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Global research trends in probiotics as adjuncts in periodontal therapy: a bibliometric and science-mapping analysis (1981-2026)[1]

Tendências globais das pesquisas sobre probióticos como adjuvantes na terapia periodontal: uma análise bibliométrica e de mapeamento da ciência (1981-2026)

Tendencias globales de la investigación sobre probióticos como coadyuvantes en la terapia periodontal: un análisis bibliométrico y de mapeo científico (1981-2026)

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ABSTRACT

Aim: To map the global scientific literature on probiotics as adjuncts in periodontal therapy using bibliometric and science-mapping approaches. Materials and Methods: A bibliometric analysis was conducted using Scopus and the Web of Science Core Collection. The search (March 3, 2026) included records from 1981 to 2026, without restrictions on language or publication year. After data merging and duplicate removal, 252 documents were analyzed. Performance indicators and science-mapping analyses were performed using the Bibliometrix R package (version 4.2.5) via Biblioshiny, with network visualizations refined using VOSviewer (version 1.6.20). Variables included annual scientific production, leading journals, productive authors, international collaboration networks, keyword co-occurrence, and co-citation patterns. Results: The field showed a steady annual growth rate of 3.64%, with a publication peak in 2025, indicating increasing global interest. A total of 154 journals contributed, with the Journal of Clinical Periodontology and the Journal of Periodontology as leading outlets. The United States and Brazil were central in collaboration networks. Teughels W led in number of publications and exhibited the highest local impact within the dataset. Thematic analysis revealed a shift from clinical inflammatory parameters toward microbiome-oriented perspectives. Co-citation analysis indicated a distributed intellectual structure. Conclusion: This field is rapidly expanding and evolving conceptually. Greater methodological standardization and multicenter collaboration are needed to strengthen the clinical evidence base.

Keywords: Probiotics. Periodontitis. Periodontal therapy. Bibliometric analysis. Microbiome.

[1]The authors declare that they used Generative Artificial Intelligence tools to assist in the conception, writing, and translation of this manuscript. The content was critically reviewed by the authors, who assume full responsibility for the final version of the text.

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RESUMO

Objetivo: Mapear a literatura científica mundial sobre o uso de probióticos como adjuvantes na terapia periodontal por meio de abordagens bibliométricas e de mapeamento da ciência. Materiais e Métodos: Foi realizada uma análise bibliométrica utilizando as bases de dados Scopus e Web of Science Core Collection. A busca foi realizada em 3 de março de 2026 e incluiu registros publicados entre 1981 e 2026, sem restrições quanto ao idioma ou ao ano de publicação. Após a integração das bases e a remoção de duplicatas, foram analisados 252 documentos. Os indicadores de desempenho e as análises de mapeamento da ciência foram conduzidos com o pacote Bibliometrix para R (versão 4.2.5), por meio da interface Biblioshiny, e as visualizações das redes foram refinadas com o software VOSviewer (versão 1.6.20). As variáveis analisadas incluíram a produção científica anual, os principais periódicos, os autores mais produtivos, as redes de colaboração internacional, a co-ocorrência de palavras-chave e os padrões de cocitação. Resultados: O tema apresentou uma taxa média anual de crescimento de 3,64%, com pico de publicações em 2025, indicando crescente interesse científico global. Um total de 154 periódicos contribuiu para a área, destacando-se o *Journal of Clinical Periodontology* e o *Journal of Periodontology*. Os Estados Unidos e o Brasil ocuparam posições centrais nas redes de colaboração internacional. Teughels W apresentou o maior número de publicações e o maior impacto local no conjunto de dados analisado. A análise temática revelou uma transição do enfoque em parâmetros inflamatórios clínicos para perspectivas orientadas ao microbioma. A análise de cocitação evidenciou uma estrutura intelectual distribuída. Conclusão: Este campo de pesquisa encontra-se em rápida expansão e evolução conceitual. Maior padronização metodológica e o fortalecimento de colaborações multicêntricas são necessários para consolidar as evidências clínicas.

Palavras-chave: Probióticos. Periodontite. Terapia periodontal. Análise bibliométrica. Microbioma.

RESUMEN

Objetivo: Mapear la literatura científica mundial sobre el uso de probióticos como coadyuvantes en la terapia periodontal mediante enfoques bibliométricos y de mapeo científico. Materiales y Métodos: Se realizó un análisis bibliométrico utilizando las bases de datos Scopus y Web of Science Core Collection. La búsqueda se llevó a cabo el 3 de marzo de 2026 e incluyó registros publicados entre 1981 y 2026, sin restricciones de idioma ni de año de publicación. Tras la integración de las bases de datos y la eliminación de duplicados, se analizaron 252 documentos. Los indicadores de desempeño y los análisis de mapeo científico se realizaron con el paquete Bibliometrix para R (versión 4.2.5), mediante la interfaz Biblioshiny, y las visualizaciones de las redes se refinaron con el software VOSviewer (versión 1.6.20). Las variables analizadas incluyeron la producción científica anual, las principales revistas, los autores más productivos, las redes de colaboración internacional, la coocurrencia de palabras clave y los patrones de cocitación. Resultados: El tema presentó una tasa media anual de crecimiento del 3,64 %, con un pico de publicaciones en 2025, lo que indica un interés científico mundial creciente. Un total de 154 revistas contribuyeron al área, entre las que destacaron *Journal of Clinical Periodontology* y *Journal of Periodontology*. Estados Unidos y Brasil ocuparon posiciones centrales en las redes de colaboración internacional. Teughels W presentó el mayor número de publicaciones y el mayor impacto local en el conjunto de datos analizado. El análisis temático reveló una transición desde un enfoque centrado en los parámetros inflamatorios clínicos hacia perspectivas orientadas al microbioma. El análisis de cocitación evidenció una estructura intelectual distribuida. Conclusión: Este campo de investigación se encuentra en rápida expansión y evolución conceptual. Se necesita una mayor estandarización metodológica y el fortalecimiento de las colaboraciones multicéntricas para consolidar la evidencia clínica.

Palabras clave: Probióticos. Periodontitis. Terapia Periodontal. Análisis Bibliométrico. Microbioma.

INTRODUCTION

Periodontal diseases constitute a highly prevalent group of chronic inflammatory disorders with significant impact on oral health globally (Tonetti *et al*., 2017). Gingivitis is

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a reversible plaque-induced inflammatory condition, whereas periodontitis is characterized by progressive clinical attachment loss and destruction of the tooth-supporting tissues, which may ultimately lead to tooth loss if not properly managed (Hajishengallis; Chavakis, 2021; Sanz *et al*., 2020).

In addition to their local effects, periodontal diseases have been consistently associated with several systemic inflammatory conditions, including diabetes mellitus and cardiovascular diseases, highlighting their relevance as a major global public health concern (Sanz *et al*., 2020; Papapanou *et al*., 2018). The functional, esthetic, and psychosocial consequences of periodontitis may impair oral health-related quality of life (Hajishengallis; Chavakis, 2021).

Contemporary understanding of periodontal pathogenesis is based on the ecological dysbiosis model, whereby shifts in the composition and interactions of the oral microbiota lead to a dysregulated host immunoinflammatory response that drives periodontal tissue destruction (Kilian *et al*., 2016; Lamont; Hajishengallis, 2015).

Actually, periodontal disease is increasingly viewed as a consequence of ecological imbalance in the microbial community rather than the effect of isolated pathogens. This conceptual shift has encouraged the development of therapeutic approaches aimed at modulating the oral biofilm ecosystem rather than focusing solely on pathogen elimination (Kilian *et al*., 2016; Lamont; Hajishengallis, 2015).

Conventional periodontal therapy is primarily based on mechanical disruption of the subgingival biofilm through scaling and root planing, with adjunctive local or systemic antimicrobials employed in selected clinical scenarios (Herrera *et al*., 2012). Although this approach has well-established clinical efficacy, some limitations remain, including bacterial recolonization, interindividual variability in treatment response, and increasing concerns about indiscriminate antibiotic use, such as antimicrobial resistance and systemic adverse effects (Feres *et al*., 2015; Pretzl *et al*., 2019). The use of antibiotics alters the bacterial populations within the commensal microbiota, resulting in dysbiosis and heightened vulnerability to diverse bacterial infections due to reduced colonization resistance (Morales *et al*., 2018). In this context, probiotics have been proposed as a potential adjunctive strategy in periodontal therapy aimed at modulating the oral microbiome and restoring microbial eubiosis. Defined as live microorganisms that, when administered in adequate amounts, confer a health benefit to the host, probiotics may exert

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their effects through multiple mechanisms, including competition for adhesion sites, production of antimicrobial compounds, and modulation of the host immune-inflammatory response (Teughels; Loózen; Quirynen, 2011; Hill *et al*., 2014). Strains primarily belonging to the genera *Lactobacillus* and *Bifidobacterium* have been investigated in clinical and experimental studies, showing the potential to reduce periodontal inflammatory parameters and modify subgingival microbial composition (Matsubara *et al*., 2016; Bilouro *et al*., 2022).

Despite the increasing number of clinical trials and systematic reviews, the reported findings remain heterogeneous regarding the strains used, therapeutic protocols, duration of administration, and clinical outcomes assessed, which limit definitive conclusions about the clinical efficacy of probiotics in periodontal therapy (Ramos *et al*., 2022; Martin-Cabezas *et al*., 2016; Gruner; Paris; Schwendicke, 2016). Over the past decades, the scientific output in this field has expanded, reflecting increasing interest in microbiome-based therapeutic strategies.

In this context, bibliometric methods offer a structured approach for examining the evolution of a research field, including thematic trends, collaboration networks, and the intellectual structure underlying knowledge development (Baas *et al*., 2020; Donthu *et al*., 2021). Beyond measuring publication growth, these analyses also provide insight into the conceptual organization of a research domain, its geographic distribution, and patterns of scientific influence (Donthu *et al*., 2021; Zupic; Čater, 2015).

Previous bibliometric studies have explored the use of probiotics in dentistry (Cruz *et al*., 2022; Mayta-Tovalino *et al*., 2023). However, these analyses did not specifically address probiotics as adjuncts in periodontal therapy.

Therefore, the aim of the present study was to conduct a comprehensive bibliometric analysis of the global scientific literature on probiotics as adjuncts in periodontal therapy, covering the period from 1981 to 2026, based on records retrieved from Scopus and the Web of Science Core Collection.

MATERIALS AND METHODS

Study Design

This study consisted of a bibliometric analysis designed to evaluate the global scientific landscape regarding the use of probiotics as adjuncts to periodontal therapy.

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Bibliometric methods combine quantitative performance indicators with science mapping techniques to explore the structure, dynamics, and evolution of scientific research in a specific domain.

The analysis aimed to identify patterns of scientific productivity, citation impact, international collaboration, and thematic development across this research area. The reporting of this study followed the principles of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), adapted for bibliometric research, as recommended in methodological studies on bibliometric reviews.

Data Sources and Search Strategy

A comprehensive literature search was conducted on March 3, 2026, in the databases: Web of Science Core Collection and Scopus. These databases were selected due to their broad coverage of peer-reviewed scientific literature and their widespread use in bibliometric analyses.

The following search strategy was applied: (probiotic* OR lactobacillus* OR bifidobacterium*) AND (gingivitis OR periodontitis OR "periodontal disease") AND ("periodontal therapy" OR "periodontal treatment" OR "scaling and root planing").

In Scopus, the search was performed in the Title, Abstract, and Keywords fields, whereas in Web of Science the Topic (TS) field was used, which includes title, abstract, author keywords, and Keywords Plus.

No restrictions were applied about publication year, language, or study design in order to capture the entire body of scientific literature related to the topic.

The final search results were exported in BibTeX and CSV formats to enable bibliometric processing.

Study Selection and Data Management

All retrieved records were imported and merged using the Bibliometrix package (version 4.2.5) implemented in the R environment. Duplicate records between databases were automatically identified and removed using the built-in deduplication algorithm based on title, DOI, and author information. Data cleaning procedures were performed to standardize author names, institutional affiliations, and country names when necessary.

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Subsequently, titles and abstracts were screened to confirm relevance to the topic of probiotics in periodontal therapy. Studies focusing exclusively on gastrointestinal probiotics or non-periodontal oral conditions were excluded. Eligible documents included: original research articles, clinical trials, observational studies, reviews, and systematic reviews. Editorials, letters to the editor, conference abstracts, and errata were excluded from the analysis.

The study selection process followed a structured workflow and is summarized in a PRISMA-based flow diagram depicting the stages of identification, screening, eligibility, and inclusion. Two reviewers (AC and MRCA) independently screened titles and abstracts and subsequently assessed full texts for eligibility. Disagreements were resolved by consensus.

Data Extraction

For each included publication, the following bibliometric variables were extracted:

- Publication characteristics: year of publication, journal title, document type, author Keywords, Authorship and collaboration indicators, authors, institutional affiliation, country of origin and international collaboration patterns.
- Citation indicators: total number of citations, average citations per document and citation density (citations per year).

These data were obtained directly from the metadata provided by the databases.

Bibliometric Performance Indicators

Descriptive bibliometric indicators were applied to evaluate research productivity and scientific impact. These included: annual scientific production, annual growth rate of publications, most productive journals, most productive authors, most productive countries, and most productive institutions.

Citation-based indicators were also calculated to identify influential authors and publications within the dataset.

Local impact indicators, including h-index and total citations within the dataset, were used to evaluate the influence of authors specifically in the research domain of probiotics in periodontal therapy.

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Science Mapping and Network Analysis

Science mapping analyses were conducted using VOSviewer (version 1.6.20). This software enables the visualization of bibliometric networks and the identification of relationships between scientific entities.

Full counting was applied for the construction of networks, and normalization of link strength was performed using the association strength method, which is commonly recommended for co-occurrence and co-citation analyses.

The following bibliometric networks were generated:

- Keyword co-occurrence analysis: This analysis shows the most frequent research themes and their relationships. A minimum threshold of five keyword occurrences was applied to include terms in the network.
- Country collaboration networks: International collaboration patterns were analyzed by constructing co-authorship networks based on countries of affiliation.
- Author co-citation analysis: Author co-citation networks were generated to show influential researchers and intellectual structures across the field.

Network visualizations were generated using both cluster maps and overlay visualizations, allowing the identification of thematic clusters as well as the temporal evolution of research topics.

Data Analysis and Visualization

Descriptive bibliometric analyses were performed using the Bibliometrix package. Graphical representations of trends in scientific production and collaboration patterns were generated using the same software.

Network visualization and clustering analyses were performed using VOSviewer, enabling graphical mapping of scientific relationships and thematic structures within the dataset.

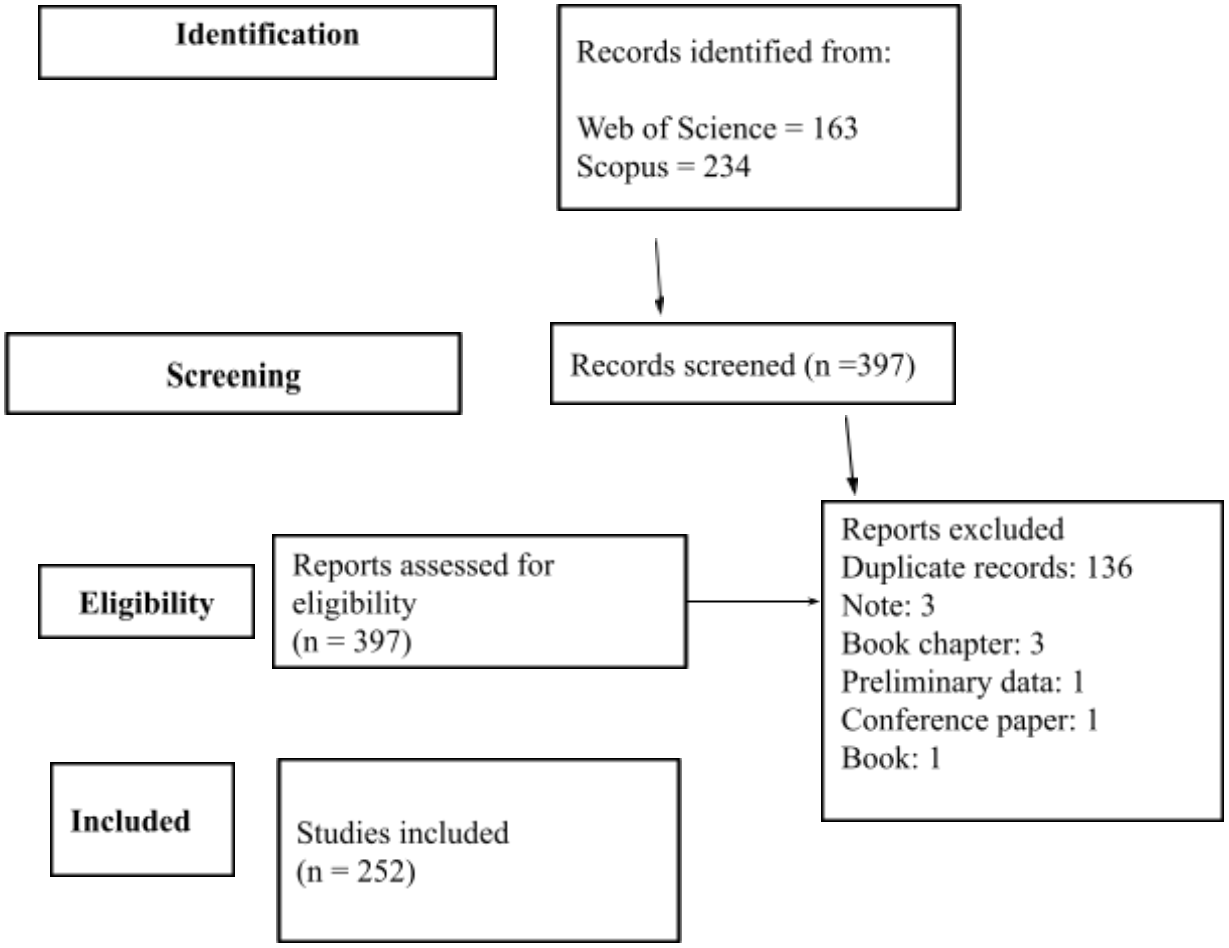
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RESULTS

Study Selection

The database search identified 397 records covering the period from 1981 to 2026, including 234 records from Scopus and 163 from Web of Science Core Collection. After the removal of 136 duplicate records, nine non-peer-reviewed document types (including notes, book chapters, conference papers, and other non-article formats) were excluded. A total of 252 unique documents were retained for the final bibliometric analysis. Original research articles accounted for the majority of publications, followed by systematic reviews.

Figure 1 - Flow diagram of study selection according to the PRISMA guidelines, adapted for bibliometric analysis.



Source: Prepared by the authors (2026).

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Descriptive Bibliometric Profile

The final dataset included 252 publications spanning from 1981 to 2026, distributed across 154 journals and authored by 1.160 researchers. The annual growth rate of 3.64% indicates a steady expansion of the field, with a marked publication peak observed in 2025. The average citation rate (27.31 citations per document) reflects moderate scientific impact, consistent with a consolidating but still developing research domain.

The observed international collaboration rate shows moderate cross-national research integration, indicating that while the field demonstrates global participation, research activity remains partially concentrated within specific academic networks. The dataset presented an average of 4.60 authors per document, reflecting a collaborative research structure.

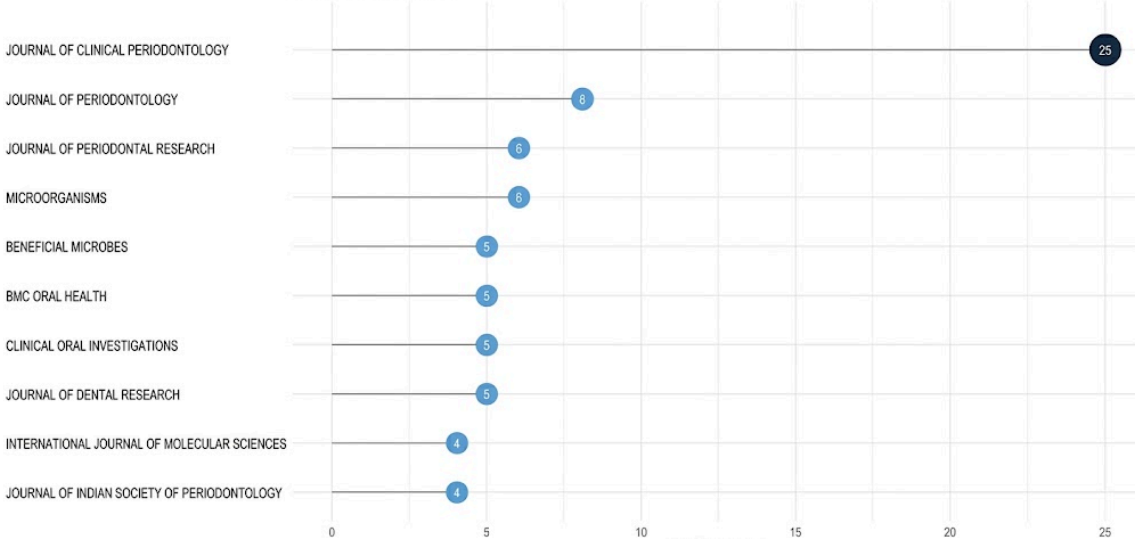
Leading Journals and Scientific Consolidation

The distribution of publications across journals (Figure 2) reveals a clear concentration in high-impact periodontal and dental research outlets. The *Journal of Clinical Periodontology* appeared as the primary publication venue, followed by the *Journal of Periodontology* and the *Journal of Periodontal Research*.

The concentration of publications within specialty journals suggests that probiotic adjunctive therapy is primarily framed in clinical periodontology rather than broader microbiology or general medicine domains, reinforcing its positioning as a clinically driven research field.

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Figure 2 - Distribution of publications across journals in the field of probiotics and periodontal therapy.

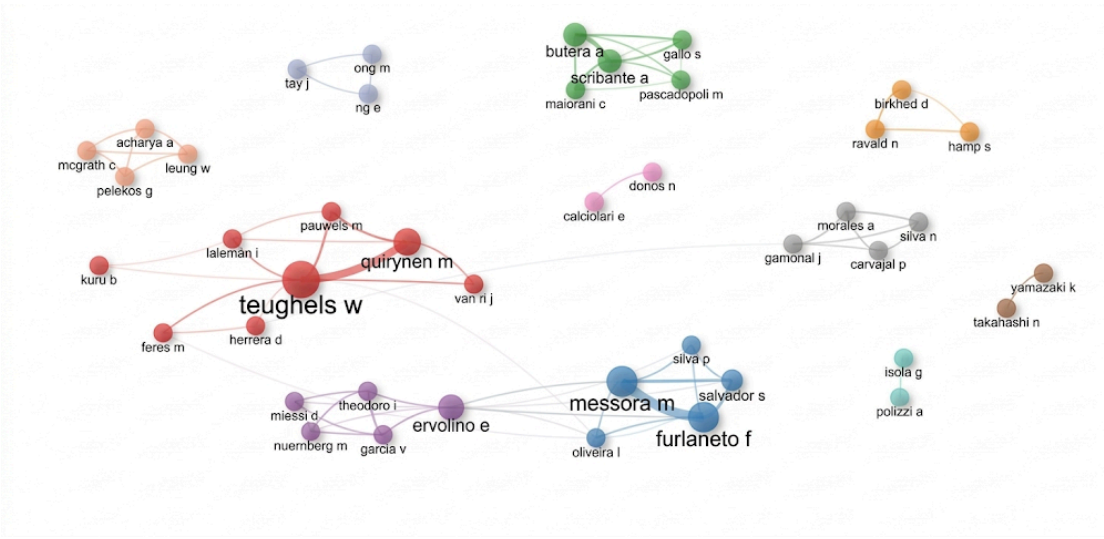


Source: Prepared by the authors (2026).

Author Productivity and Collaboration Structure

The most productive authors (Figure 3) were central figures in both publication output and citation impact.

Figure 3 - Author collaboration network generated using the Bibliometrix package. Nodes represent individual authors, and links indicate co-authorship relationships. The size of each node reflects publication productivity, while the thickness of connecting lines corresponds to the strength of collaboration between



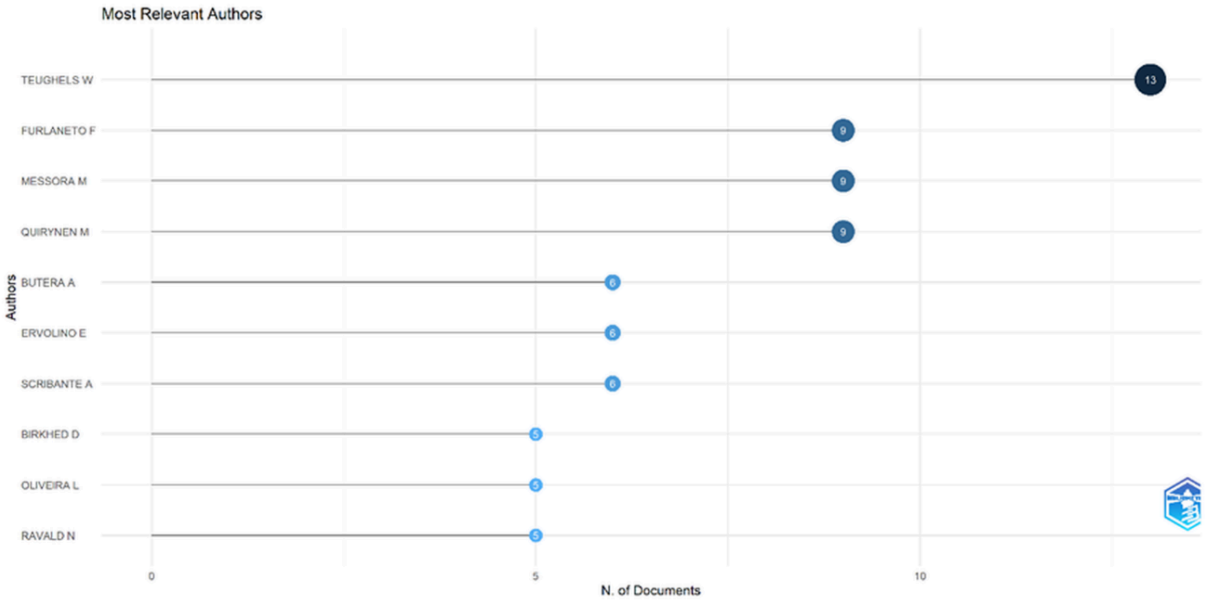
authors.
Source: Prepared by the authors (2026).

Teughels W not only led in number of publications (n = 13) but also exhibited the highest local impact within the dataset (local h-index = 11), indicating sustained

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intellectual leadership in this domain. Additionally, Furlaneto F, Messora M, and Quirynen M each contributed nine publications (Figure 4), highlighting their substantial productivity in the field. Regarding local scientific impact, Furlaneto F achieved a local h-index of 9, whereas Messora M and Quirynen M each presented a local h-index of 7, reinforcing their relevance as influential contributors to the development of this research area.

Figure 4 - Distribution of the most productive authors based on the number of publications included in the bibliometric dataset.



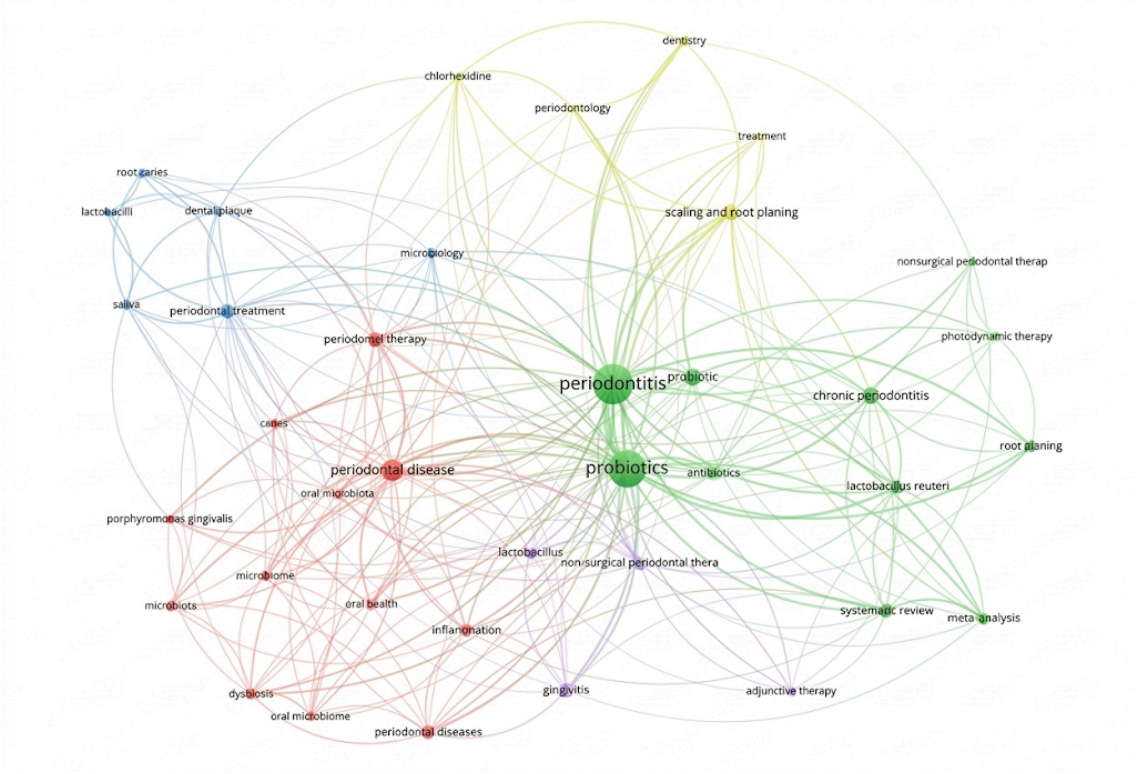
Source: Prepared by the authors (2026).

Peripheral clusters related to microbiological modulation and host inflammatory response indicate an expansion from purely clinical endpoints toward mechanistic exploration. The observed structural arrangement indicates a gradual transition from efficacy-oriented clinical trials toward more biologically integrated research approaches.

The refined visualization using VOSviewer (Figure 5) corroborated these findings, showing strong link strength between clinical and microbiological domains, reinforcing the interdisciplinary consolidation of the topic.

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Figure 5 - Keyword co-occurrence network constructed using VOSviewer (minimum threshold: five occurrences). Node size represents keyword frequency, and link strength indicates the frequency of co-occurrence. Different colors represent distinct thematic clusters within the research field.



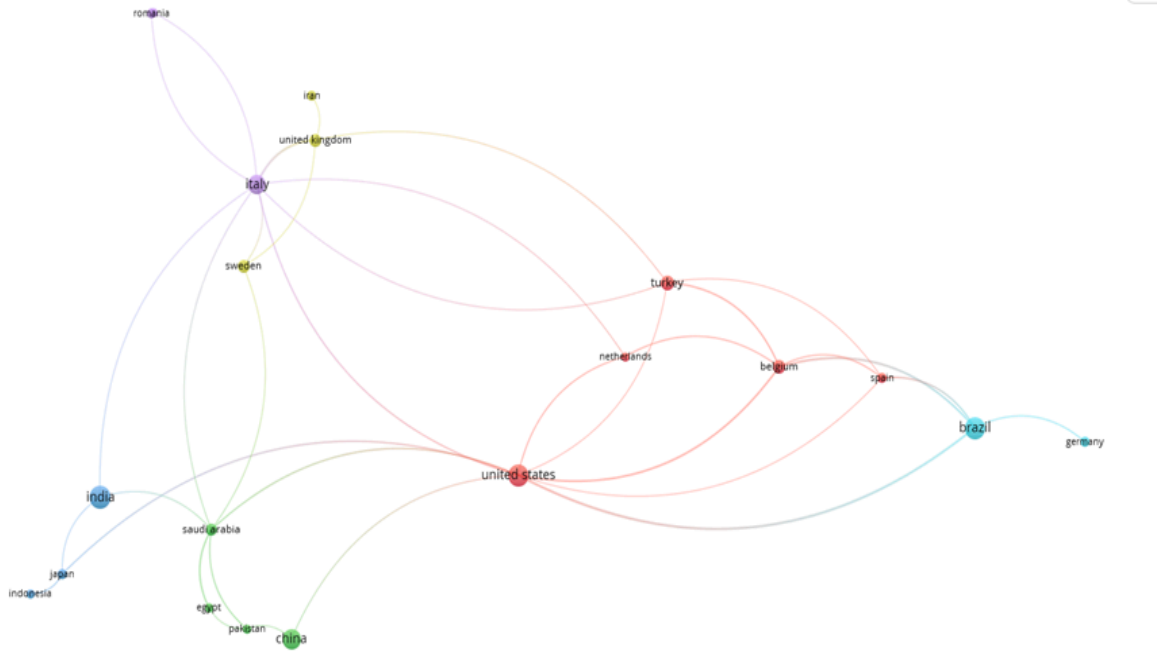
Source: Prepared by the authors (2026).

International Collaboration Patterns

Analysis of country collaboration networks revealed a semi-centralized global research structure (Figure 6). European countries, particularly the Netherlands, Turkey, Belgium, and Spain, appear as dominant hubs, with expanding contributions from Latin America and Asia.

The moderate international co-authorship rate suggests that while collaboration exists, the field remains influenced by regionally concentrated expertise. This may partially explain the consistency observed in methodological approaches and clinical trial designs.

Figure 6 - Country collaboration network generated using VOSviewer (minimum threshold: five documents per country). Nodes represent countries meeting the inclusion criterion, and links illustrate international co-authorship. Node size corresponds to publication output, and link thickness indicates collaboration intensity.



Source: Prepared by the authors (2026).

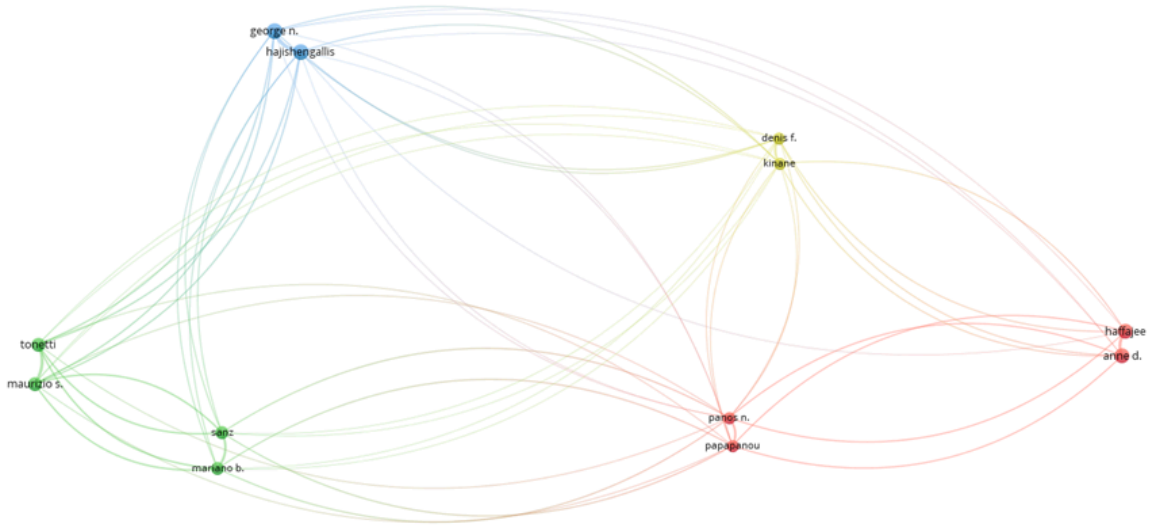
Intellectual Structure and Foundational Knowledge Base

Author co-citation analysis (Figure 7) revealed a cohesive intellectual core composed of highly co-cited researchers who established the biological and clinical rationale for probiotic use in periodontal therapy. The absence of fragmented clusters indicates theoretical convergence rather than competing paradigms.

The cohesive co-citation structure supports the interpretation that the field has reached a certain level of conceptual maturity, with a stable knowledge base guiding subsequent investigation.

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Figure 7 - Author co-citation network constructed using VOSviewer (minimum threshold: fifteen citations). Nodes represent cited authors, and links indicate the frequency with which two authors are cited together in the reference lists of the included documents. Cluster colors represent distinct intellectual groupings within the field.



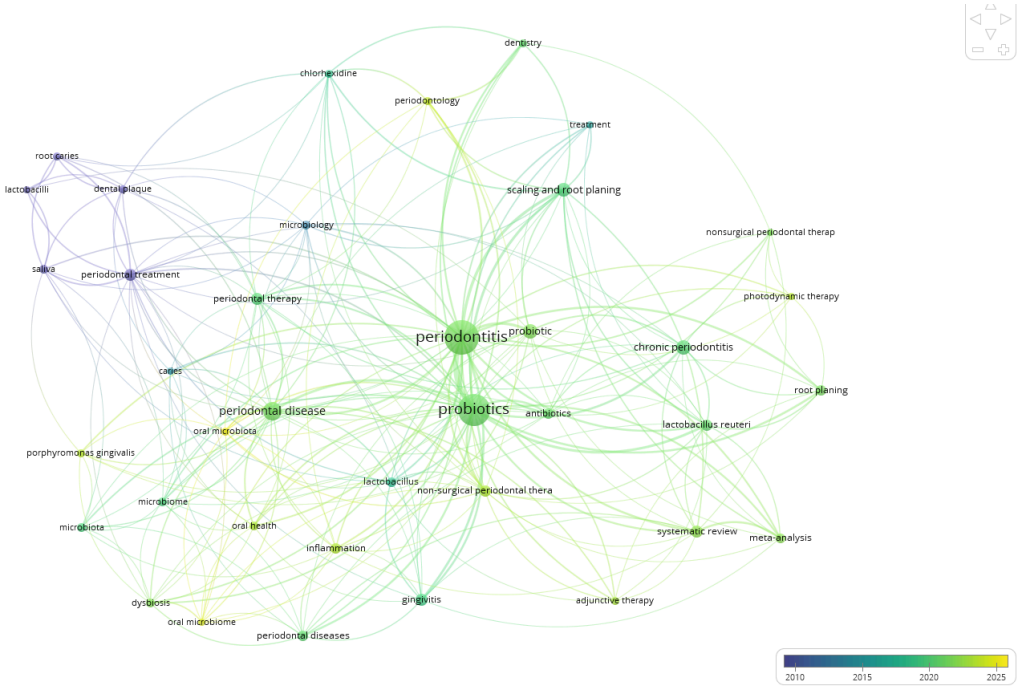
Source: Prepared by the authors (2026).

Temporal Evolution of Research Themes

The overlay visualization (Figure 8) demonstrates a chronological shift in research emphasis. Earlier publications were centered on clinical parameters and non-surgical periodontal therapy, whereas more recent studies increasingly emphasize microbiome modulation, host-microbe interactions, and molecular biomarkers.

These temporal patterns suggest a gradual shift in research emphasis from clinical efficacy evaluation toward mechanistic and translational investigation, reflecting scientific maturation and alignment with contemporary periodontal research trends.

Figure 8 - Overlay visualization of keyword co-occurrence generated using VOSviewer. Node color represents the average publication year of documents in which each keyword appears, illustrating the temporal evolution of research themes. Warmer colors indicate more recent research trends.



Source: Prepared by the authors (2026).

DISCUSSION

The present bibliometric analysis examined the evolution of scientific publications addressing probiotics as adjuncts in periodontal therapy between 1981 and 2026, based on 252 documents retrieved from Scopus and the Web of Science Core Collection. The combined use of two major multidisciplinary citation databases increases dataset representativeness while minimizing database-specific indexing bias, in accordance with current methodological recommendations for bibliometric research in the health sciences (Baas *et al.*, 2020; Donthu *et al.*, 2021). The results revealed a sustained annual growth rate of 3.64% in scientific publications, with a pronounced peak observed in 2025, reflecting the progressive consolidation of this research domain. The growing scientific interest in probiotics seen in this study reflects the increasing recognition of microbiome-modulating strategies in periodontal therapy and underscores the need for well-designed clinical trials to clarify the therapeutic role of probiotics.

From a clinical perspective, the increasing number of publications reflects the growing interest in microbiome-modulating strategies as adjuncts to conventional periodontal therapy. Probiotics have been proposed as potential agents to help restore

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microbial balance and modulate host-microbiome interactions within the periodontal environment (Hajishengallis; Lamont, 2012; Teughels; Loózen; Quirynen, 2011). Nevertheless, current clinical evidence remains heterogeneous about probiotic strains, dosage regimens, treatment duration, and reported clinical outcomes (Hardan *et al*., 2022). Importantly, according to the S3 clinical practice guideline of the European Federation of Periodontology, the routine use of probiotics as adjuncts to subgingival instrumentation is not currently recommended due to limited and inconsistent evidence (Sanz *et al*., 2020). Therefore, additional well-designed randomized clinical trials using standardized protocols are needed to clarify the magnitude and consistency of the potential benefits of probiotics in periodontal therapy.

Bibliometric approaches have also been applied to other areas of dental probiotic research (Cruz *et al*., 2022; Mayta-Tovalino *et al*., 2023). Farias da Cruz *et al*. (2022) examined randomized clinical trials involving probiotic-containing dairy products in dentistry, focusing on clinical trial characteristics and probiotic delivery vehicles. Similarly, Mayta-Tovalino *et al*. (2023) investigated global research trends in probiotics related to oral health. However, these studies addressed probiotics in dentistry or oral health more broadly and did not specifically evaluate their role as adjuncts in periodontal therapy. The present analysis therefore provides a focused evaluation of the global scientific development of probiotics within periodontal treatment.

The temporal publication pattern observed in the present study aligns with the paradigm shift from pathogen-centered models toward ecological dysbiosis frameworks in periodontal pathogenesis (Kilian *et al*., 2016; Lamont; Hajishengallis, 2015). As the understanding of host-microbiome interactions has advanced, interest in microbiome-based therapeutic strategies – including probiotics – has intensified. The accelerated growth observed in recent years reflects the convergence of conceptual advances in oral microbiome ecology and the increasing number of translational clinical studies investigating probiotics as adjunctive therapies in periodontal treatment (Martin-Cabezas *et al*., 2016; Mendonça *et al*., 2024; Mehrnia; Van Dyke, 2026). Within this ecological framework, probiotics have been increasingly investigated as potential modulators capable of restoring microbial balance rather than targeting specific pathogens (Teughels; Loózen; Quirynen, 2011; Lamont; Hajishengallis, 2015).

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The predominance of original research articles, followed by systematic reviews, indicates a field transitioning from exploratory experimentation toward evidence consolidation and synthesis. Such a distribution is characteristic of scientific domains approaching methodological refinement (Niforatos *et al*., 2019). Nevertheless, the bibliometric profile also reflects persistent heterogeneity across clinical trials – particularly regarding probiotic strains, dosage regimens, administration routes, and evaluated endpoints such as probing depth, clinical attachment level, and bleeding on probing (Mendonça *et al*., 2024; Martin-Cabezas *et al*., 2016). From an interpretive perspective, this heterogeneity helps explain the parallel increase in systematic reviews attempting to synthesize inconsistent findings.

The intellectual and collaborative structure of the field revealed additional nuances. Co-authorship network analysis identified distinct collaboration clusters, suggesting the presence of autonomous research communities. Although certain clusters displayed high internal density, indicating established and productive scientific hubs, the limited inter-cluster connectivity, and a moderate international co-authorship rate (20.63%) point to partial collaborative fragmentation. Such patterns are often observed in expanding scientific areas undergoing thematic diversification (van Eck; Waltman, 2010; Donthu *et al*., 2021). Strengthening cross-national collaborative networks may enhance methodological harmonization and help large-scale multicenter trials. Greater international collaboration may also support the development of standardized probiotic protocols and improve the external validity of clinical trials.

Conceptual structure analysis further highlighted the field's multidimensional evolution. Keyword co-occurrence mapping revealed a dominant clinical-inflammatory cluster centered on periodontitis and therapeutic outcomes, alongside an ecological-microbiological cluster reflecting the integration of dysbiosis and microbiome concepts (Lamont *et al*., 2017). The recurrent presence of specific strains – particularly *Lactobacillus reuteri* – suggests a shift from theoretical microbiome modulation toward more targeted, strain-based translational applications. Overlay visualization further showed that microbiome-related terminology has become increasingly prominent in recent years, suggesting convergence with precision medicine paradigms and ecosystem-based therapeutic approaches (Kilian *et al*., 2016; Lamont *et al*., 2021). Such temporal shift indicates that contemporary research is increasingly moving toward microbiome-informed

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therapeutic strategies rather than traditional pathogen-centered models of periodontal therapy.

Co-citation analysis revealed a pluralistic intellectual structure characterized by multiple influential studies rather than dominance by a single seminal publication. Highly cited works formed interconnected citation clusters supporting diverse conceptual trajectories, consistent with patterns of cumulative scientific development (Small, 1973; van Eck; Waltman, 2010). The distributed citation architecture indicates that probiotic-based periodontal therapy is advancing through multiple complementary investigative streams rather than through a single unidirectional theoretical framework. Such intellectual plurality reflects the interdisciplinary nature of probiotic research, which integrates clinical periodontology, microbiology, and host-microbe interaction studies.

From a geographic perspective, scientific production was concentrated in a limited number of countries, with notable prominence of the United States and Brazil within one of the major collaboration clusters. Brazil's high publication productivity reflects its consolidated postgraduate research infrastructure and long-standing tradition in periodontal research. While such concentration shows the presence of well-established scientific hubs, it also underscores the need to broaden global research participation, particularly from underrepresented regions, to improve population representativeness and contextual diversity in periodontal research (Hu *et al*., 2025). Expanding geographic representation is particularly important given the variability in oral microbiome composition, dietary patterns, and healthcare systems across populations.

Analysis of journal distribution revealed that publications are concentrated in leading periodontal journals, including the *Journal of Clinical Periodontology* and the *Journal of Periodontology*. The observed publication pattern suggests increasing visibility of probiotic-based periodontal therapy within the core literature of clinical periodontology. The presence of interdisciplinary journals in microbiology and molecular sciences within the dataset further highlights the translational and interdisciplinary nature of this research domain (Qiu *et al*., 2025). The observed distribution of publications also shows that the topic has transitioned from exploratory microbiological research toward clinically oriented periodontal investigation.

Taken together, these findings indicate that probiotic-based periodontal therapy represents a steadily expanding research field, characterized by sustained publication

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growth, thematic diversification, and progressive scientific consolidation. However, collaborative fragmentation and methodological heterogeneity remain important challenges for the field. Future research should prioritize well-designed international multicenter trials, standardized probiotic protocols, clearly defined strain specificity, and harmonized clinical outcome measures, to improve comparability and strengthen evidence synthesis (Lamont *et al*., 2017; Lamont *et al*., 2021).

Some limitations of this bibliometric analysis should be acknowledged. Although combining Scopus and the Web of Science Core Collection improves dataset coverage, relevant studies indexed exclusively in other databases may not have been captured. In addition, bibliometric results depend on the search strategy and database indexing practices, which may influence document retrieval and citation counts. Citation-based indicators also do not necessarily reflect the methodological quality or clinical relevance of individual studies. Despite these limitations, the combined use of performance analysis and science-mapping techniques provides a useful framework for identifying research trends, collaboration networks, and emerging themes within a scientific field (Donthu *et al*., 2021; Aria; Cuccurullo, 2017).

CONCLUSION

This bibliometric analysis mapped the global scientific literature on probiotics as adjuncts in periodontal therapy from 1981 to 2026. The findings reveal a steady growth in publications, increasing conceptual diversification, and strong representation in leading periodontal journals. Collaboration networks were structured but partially fragmented, while thematic evolution shifted from clinical-inflammatory outcomes toward microbiome-focused research. Despite the expanding literature, substantial methodological heterogeneity persists, highlighting the need for well-designed multicenter clinical trials to strengthen the evidence base.

AUTHOR CONTRIBUTIONS

All authors contributed to the study conception and design, data acquisition, analysis and interpretation and manuscript drafting, and gave their final approval of the version to be published.

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The authors have nothing to report.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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