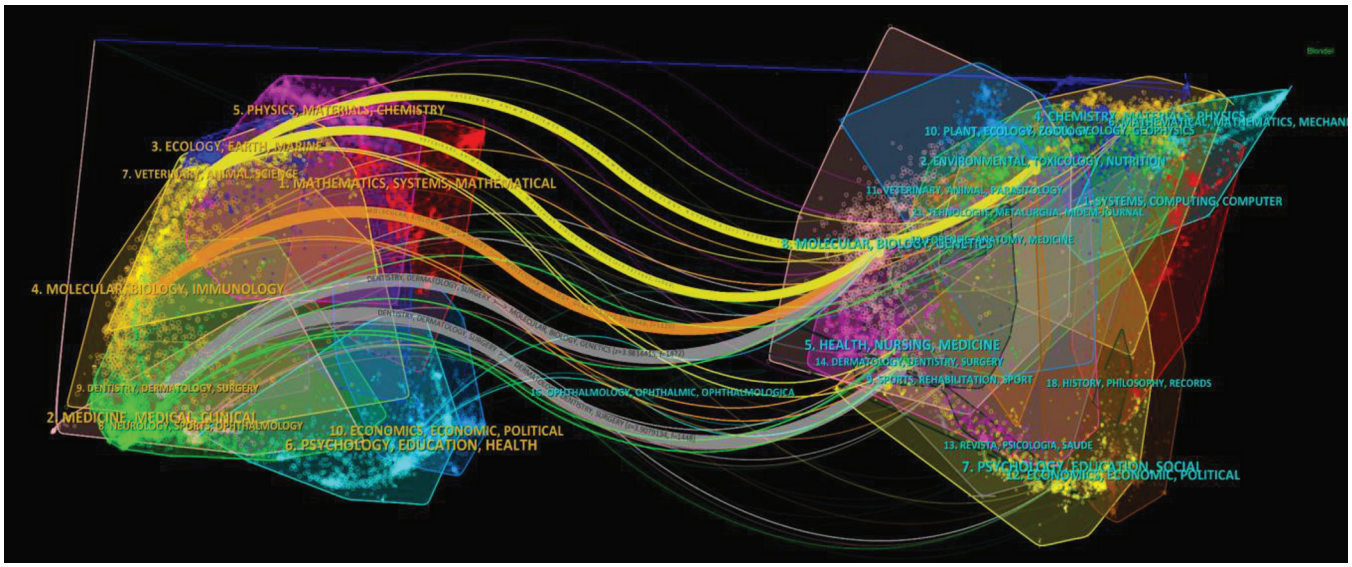


Fig. 5: Overlay map

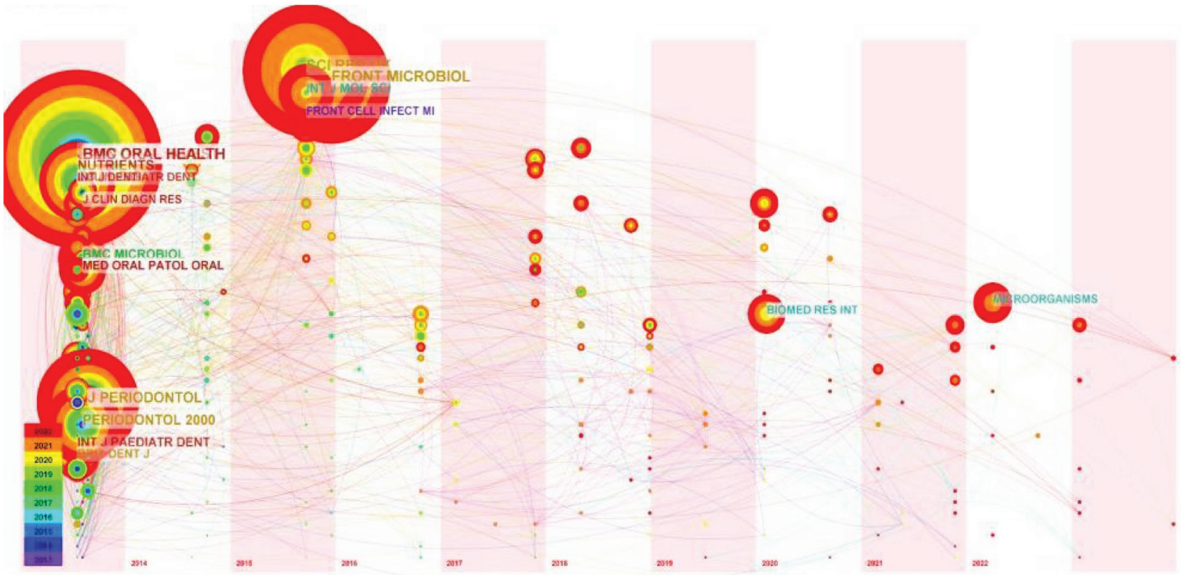


Fig. 6: Time zone visualization according to source and author

Thus, it is necessary to evaluate the performance and impact of scientific production in this area related to oral health.

Interest in probiotics has not only increased in the commercial aspect but also in their application and use in different fields. Monteiro et al.[15] carried out a bibliometric review in which they demonstrated that scientific production related to probiotics in citrus fruit products has increased; along the same lines, our study evidences a progressive increase in publications, as well as greater visibility of these, showing the correspondence between scientific development with the social demands of the health of each population, based on each reality.

Research progress is necessary in all countries, although some researchers and teams have greater and better possibilities in the contexts of developed regions compared to developing ones. The topic of probiotics applied to oral health is led by the United States, Italy, and China, but it is worth highlighting the role of Brazil as a Latin American country with an important position in this area. A previous study that explores part of this field of knowledge has also described that the United States leads the ranking of scientific production and Brazil occupies the fourth position.[16] On the contrary, it is important to point out that the United States has collaborated more actively with other countries; similarly, Deng et al.[17] showed in their study that this country was the most cooperative, whose relations were established mainly with China, Canada, and England, reflecting its research leadership.

In the realm of research, Seminario-Amez M et al.[18] have been identified as leading contributors to the field of probiotics and oral health. Their work is disseminated through high-impact, reputable scientific journals such as Oral Medicine, Oral Pathology, and Oral Surgery. Notably, one study by Seminario–Amez M et al.[18] posits that the maintenance of adequate oral health could be facilitated using probiotics. In this scenario, it is important to highlight the

positioning and activity of health institutions and trainers as relevant agents for the improvement of research in the field of dentistry.[19,20]

In the broad chronological overview, seven major clusters are observed, with *S. mutans* being particularly prominent. This observation aligns with a report by Farias da Cruz et al.,[11] who, in their bibliometric research, found that the term *Streptococcus mutans* was frequently used in studies related to dairy products in dentistry and probiotics. The bibliometric exploration allows us to reflect on new horizons and establish new lines of action in research on oral health care with the use of probiotics, such as their application in the pediatric population, whose scientific production is clearly increasing, or other groups with greater vulnerability, such as pregnant women.[19]

As for the limitations of this research, it is acknowledged that the search was confined to WOS, which may not encompass all scientific publications pertinent to the topic. Nevertheless, WOS is a significant database that can effectively characterize research, particularly high-quality studies. Additionally, the strategy may not have retrieved all relevant publications due to the exclusion of non-indexed terms. The reported parameters are based on indexed metadata, which may contain errors inherent to the publications. Furthermore, visibility and impact could be influenced by self-citation. Despite these limitations, it is believed that the findings provide a comprehensive and clear overview of scientific activity in this field of knowledge.

Conclusion

In this research, the results demonstrated a consistent rise in article production, with an annual growth rate averaging 10.72%, and an average document age of 4.28 years. The study found that collaborative authorship is prevalent, with an average of 5.76 coauthors per paper. The top contributors to the field were determined to be the United States, Italy, and China, while Seoul National University ranked as the leading affiliation in dental research. Furthermore, the research emphasizes the significance of international scientific collaborations and the requirement for additional investigation in this field. Lastly, the thematic distribution map of scientific publications on probiotics in oral health recognized two primary citation paths between dentistry and molecular biology/genetics.

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