European Journal of Dental and Oral Health
Vol 6 | Issue 5 | September 2025
ISSN 2684-4443

REVIEW

A Bibliometric Analysis of Research Trends in Herbal Medicine for Periodontal Disease

Simin Li[1,*], Deborah Kreher[2], and Gerhard Schmalz[2]

ABSTRACT

Background: **Periodontal disease represents a significant global oral health challenge, with increasing interest in herbal medicine as an alternative or complementary treatment approach. Despite growing research in this field, no bibliometric analysis has systematically mapped the global research and evolution of herbal medicine for periodontal disease.**

Objective: **This study aimed to analyze global research trends, collaboration patterns, and thematic evolution related to herbal medicine for periodontal disease research through bibliometric analysis of the scientific literature from 1988 to 2025.**

Methods: **Publications were retrieved from the Web of Science Core Collection database using a comprehensive search strategy combining herbal medicine terminologies with periodontal disease terms. Bibliometric analysis was conducted using CiteSpace and VOSviewer to generate visualizations of publication patterns, collaboration networks, and keyword co-occurrence networks. Research clusters were identified through keyword co-occurrence analysis, with silhouette values calculated to evaluate cluster quality.**

Results: **The analysis revealed 257 relevant publications with a significant increase in annual publication output, particularly after 2016. China emerged as the leading country (89 publications), followed by Brazil (34), India (30), and the USA (28). Sichuan University was the most productive institution (15 publications). Journal of Ethnopharmacology was the primary publication venue (23 articles). The keyword co-occurrence analysis identified 13 distinct research clusters with high silhouette values (0.782–0.976), representing diverse research directions including anti-inflammation mechanisms, network pharmacology, alveolar bone loss, and periodontal regeneration. Temporal analysis demonstrated an evolution from basic antimicrobial studies toward more sophisticated molecular mechanisms and computational approaches.**

Conclusion: **Research on herbal medicine for periodontal disease has experienced significant growth and diversification, with emerging research fronts in network pharmacology, anti-inflammatory mechanisms, and tissue regeneration. International collaboration networks have expanded, with Asian countries increasingly contributing to the field. This bibliometric analysis provides a comprehensive overview of the current research landscape and identifies potential directions for future investigation in herbal approaches to periodontal disease management.**

Keywords: Bibliometric analysis, herbal medicine, periodontal disease, research trends.

Submitted: August 16, 2025

Published: September 25, 2025

10.24018/ejdent.2025.6.5.403

[1] *Stomatological Hospital, School of Stomatology, Southern Medical University, China.*
[2] *Department of Conservative Dentistry and Periodontology, Brandenburg Medical School Theodor Fontane (MHB), Germany.*

* ***Corresponding Author:***
e-mail: simin.li.dentist@gmail.com

1. Introduction

The increasing interest in herbal medicine as a treatment for periodontal disease reflects a broader trend towards natural and alternative therapies in healthcare. Periodontal disease, a significant global health concern affecting millions worldwide, has prompted researchers to explore complementary approaches to conventional treatments [1]. Herbal remedies offer multiple therapeutic benefits through their anti-inflammatory, antioxidant, and antibacterial properties, which are particularly relevant in managing periodontal conditions [2]. Studies have demonstrated that plant-based phytochemicals can significantly improve clinical parameters in periodontal treatment, suggesting their potential as to conventional pharmaceuticals [3]. Various herbs, including Glycyrrhiza glabra, Aloe barbadensis Miller, and Curcuma longa, have been identified for their effectiveness in inhibiting periodontal pathogens, preventing plaque formation, and reducing gingival inflammation [3]. These herbal interventions are gaining traction due to their perceived safety profile and reduced side effects compared to conventional treatments [4]. The global research landscape reveals significant contributions from countries like the United States and China, reflecting worldwide recognition of herbal therapies' potential in periodontal care [5]. Despite promising results, challenges remain in fully integrating herbal medicine into mainstream periodontal care, including the need for more high-quality randomized clinical trials to confirm efficacy and safety, as well as a better understanding of mechanisms of action and potential interactions with conventional treatments [6]. As research continues to evolve, balancing traditional knowledge with scientific validation remains essential for ensuring the safe and effective use of herbal therapies in dentistry [7].

Bibliometric analysis has emerged as a valuable methodological approach to systematically evaluate research landscapes across various medical fields, including herbal medicine applications for different conditions. Previous studies have employed this technique to analyze herbal medicine research in chronic kidney disease. [8], cardiovascular diseases [9], [10], pain management [11], male infertility [12], hypertension [13], and cancer [14]. These analyses have consistently revealed China and the United States as leading contributors, while identifying key research hotspots and collaboration patterns specific to each condition. However, despite the growing body of research on herbal medicine for periodontal disease, a comprehensive bibliometric analysis specifically examining this field remains notably absent from the literature. This research gap is particularly significant given the increasing prevalence of periodontal disease globally and the growing interest in herbal alternatives to conventional treatments. Our study addresses this gap by providing the first systematic bibliometric evaluation of the global research landscape in herbal medicine for periodontal disease, offering unique insights into publication trends, international collaboration networks, and thematic evolution that have not been previously documented.

This study aims to conduct a comprehensive bibliometric analysis of global research on herbal medicine for periodontal disease from 1988 to 2025 June. Our objectives include analyzing publication trends, mapping collaboration networks among countries and institutions, identifying core journals and research themes through keyword co-occurrence analysis, and detecting emerging

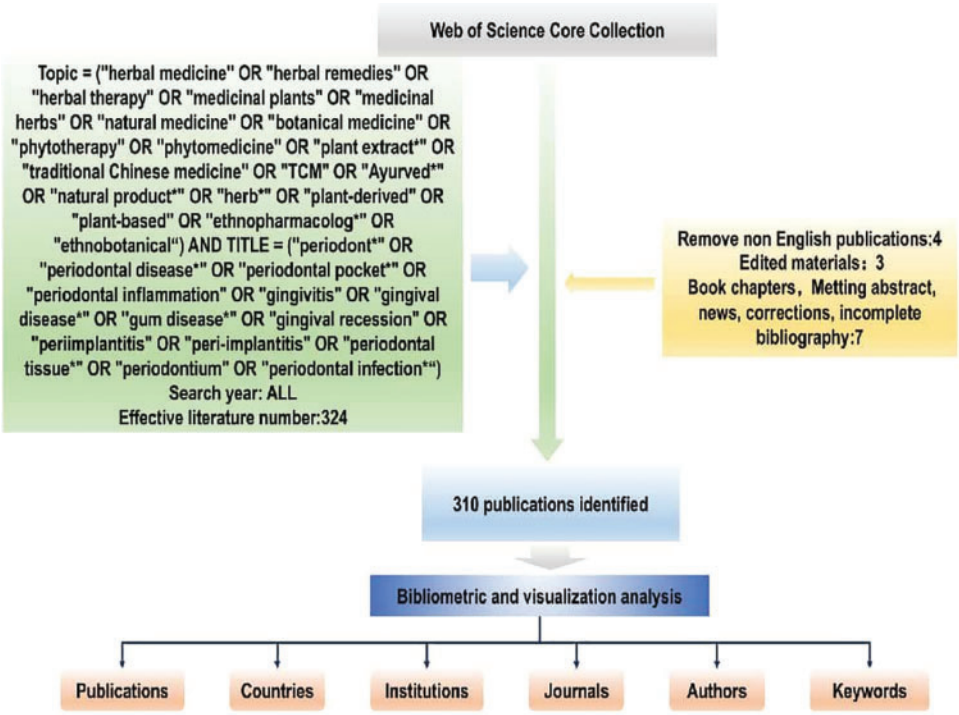

Fig. 1. PRISMA-style flowchart.

research fronts through timeline visualization. By achieving these objectives, we seek to provide a systematic overview of the current research landscape and identify potential directions for future investigation that could advance the evidence-based application of herbal medicine in periodontal disease management.

2. Methods

2.1. Data Collection and Search Strategy

Fig. 1 illustrates the systematic literature selection process employed in this bibliometric analysis. A comprehensive search strategy was implemented in the Web of Science Core Collection database, combining herbal medicine terminologies (Topic = "herbal medicine" OR "herbal remedies" OR "medicinal plants" OR "traditional Chinese medicine" OR "phytotherapy" OR "plant extract∗" OR "Ayurved∗" OR "natural product∗" OR "herb∗" OR other related terms) with periodontal disease terms (Title = "periodont∗" OR "periodontal disease∗" OR "gingivitis" OR "gum disease∗" OR "periodontal pocket∗" OR other related terms). The initial search yielded 324 publications, from which 14 records were excluded (4 non-English publications, 3 edited materials, and 7 book chapters, meeting abstracts, news, corrections, or incomplete bibliographies), resulting in 310 publications for bibliometric and visualization analysis across six analytical dimensions: publications, countries, institutions, journals, authors, and keywords. To ensure data quality and reliability, all retrieved publications underwent independent assessment by three authors (S.L., D.K., and G.S.) using predefined inclusion and exclusion criteria. Any discrepancies in study selection were resolved through discussion and consensus among the research team.

2.2. Bibliometric Analysis Tools and Methods

The bibliometric analysis was conducted using CiteSpace (version 6.1.R2), a visualization software for analyzing scientific literature and identifying knowledge domains. We employed multiple analytical modules to generate visualizations of publication patterns, including annual trends, collaboration networks, and keyword co-occurrence networks. For network analysis, parameters were set with a time slice of one year and a selection criterion of the top 50 items per slice. We calculated bibliometric indicators, including citation counts, h-index, and collaboration index, to assess research impact and collaborative patterns.

2.3. Co-Authorship and Country Analysis

Co-authorship analysis was performed to map collaboration patterns among researchers, institutions, and countries in the field. We constructed network maps where nodes represented authors, institutions, or countries, while edges indicated collaborative relationships based on co-authored publications. Centrality measures, including degree centrality, betweenness centrality, and closeness centrality, were calculated to identify key contributors. The geographic distribution of research was visualized using density maps, highlighting countries with significant research output and identifying potential geographical clusters of expertise.

2.4. Keyword Co-Occurrence and Cluster Analysis

Keyword co-occurrence analysis was conducted to identify core research themes within the field. Author keywords and KeyWords Plus were extracted and standardized to merge synonyms and variations of the same concept. The co-occurrence network was generated with nodes representing keywords and edges indicating their co-appearance in publications. Hierarchical clustering analysis using the VOSviewer algorithm was performed to group related keywords into distinct research clusters. We identified 13 major clusters representing various research directions in herbal medicine for periodontal disease treatment.

2.5. Research Trend and Burst Detection Analysis

We employed burst detection analysis to identify research frontiers and the temporal evolution of topics in herbal medicine for periodontal disease. Using Kleinberg's burst detection algorithm in CiteSpace, we detected keywords that experienced sudden increases in frequency over specific periods, indicating emerging research interests. Each detected keyword burst was characterized by its strength, starting year, ending year, and duration. Timeline visualizations were generated to chronologically map the emergence, persistence, and decline of research themes from 2000 to 2025.

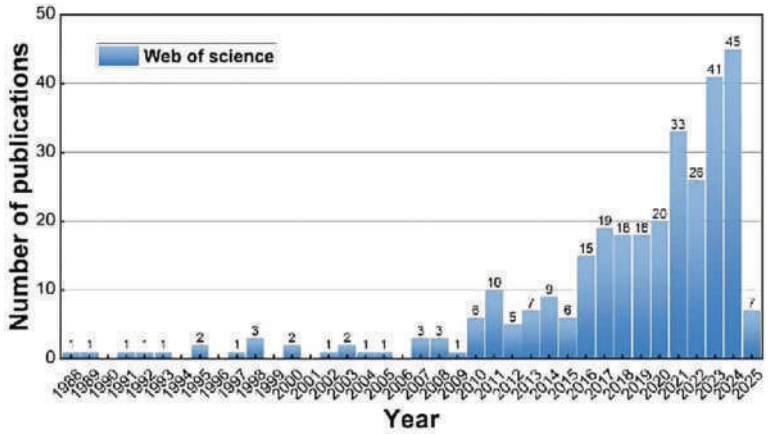

Fig. 2. Annual distribution of publications on herbal medicine for periodontal disease indexed in Web of Science from 1988 to 2025.

TABLE I: Top 25 Keywords with the Strongest Citation Bursts in Herbal Medicine for Periodontal Disease Research

Year	Publication number
2024	45
2023	41
2021	33
2022	26
2020	20
2017	19
2018	18
2019	18
2016	15
2011	10
2014	9
2013	7
2025	7
2010	6
2015	6
2012	5
1998	3
2007	3
2008	3
1995	2
2000	2
2003	2
1988	1
1989	1
1991	1
1992	1
1993	1
1997	1
2002	1
2004	1
2005	1
2009	1

3. Results

3.1. Annual Publication Trends

Fig. 2 and Table I illustrate the annual distribution of publications on herbal medicine for periodontal disease from 1988 to 2025 indexed in the WoS database. The publication output remained relatively low from 1988 to 2004, with fewer than 3 publications per year. A gradual increase began around 2005, followed by more sustained growth starting in 2007. The publications exhibited a moderate increase from 2010 (6 publications) to 2015 (6 publications). A substantial acceleration occurred from 2016 (15 publications) onwards, with publication numbers rising to 19 in 2017 and remaining at 18 publications in both 2018 and 2019. The highest productivity was observed in recent years, with notable peaks in 2021 (33 publications), 2023 (41 publications), and 2024 (45 publications), representing the maximum annual output in the analyzed timeframe. The final data point shows a decrease to 7 publications in 2025, which likely reflects incomplete data collection for the current year.

3.2. Country Distribution and Collaboration

The international collaboration and publication distribution in herbal medicine for periodontal disease research demonstrated significant geographical variations (Fig. 3, Table II). China emerged as the dominant contributor with 89 publications, clearly visible as the largest node in the center of the collaboration network, with extensive connections to other countries. Brazil, India, and the USA followed as major contributors with 34, 30, and 28 publications, respectively (Table II), also appearing as prominent nodes with multiple collaborative links in the network visualization. The second tier of productive countries included Iran (19 publications), South Korea (17 publications), Germany, Italy, Japan, and Saudi Arabia (each with 13 publications), as well as Malaysia (11 publications) and Thailand (10 publications) (Fig. 3, Table II). The collaboration network revealed dense interconnections between leading countries, with particularly strong collaborative relationships observed between China and other productive nations.

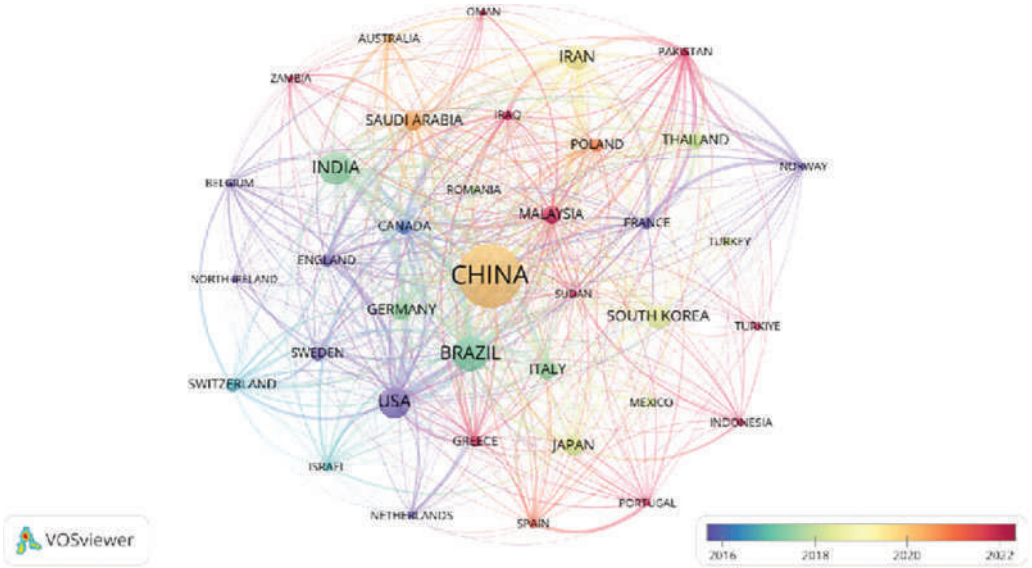

Fig. 3. Visualization of international collaboration network in herbal medicine for periodontal disease research.

TABLE II: Countries with Publication Counts ≥10 in Herbal Medicine for Periodontal Disease Research

Label	Weight<Documents>
CHINA	89
BRAZIL	34
INDIA	30
USA	28
IRAN	19
SOUTH KOREA	17
GERMANY	13
ITALY	13
JAPAN	13
SAUDI ARABIA	13
MALAYSIA	11
THAILAND	10

3.3. Author Distribution and Collaboration

The author collaboration network and publication distribution in herbal medicine for periodontal disease research revealed distinct collaborative clusters and productive researchers (Fig. 4, Table III). Baharin, Badiah emerged as the most productive with 5 publications, visible as a prominent node in the collaboration network. Mohd, Nurulhuda, followed with 4 publications, while 23 other researchers each contributed 3 publications to the field, including Adam, Fara Azwin; Ahmad, Irfan; Gui, Shuangying; Guo, Jian; Hu, Tao; Kim, Mi Hye; Lee, Hye Ji (Table III). The visualization demonstrated several well-defined collaborative groups distinguished by different colors, with researchers like Gui, Jian; Wang, Guichun; and Li, Jiaxin forming a noticeable cluster (shown in red) representing more recent collaborations (2022–2024). Another significant collaborative group included Ahmad, Irfan; Baharin, Badiah; and Rani, Haslina (shown in orange-yellow), while researchers such as Del Corso, M.; Ehrenfest, D.M. Dohan; and Sammartino, G. formed a distinct cluster (shown in purple) representing earlier collaborations (around 2016) (Fig. 4).

3.4. Institutional Distribution and Collaboration

The institutional collaboration network and publication distribution in herbal medicine for periodontal disease research exhibited clear patterns of productivity and collaboration (Fig. 5, Table IV). Sichuan University emerged as the leading institution with 15 publications, appearing as the largest node, centrally positioned in the collaboration network. Mashhad University of Medical Sciences and University of Tehran Medical Sciences each contributed 7 publications, both visible as prominent nodes in the network. Four institutions followed with 6 publications each: Kyung Hee University, University of Bern, University Federal Ceara, and University Kebangsaan Malaysia. King Khalid University, Shanghai Jiao Tong University, and the University of Sao Paulo each contributed 5 publications. Five institutions with 4 publications each, while 27 other institutions contributed 3 publications each to the field (Fig. 5, Table IV). The visualization revealed several distinct collaborative clusters with varying temporal characteristics, indicated by the color gradient from blue (around 2010) to red (approaching 2025). Notable collaborative relationships were observed between Sichuan University and other Chinese institutions such as Shanghai Jiao Tong University and Anhui Academy of Chinese Medicine (shown in red), indicating more recent collaborations (Fig. 5). Earlier collaborative networks (shown in blue and purple) were formed among institutions like the University of California, Lob5 Foundation Research, and the University of Naples Federico II.

3.5. Journal Distribution and Co-Citation

The journal publication distribution and co-citation network in herbal medicine for periodontal disease research revealed distinct publication patterns and journal relationships (Fig. 6, Table V). Journal of Ethnopharmacology emerged as the most prominent publication venue with 23 articles, visible as a large central node in the co-citation network. Journal of Herbal Medicine and Molecules each published 10 articles, forming significant nodes with strong co-citation links to other journals. Specialized periodontal journals also contributed substantially to the field,

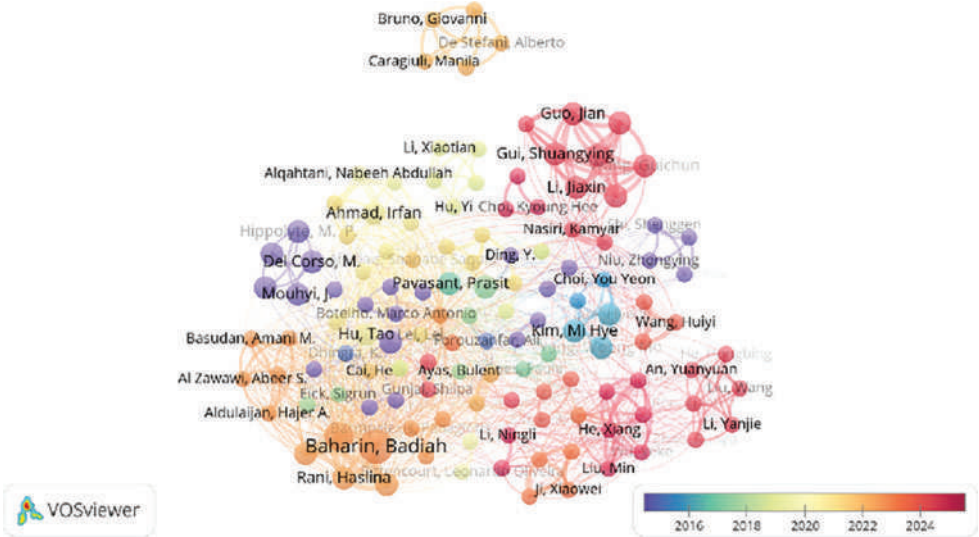

Fig. 4. Visualization of author collaboration network in herbal medicine for periodontal disease research.

TABLE III: Authors with Publication Counts ≥3 in Herbal Medicine for Periodontal Disease Research

Label	Weight<Documents>
Baharin, Badiah	5
Mohd, Nurulhuda	4
Adam, Fara Azwin	3
Ahmad, Irfan	3
Del Corso, M.	3
Ehrenfest, D. M. Dohan	3
Gui, Shuangying	3
Guo, Jian	3
Hippolyte, M. P.	3
Hu, Tao	3
Kim, Mi Hye	3
Lee, Hye Ji	3
Li, Jiaxin	3
Mouhyi, J.	3
Pavasant, Prasit	3
Peng, Chengjun	3
Pradeep, A. R.	3
Rani, Haslina	3
Sammartino, G.	3
Tang, Maomao	3
Wang, Guichun	3
Wang, Yuxiao	3
Yang, H.	3
Yang, Woong Mo	3
Yusof, Mohd Yusmiaidil Putera Mohd	3

with Journal of Periodontal Research (9 publications), Clinical Oral Investigations (7 publications), International Journal of Dental Hygiene (7 publications), Journal of Clinical Periodontology (7 publications), and Journal of Periodontology (7 publications) all appearing as notable nodes in the network (Table V). The journal Nutrients also published 7 articles in this field. The color gradient in the visualization indicated temporal changes in citation patterns, with blue representing earlier citations (around 2010) and red showing more recent citation relationships (approaching 2025) (Fig. 6). The network revealed several distinct journal clusters, with specialized periodontal journals forming one interconnected group, while journals focused on natural products and pharmacology formed another cluster, demonstrating the interdisciplinary nature of this research field.

3.6. *Keyword Distribution and Co-Occurrence*

As shown in Fig. 7 and Table VI, the keyword co-occurrence analysis revealed that the most occurring keyword was "disease" with 53 occurrences (first appearing in 2000), followed by "periodontal disease" with 47 occurrences (first appearing in 1992). Other high-frequency keywords included "inflammation" (35 occurrences, first appearing in 2007), "porphyromonas gingivalis" (33 occurrences, first appearing in 1993), and "efficacy" (32 occurrences, first appearing in 1998) (Fig. 7, Table VI). The visualization depicted these high-frequency keywords as larger nodes in the co-occurrence network, with "disease," "periodontitis," and "inflammation" prominently positioned in the central area (Fig. 7, Table VI). The keyword co-occurrence network displayed several interconnected clusters differentiated by colors, with the color gradient representing temporal evolution from blue (2016) to red (2021). Keywords related to microbiology, such as "porphyromonas gingivalis" and "antibacterial activity" (26 occurrences), formed distinct clusters, while treatment-related terms like "efficacy" and "chlorhexidine" (17 occurrences) formed another group. Research methodology terms such as "in vitro" (24 occurrences) and analytical terms like "expression" (28 occurrences) and "oxidative stress" (26 occurrences) were also prominently represented in the network, demonstrating the diverse approaches in this research field.

3.7. *Keyword Cluster Analysis*

As shown in Fig. 8 and Table VII, the keyword clustering analysis identified 13 distinct clusters (cluster 0–12). Cluster 0 (labeled "anti-inflammation") contained 42 keywords with a high silhouette value of 0.948 and a mean

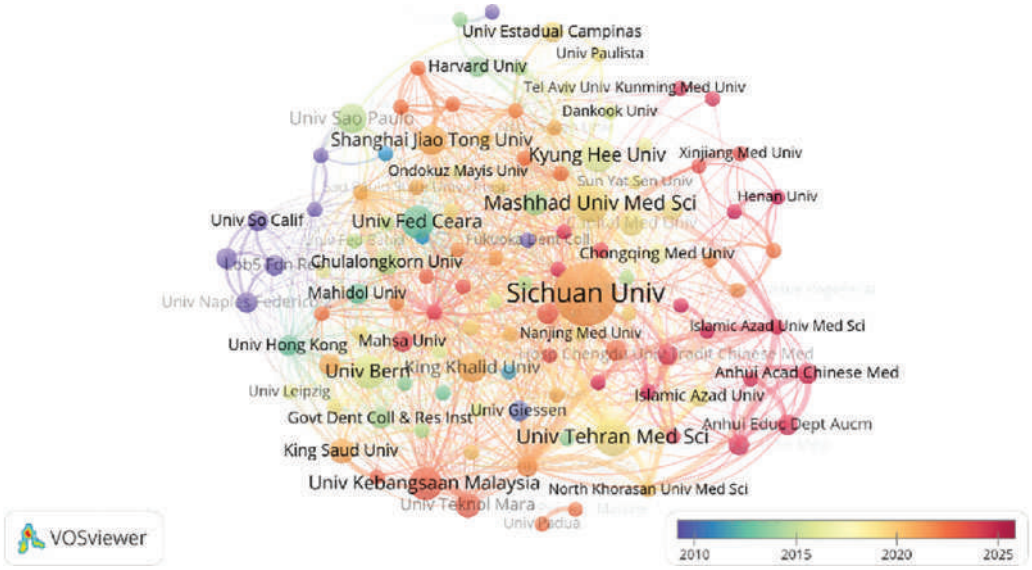

Fig. 5. Visualization of institutional collaboration network in herbal medicine for periodontal disease research.

TABLE IV: Institutions with Publication Counts ≥3 in Herbal Medicine for Periodontal Disease Research

Label	Weight<Documents>
Sichuan Univ	15
Mashhad Univ Med Sci	7
Univ Tehran Med Sci	7
Kyung Hee Univ	6
Univ Bern	6
Univ Fed Ceara	6
Univ Kebangsaan Malaysia	6
King Khalid Univ	5
Shanghai Jiao Tong Univ	5
Univ Sao Paulo	5
Capital Med Univ	4
Chulalongkorn Univ	4
King Saud Univ	4
Univ Teknol Mara	4
Univ Toronto	4
Anhui Acad Chinese Med	3
Anhui Educ Dept Aucm	3
Anhui Univ Chinese Med	3
Chongqing Med Univ	3
Govt Dent Coll & Res Inst	3
Harbin Med Univ	3
Harvard Univ	3
Hosp Chengdu Univ Tradit Chinese Med	3
Islamic Azad Univ	3
Kyungpook Natl Univ	3
Lob5 Fdn Res	3
Mahidol Univ	3
Mahsa Univ	3
Manipal Acad Higher Educ	3
Shahid Beheshti Univ Med Sci	3
Univ Estadual Campinas	3
Univ Giessen	3
Univ Gothenburg	3
Univ Hong Kong	3
Univ Naples Federico 2	3
Univ So Calif	3
Zhejiang Univ	3

publication year of 2009, focusing primarily on bone regeneration and Chinese herbal medicine applications. Cluster 1 (labeled "in vitro") comprised 41 keywords with a silhouette value of 0.782 and a mean publication year of 2011, emphasizing laboratory studies of natural products and antibacterial properties. Cluster 2 (labeled "network pharmacology") contained 40 keywords with a silhouette value of 0.838 and a mean publication year of 2016, representing more recent research trends in computational approaches and specific medicinal plants like Salvadora persica. Cluster 3 (labeled "alveolar bone loss") included 39 keywords with a silhouette value of 0.874 and a mean publication year of 2010, focusing on bone-related aspects and specific compounds like resveratrol. Clusters 4-12 represented additional research directions including chronic periodontitis (37 keywords, silhouette 0.823, mean year 2014), zinc citrate applications (33 keywords, silhouette 0.938, mean year 2000), aloe vera studies (32 keywords, silhouette 0.923, mean year 2008), anti-inflammatory activity (30 keywords, silhouette 0.948, mean year 2020), osteogenic differentiation (28 keywords, silhouette 0.895, mean year 2010), alkaline phosphatase (22 keywords, silhouette 0.872, mean year 2016), periodontal ligament cells (18 keywords, silhouette 0.973, mean year 2012), znps applications (18 keywords, silhouette 0.957, mean year 2011), and drug delivery systems (15 keywords, silhouette 0.976, mean year 2010).

3.8. *Timeline View of Keyword Clusters*

Fig. 9 displays a timeline visualization of the 13 keyword clusters identified in herbal medicine for periodontal disease research, generated using CiteSpace. The horizontal axis represents the chronological progression of research from left to right, while clusters are arranged vertically with connecting lines indicating relationships between research themes across periods. Each cluster is color-coded and labeled (#0-#12) with its main research focus: #0 (anti inflammation), #1 (in vitro), #2 (network pharmacology), #3 (alveolar bone loss), #4 (chronic periodontitis), #5 (zinc citrate), #6 (aloe vera), #7 (anti-inflammatory activity), #8 (osteogenic differentiation), #9 (alkaline phosphatase), #10 (periodontal ligament cells), #11 (znps), and #12 (injectables). The size of nodes within each cluster corresponds to the frequency or importance of specific keywords. Earlier research themes appear predominantly on the left side of the timeline (clusters #5, #6), while more recent research directions are positioned toward the right (clusters #2, #7, #9). The visualization reveals temporal relationships between research themes, with some clusters showing continuous development across the timeline while others demonstrate more concentrated activity during specific periods.

3.9. *Temporal Distribution of Keywords with the Strongest Citation Bursts*

Fig. 10 presents the top 25 keywords with the strongest citation bursts in herbal medicine for periodontal disease research between 1988 and 2025. "Network pharmacology" demonstrated the highest burst strength (3.57) beginning in 2022 and continuing through 2025. "Bone to" showed the second highest burst strength (3.77) with the burst occurring from 2016 to 2019. "Efficacy" ranked third with a burst strength of 3.74, with its burst period from 2020 to 2022. "Inflammation" exhibited a burst strength of 3.32, with the burst occurring between 2016 and 2020. "Cytokine" showed a burst strength of 3.07, with the burst period spanning from 2013 to 2019. The earliest keyword burst was observed for "mouthrinse" (burst strength 2.55) occurring from 2008 to 2012, while the most recent burst was for "oxidative stress" (burst strength 2.5) starting in 2023 and continuing through 2025. The majority of keyword bursts occurred after 2016, with particularly intense burst activity between 2020 and 2022. Several keywords, including "network pharmacology," "molecular docking," and "natural product," show burst periods extending to the end of the study timeframe in 2025.

4. Discussion

This bibliometric analysis of research trends in herbal medicine for periodontal disease reveals a significant paradigm shift from traditional empirical approaches

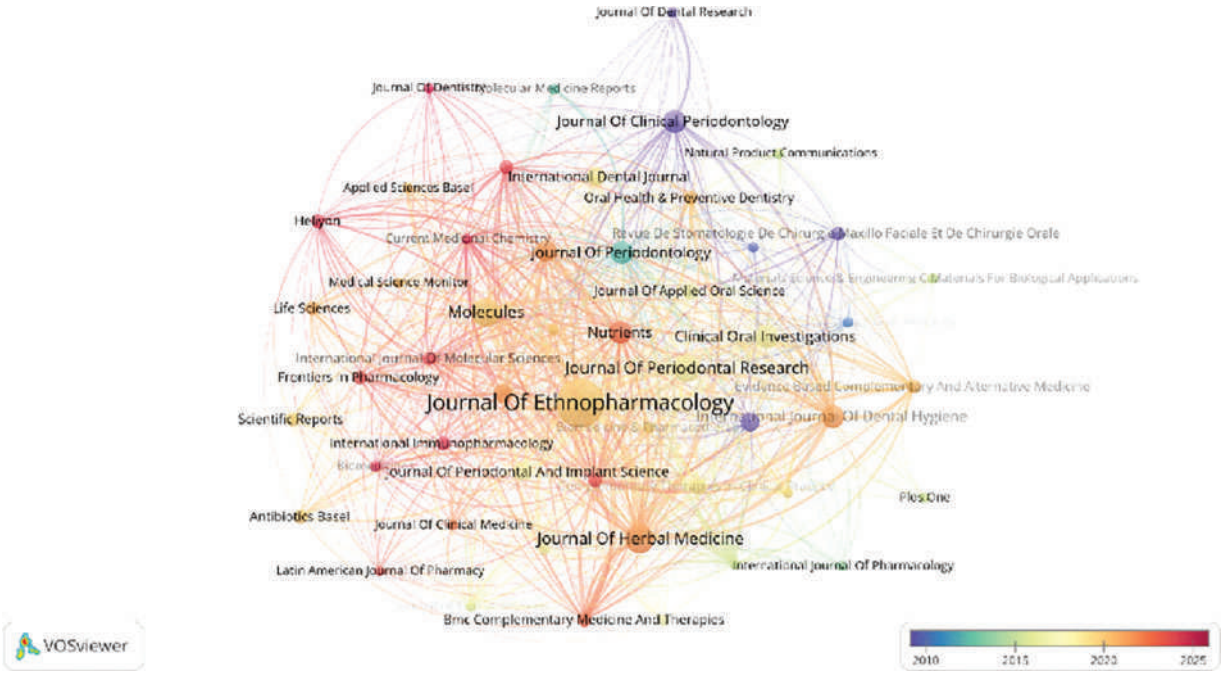

Fig. 6. Visualization of journal co-citation network in herbal medicine for periodontal disease research.

toward scientific mechanism-based investigations. The emergence of "network pharmacology" (2022–2025, strength 3.57) and "molecular docking" (2022–2025, strength 2.77) as high-strength burst keywords indicates researchers' increasing focus on understanding the complex components and multi-target mechanisms of herbal medicines. Network pharmacology approaches enable researchers to explore synergistic interactions between

TABLE V: Journals with Publication Counts ≥3 in Herbal Medicine for Periodontal Disease Research

Journal	Weight<Documents>
Journal of Ethnopharmacology	23
Journal of Herbal Medicine	10
Molecules	10
Journal of Periodontal Research	9
Clinical Oral Investigations	7
International Journal of Dental Hygiene	7
Journal of Clinical Periodontology	7
Journal of Periodontology	7
Nutrients	7
Antioxidants	6
Archives of Oral Biology	5
International Dental Journal	5
Journal of Periodontal and Implant Science	5
Phytotherapy Research	5
Complementary Therapies in Clinical Practice	4
Journal of Applied Oral Science	4
Antibiotics Basel	3
Bmc Complementary Medicine and Therapies	3
Bmc Oral Health	3
Evidence Based Complementary and Alternative Medicine	3
Frontiers in Pharmacology	3
Heliyon	3
International Immunopharmacology	3
International Journal of Molecular Sciences	3
Life Sciences	3
Microorganisms	3
Oral Health & Preventive Dentistry	3
Revue De Stomatologie De Chirurgie Maxillo Faciale Et De Chirurgie Orale	3
Scientific Reports	3

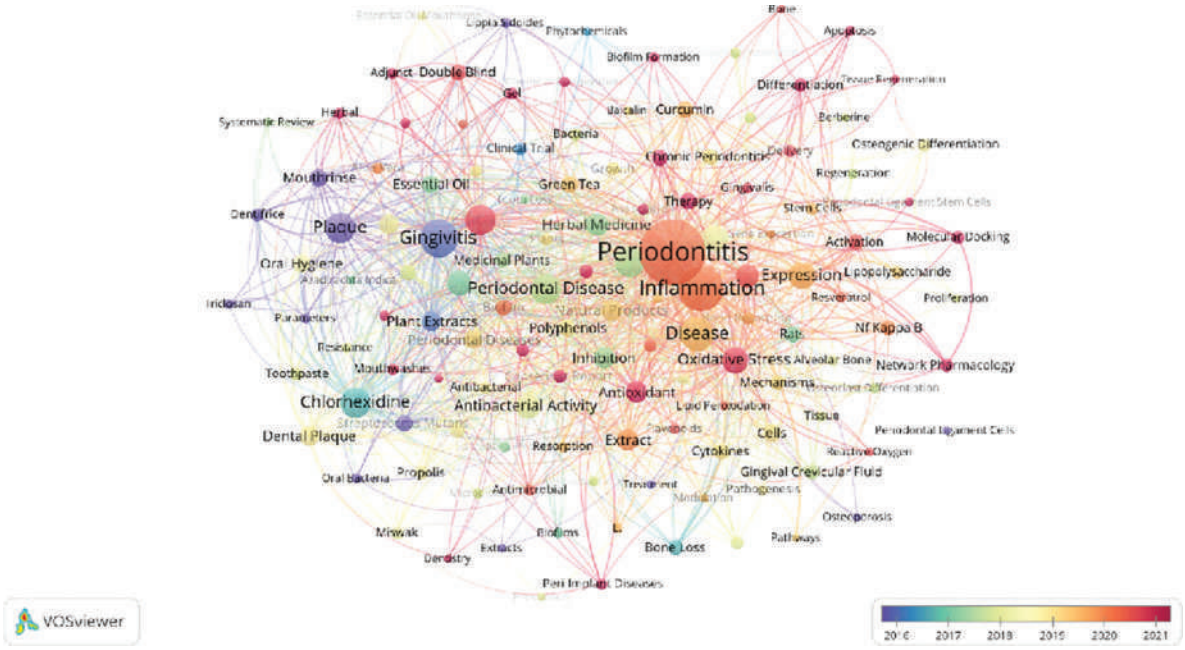

Fig. 7. Visualization of keyword co-occurrence network in herbal medicine for periodontal disease research.

TABLE VI: Keywords with Frequency ≥10 in Herbal Medicine for Periodontal Disease Research

Centrality	Keywords	Year	Frequency
0.15	Disease	2000	53
0.19	Periodontal disease	1992	47
0.04	Inflammation	2007	35
0.08	Porphyromonas gingivali	1993	33
0.01	Efficacy	1998	32
0.03	Expression	2012	28
0.15	Antimicrobial activity	2003	27
0.25	Antibacterial activity	2003	26
0.04	Oxidative stress	2010	26
0.07	in vitro	2000	24
0.2	Alveolar bone lo	2005	23
0.21	Extract	2000	23
0.08	Essential oil	2007	21
0.06	Herbal medicine	2002	19
0.17	Natural product	2002	19
0.12	Chlorhexidine	1991	17
0.03	Inhibition	1991	16
0.17	Plaque	2000	15
0.03	Plant extract	1991	15
0.02	Dental plaque	2010	14
0.02	Antioxidant	2019	14
0.1	Activation	2013	12
0	Chronic periodontiti	2012	11
0.06	Cell	2012	11
0.04	Medicinal plant	2003	10

multiple herbal components and their targets, providing a holistic theoretical foundation for the herbal treatment of periodontal disease [15]. Meanwhile, the widespread application of molecular docking techniques (strength 2.77) has greatly facilitated the prediction of binding affinities between active herbal compounds and periodontal pathogens or host proteins, offering herbal formulation design. [16]. Furthermore, the significant growth in research on "mechanisms" (2018–2020, strength 2.77) and "chemical composition" (2020–2021, strength 2.06) further confirms the shift from traditional experience-based usage toward evidence-based phytotherapy. [17], with various alkaloids, flavonoids, and tannins being identified as key contributors to the antimicrobial and anti-inflammatory properties of herbal treatments [18], [19]. Although the trend toward scientific exploration is evident, integrating traditional knowledge with modern scientific methods remains an important direction for future research. Recent studies also emphasize the need to address safety assessments of herbal medicines to ensure

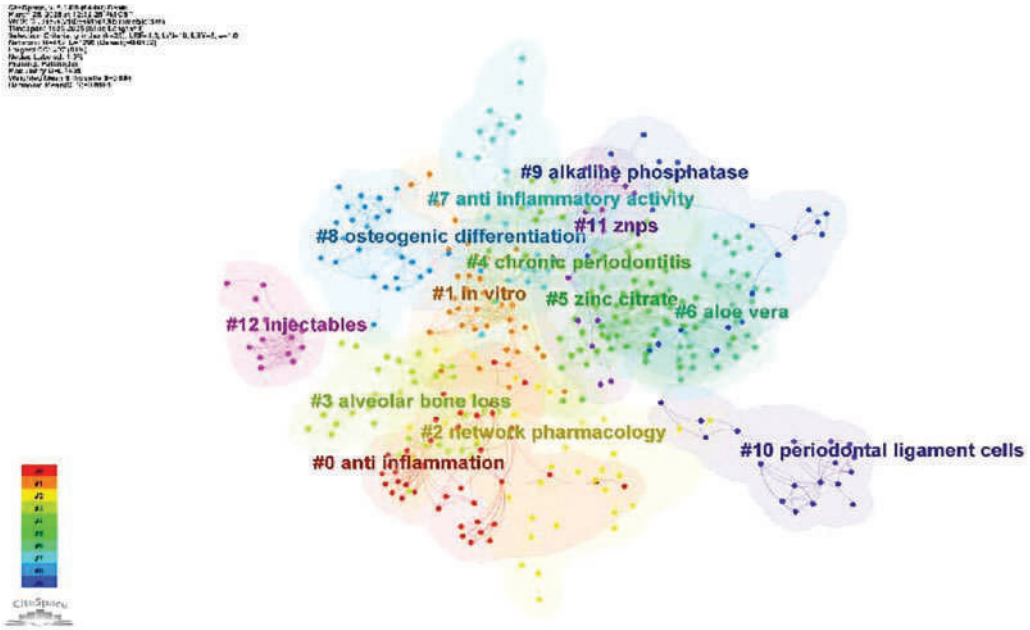

Fig. 8. Visualization of keyword clusters in herbal medicine for periodontal disease research.

TABLE VII: Statistical Parameters of Keyword Clusters in Herbal Medicine for Periodontal Disease Research

Cluster ID	Size	Silhouette	Mean (Year)	Top Terms (log-likelihood)	Top Terms (LSI)
0	42	0.948	2009	Anti inflammation (10.88, 0.001); bone regeneration (10.88, 0.001); periodontal regeneration (7.2, 0.01); chinese herbal medicine (5.43, 0.05); osteoblast (5.43, 0.05)	Bone regeneration; periodontal regeneration; animal studies; therapeutic use; zanthoxylum piperitum | anti inflammation; experimental periodontitis; traditional chinese medicine; periodontal therapy; chi tong ning
1	41	0.782	2011	in vitro (7.62, 0.01); alternative medicine (7.62, 0.01); natural products (6.84, 0.01); antibacterial activity (5.86, 0.05); dentistry (4.12, 0.05)	Periodontal disease; dental caries; antimicrobial activities; justicia glauca; silver nanoparticles | antibacterial activity; medicinal plant; periodontopathic bacteria; metal oxide nanoparticles; metal nanoparticles
2	40	0.838	2016	Network pharmacology (21.97, 1.0E-4); molecular docking (18.92, 1.0E-4); herbal medicine (12.12, 0.001); salvadora persica (9.35, 0.005); azadirachta indica (9.1, 0.005)	Molecular docking; network pharmacology; alveolar bone loss; uplc q tof ms; bioconverted milk | herbal medicine; dental plaque; clinical trial; human periodontal ligament stem cells; alpha glucosidase
3	39	0.874	2010	Alveolar bone loss (14.34, 0.001); estrogen deficiency (6.27, 0.05); resveratrol (6.03, 0.05); bone mineral content (4.95, 0.05); rat (4.95, 0.05)	Alveolar bone loss; physalis angulata; human periodontal ligament stem cells; intestinal barrier; lycii radicis | periodontal disease; innate immunity; postmenopausal osteoporosis; matrix metalloproteinase; medicinal herbs
4	37	0.823	2014	Chronic periodontitis (13.63, 0.001); propolis (9.35, 0.005); phytotherapy (9.29, 0.005); periodontal pocket (9.07, 0.005); lippia sidoides (7.33, 0.01)	Periodontal disease; blind; grape seed; herbal toothpaste; periodontal pocket | dental plaque; plant extracts; periodontal pocket; myracrodruon urundeuva; adjunctive therapy
5	33	0.938	2000	Zinc citrate (9.52, 0.005); periodontal disease (6.94, 0.01); periodontitis (6.68, 0.01); triclosan (5.9, 0.05); antimicrobial agents (4.75, 0.05)	Periodontal disease; porphyromonas gingivalis; actinomyces viscosus; clinical trial; biofilm vitality | plaque; gingivitis; jordan; triclosan; toothpaste
6	32	0.923	2008	Aloe vera (13.48, 0.001); systematic review (8.97, 0.005); chlorhexidine (7.77, 0.01); plaque (5.13, 0.05); gingivitis (5.08, 0.05)	Plant extracts; antibacterial activity; medicinal plants; periodontal diseases; dental biofilm | chlorhexidine; children; adolescents; triphala; adults
7	30	0.948	2020	Anti inflammatory activity (5.24, 0.05); dental caries (5.24, 0.05); quorum sensing (5.23, 0.05); north kalimantan (5.23, 0.05); bioactive compounds (5.23, 0.05)	Periodontal disease; matrix metalloproteinases; bioactive compounds; immune modulation; antimicrobial peptides | periodontal diseases; dental biofilm; dental hygiene aid; antibacterial activity; garcidepsidone b
8	28	0.895	2010	Osteogenic differentiation (6.23, 0.05); dental (4.93, 0.05); gum bleeding (4.93, 0.05); gingival inflammation (4.93, 0.05); h 1 nuclear magnetic resonance (4.93, 0.05)	Oral hygiene; salvadora persica; natural product; plaque; beta catenin | osteogenic differentiation; beta catenin; periodontal ligament stem cells; glycemic control; systemic inflammation

TABLE VII: (CONTINUED)

Cluster ID	Size	Silhouette	Mean (Year)	Top Terms (log-likelihood)	Top Terms (LSI)
9	22	0.872	2016	Alkaline phosphatase (12.69, 0.001); oral microbiota (6.32, 0.05); attachment loss (6.32, 0.05); human periodontal ligament fibroblasts (6.32, 0.05); natural ingredients (6.32, 0.05)	Environmental factors; oral microbiota; systemic diseases; immune responses; natural ingredients | alkaline phosphatase; periodontal ligament cells; cell proliferation; human periodontal ligament fibroblasts; environmental factors
10	18	0.973	2012	Periodontal ligament cells (12.29, 0.001); rhizoma coptidis (7.99, 0.005); protein synthesis (7.99, 0.005); biodegradable (7.99, 0.005); angiogenic (7.99, 0.005)	Periodontal ligament cells; rhizoma drynariac; radix scutellariae; protein synthesis; rhizoma coptidis | propolis flavone; periodontal ligament stem cells; tissue regeneration; lyotropic liquid crystals; calcium silicate
11	18	0.957	2011	znps (6.72, 0.01); progression of periodontitis (6.72, 0.01); hplc (6.72, 0.01); collagen traditional chinese medicines (6.72, 0.01); biosynthesis (6.72, 0.01)	Microbiota; znps; optimization; biosynthesis; stability | periodontal disease; risk factor; traditional chinese medicines; dental regeneration; periodontal ligament fibroblast
12	15	0.976	2010	Injectables (8.65, 0.005); hydrogels (8.65, 0.005); oral drug delivery (8.65, 0.005); buccal (8.65, 0.005); non surgical periodontal treatment (npt) (8.65, 0.005)	Natural products; oral drug delivery; biodegradable polymers; mechanical properties; non surgical periodontal treatment | meta analysis; periodontal disease; non surgical periodontal treatment; natural products; adjunctive periodontal treatment

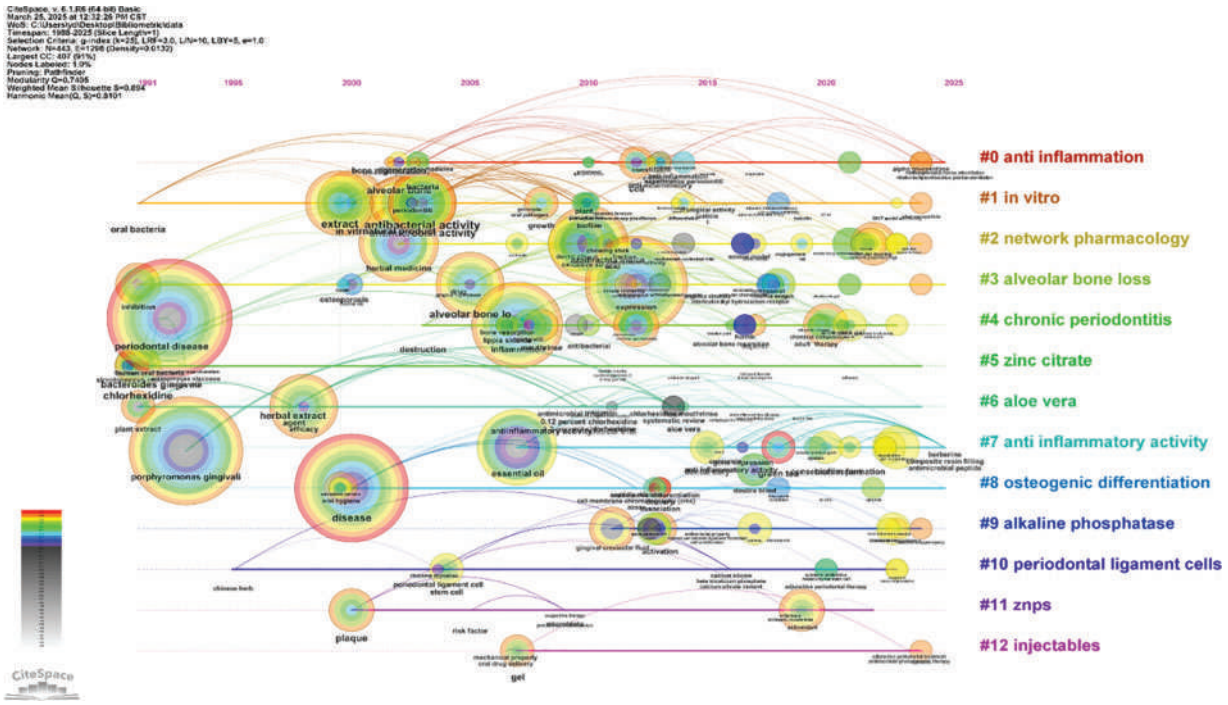

Fig. 9. Timeline visualization of keyword clusters in herbal medicine for periodontal disease research.

their safe and effective application in clinical practice [3], [15].

Our bibliometric analysis demonstrates a consistent emphasis on antioxidant and anti-inflammatory mechanisms. The emergence of "antioxidant" (2021–2025, strength 2.51) and "oxidative stress" (2023–2025, strength 2.5) as recent burst keywords, coupled with the earlier prominence of "inflammation" (2016–2020, strength 3.32) and "cytokines" (2013–2019, strength 3.07), reveals a progressive research focus on understanding the therapeutic mechanisms of herbal treatments. This temporal pattern suggests that initial research concentrated on inflammatory pathways and has recently expanded to include oxidative mechanisms, references. Herbal compounds containing flavonoids and essential oils have been extensively studied for their ability to neutralize free radicals and reduce oxidative damage in periodontal tissues [3], [19]. Similarly, phytochemicals found in traditional medicinal plants such as turmeric, neem, and aloe vera have demonstrated significant anti-inflammatory properties through modulation of cytokine production, offering natural alternatives to conventional anti-inflammatory medications [18], [20]. Clinical studies have further validated these findings, showing improvements in periodontal parameters, including reduced gingival inflammation and bleeding when herbal medicines are used as adjuncts in therapy [2], [6]. The continuous research interest in these mechanisms over more than a decade, with evolving focus from inflammatory to antioxidative properties, underscores the fundamental role these pathways play in the therapeutic effects of herbal medicine for periodontal disease and

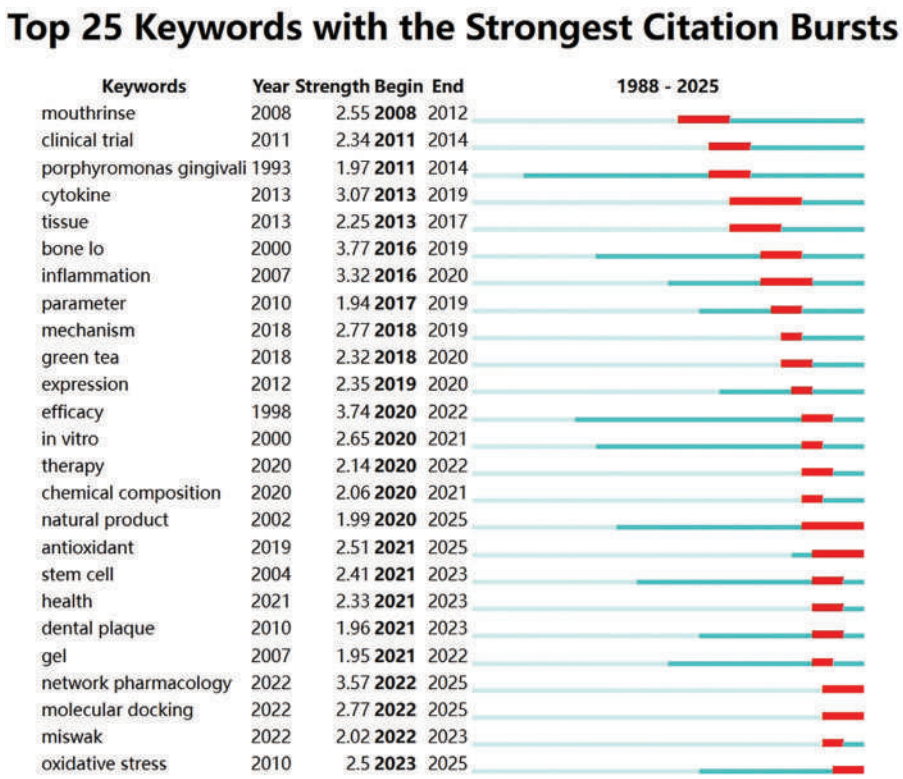

Fig. 10. Top 25 keywords with the strongest citation bursts in herbal medicine for periodontal disease research.

suggests that future treatments may increasingly target the oxidative stress-inflammation axis [16], [21].

Our bibliometric analysis demonstrates a clear evolution in research focus from early clinical applications to more rigorous efficacy assessment. The chronological progression of burst keywords illustrates this shift, beginning with "mouthrinse" (2008–2012, strength 2.55) and "clinical trial" (2011–2014, strength 2.34) representing initial exploratory applications, followed by "parameter" evaluation (2017–2019, strength 1.94), and culminating in more comprehensive assessments of "efficacy" (2020–2022, strength 3.74) and "therapy" (2020–2022, strength 2.14). Early research (2008–2014) emphasized the development of herbal mouthwash formulations containing active ingredients from plants like neem and pomegranate, which demonstrated effectiveness in reducing plaque and gingivitis while offering advantages over chemical-based products that often cause tooth staining and other side effects. [22], [23]. The middle phase (2017–2019) showed increased attention to standardized parameter evaluation, particularly examining the anti-inflammatory and antimicrobial properties of specific phytochemicals in controlled studies. [17], [18]. Most recently (2020–2022), research has progressed to comprehensive efficacy assessments with the highest burst strength (3.74), focusing on clinical outcomes of herbal extracts in reducing periodontal inflammation and improving measurable parameters, thereby validating their role as valuable adjuncts to conventional therapies. [2], [19]. This evolution reflects growing scientific rigor in evaluating herbal medicine for periodontal disease, transitioning from preliminary clinical observations to evidence-based validation through standardized methodologies and outcomes assessment. [3], [6].

Our bibliometric analysis reveals a sustained interest in regenerative applications, demonstrated by the temporal progression of burst keywords related to tissue repair and regeneration. The keyword "tissue" (2013–2017, strength 2.25) represents early investigations into herbal medicine's potential for soft tissue regeneration, where various herbal remedies were found to reduce plaque formation and strengthen gums [23]. This research foundation was expanded with the prominent emergence of "bone" (2016–2019, strength 3.77) as the strongest burst keyword in our entire analysis, reflecting intensified focus on herbs that stimulate osteoblast activity while inhibiting osteoclasts to promote alveolar bone regeneration in periodontal disease [24]. Most recently, research has evolved toward "stem cell" applications (2021–2023, strength 2.41), indicating a sophisticated integration of herbal compounds with advanced regenerative techniques, where bioactive plant compounds are being investigated for their ability to enhance the proliferation and differentiation of dental stem cells [25], [26]. This decade-long progression from basic tissue repair to advanced stem cell applications demonstrates a paradigm shift in periodontal regenerative medicine, moving from conventional artificial replacements toward biological regeneration approaches that combine traditional herbal knowledge with cutting-edge cellular technologies. The consistently high burst strengths across these keywords, particularly for bone-related research, underscore the significant potential and scientific interest in herbal medicine's role in periodontal tissue regeneration [27], [28].

The temporal analysis of publication trends in herbal medicine for periodontal disease research reveals significant evolutionary patterns that reflect the global

acceptance and scientific validation of natural therapeutic approaches. Our findings demonstrate a marked acceleration in research output beginning in 2016, with publication numbers increasing from 15 in 2016 to 45 in 2024, representing a three-fold increase over eight years. This exponential growth pattern aligns with similar bibliometric analyses in complementary medicine fields, where increased research activity often correlates with growing clinical acceptance and regulatory support for evidence-based natural therapies [29], [30]. The geographic distribution analysis revealed China's dominance with 89 publications, followed by Brazil, India, and the USA, indicating a strong contribution from countries with rich traditional medicine heritage. This pattern is consistent with previous studies in herbal medicine research, where nations with established traditional medicine systems often lead in scientific publications, combining traditional knowledge with modern research methodologies [9], [11]. The prominence of Asian countries, particularly China and India, reflects their substantial investment in traditional medicine research infrastructure and government policies supporting integrative healthcare approaches [31]. Brazil's significant contribution (34 publications) demonstrates the growing importance of South American biodiversity in global herbal medicine research, particularly given the Amazon rainforest's vast pharmaceutical potential [32]. The collaborative networks observed between these leading countries suggest effective knowledge transfer mechanisms and international research partnerships that accelerate scientific advancement in this field [33].

The institutional distribution analysis reveals concentrated research excellence in specific academic centers, with Sichuan University leading with 15 publications, followed by specialized medical universities from Iran and Malaysia. This concentration pattern is characteristic of emerging research fields where expertise development requires sustained institutional commitment and specialized infrastructure [34], [35]. The predominance of universities over commercial research institutions indicates that herbal medicine for periodontal disease research remains primarily academically driven, focusing on fundamental understanding rather than immediate commercial applications. This academic focus is beneficial for ensuring rigorous scientific standards and unbiased research outcomes, though it may slow clinical translation compared to industry-driven research [36]. The author productivity analysis, with Baharin, Badiah leading with 5 publications and multiple researchers contributing 3–4 publications each, suggests a relatively distributed research community without extreme concentration in single research groups. This distribution pattern indicates healthy research diversity and reduces the risk of publication bias that might occur with excessive concentration of research output from few sources [37], [38]. The collaborative networks visualized in our analysis demonstrate active inter-institutional partnerships, particularly between Asian institutions, which facilitates knowledge exchange and resource sharing essential for advancing this interdisciplinary field [39]. The temporal evolution of author collaborations, from Western-dominated early networks to increasingly Asian-centric recent collaborations, reflects the geographical shift in research focus and the growing recognition of traditional medicine knowledge systems in scientific communities [40], [41]. These collaboration patterns are crucial for integrating traditional herbal knowledge with modern periodontal research methodologies, ultimately advancing evidence-based applications of herbal medicine in clinical practice [42].

Despite its comprehensive approach, this study has several limitations that should be acknowledged. First, our analysis was restricted to publications indexed in the WoS database, potentially missing relevant articles from other databases or non-indexed journals, particularly those publishing in languages other than English (flow chart of study selection is missing). Second, the bibliometric approach captures quantitative aspects of research output but cannot fully assess the quality, methodological rigor, or clinical significance of individual studies on herbal medicine for periodontal disease. Third, citation metrics may be influenced by factors beyond scientific merit, such as journal reputation or author prominence, potentially skewing the perceived impact of certain publications. Fourth, the keyword-based search strategy, while carefully designed, may not have captured all relevant literature due to terminology variations across different research traditions. Fifth, the most recent developments may not be fully represented in our findings.

This bibliometric analysis reveals several important implications for future research directions. First, there is a need for more high-quality randomized controlled trials to validate the efficacy and safety profiles of promising herbal compounds identified in our keyword analysis, particularly those appearing in emerging research clusters. Second, future studies should focus on standardizing herbal formulations and dosages to improve reproducibility and clinical applicability, as the current literature shows considerable heterogeneity in preparation methods. Third, research collaborations between countries with strong traditional medicine knowledge (such as China and India) and those with advanced clinical research infrastructure could accelerate the translation of promising herbal treatments into mainstream periodontal care. Fourth, mechanistic studies exploring the molecular pathways through which herbal compounds exert their effects on periodontal tissues would strengthen the scientific foundation of this field. Fifth, interdisciplinary research combining pharmacology, periodontology, and material science could lead to innovative herbal-based delivery systems specifically designed for periodontal applications.

5. Conclusion

This bibliometric analysis of herbal medicine for periodontal disease research reveals a dynamic field that has evolved from preliminary clinical applications to sophisticated mechanistic investigations. Our findings demonstrate a significant shift toward scientific approaches, with emerging research fronts in network pharmacology, molecular docking, and oxidative stress mechanisms gaining prominence in recent years. International collaboration patterns highlight China's leadership in this field, while revealing opportunities for enhanced global cooperation

to advance herbal medicine integration into mainstream periodontal care. As research continues to validate the efficacy and elucidate the mechanisms of herbal treatments, future studies should focus on standardization of herbal preparations, controlled clinical trials, and interdisciplinary approaches combining traditional knowledge with modern scientific methods to optimize therapeutic outcomes for periodontal patients.

Ethics Approval and Consent to Participate

Not applicable, as this study involved analysis of publicly available bibliometric data.

Consent for Publication

Not applicable.

Availability of Data and Materials

The data generated and analyzed during the current study are available from the Web of Science Core Collection database. The search strategy and criteria used to generate the dataset are detailed in the Methods section of this paper.

Conflict of Interest

The authors declare that they have no competing interests.

Funding Statement

Self-funded.

Authors' Contributions

S.L. conceived and designed the study, conducted the comprehensive literature search and data extraction, performed the bibliometric analysis using relevant software tools, interpreted the results, and drafted the initial manuscript. D.K. contributed to the study design, assisted with data validation and quality assessment, and provided critical revisions to the manuscript. G.S. supervised the overall research project, contributed to the conceptual framework and methodology, provided expert guidance on oral cancer treatment and adverse drug reactions, and critically reviewed and edited the manuscript for important intellectual content. All authors contributed to the final approval of the manuscript and agree to be accountable for all aspects of the work.

References

[1] Hajishengallis G. Complement and periodontitis. *Biochem Pharmacol*. 2010;80(12):1992–2001.

[2] Abu Tamam AN, Kukreja BJ, Ramachandra SS, Reddy MS, Souza JLD, Abdelmagyd HAE. Herbal medicine as an adjunct in the treatment of periodontal diseases—a systematic review. *The Open Dent J*. 2024;18(1):1–42.

[3] Pasupuleti MK, Nagate RR, Alqahtani SM, Penmetsa GS, Gottumukkala SN, Ramesh K. Role of medicinal herbs in periodontal therapy: a systematic review. *J Int Soc Prev Community Dent*. 2023;13(1):9–16.

[4] Musa HH, Musa TH, Oderinde O, Musa IH, Shonekan OO, Akintunde TY, *et al.* Traditional herbal medicine: overview of research indexed in the scopus database. *Adv in Traditional Med*. 2023;23(4):1173–83.

[5] Ng JY, Anant S, Parakh ND. Characteristics of the research literature on herbal medicines corresponding with herbal supplements yielding the highest total sales: a bibliometric analysis. *Adv Integr Med*. 2023;10(2):64–79.

[6] Abdelmagyd HAE, Shetty SR, Al-Ahmari MMM. Herbal medicine as adjunct in periodontal therapies—A review of clinical trials in past decade. *J Oral Biol Craniofac Res*. 2019;9(3):212–7.

[7] Kumar G, Jalaluddin M, Rout P, Mohanty R, Dileep CL. Emerging trends of herbal care in dentistry. *J Clin Diagn Res*. 2013;7(8):1827–9.

[8] Xu Y, Chen J, Wang H, Lu Y. Research and application of herbal medicine in the treatment of chronic kidney disease since the 21st century: a visualized bibliometric analysis. *Front Pharmacol*. 2022;13:971113.

[9] Huang Y, Deng Q, Zhang J, Sajid A, Shang X, Zhou M. A bibliometric study on chinese herbal medicine treatment of cardiovascular diseases. *Afr J Tradit Complement Altern Med*. 2015;13(1):33–9.

[10] Chen Y, Li W-W, Bi S-L, Zhang H-M, Sun Z, Zuo Y-Y, *et al.* Visualizing research trends and identifying hotspots of herbal components for treating cardiovascular diseases: a bibliometric analysis from 2000 to 2023. *Medicine*. 2024;103(6):e35047.

[11] Wang C, Meng Q. Global research trends of herbal medicine for pain in three decades (1990–2019): a bibliometric analysis. *J Pain Res*. 2021;14:1611–26.

[12] Zhang Y, Xiao F, Lu S, Song J, Zhang C, Li J, *et al.* Research trends and perspectives of male infertility: a bibliometric analysis of 20 years of scientific literature. *Andrology*. 2016;4(6):990–1001.

[13] Susanty S, Sukurni S, Siagian HJ. Analisis Bibliometrik Penelitian Pengobatan Herbal Penderita Hipertensi di Indonesia Menggunakan VOS-Viewer. *J Keperawatan Silampari*. 2022;5(2):764–71.

[14] Basu T, Mallik A, Mandal N. Evolving importance of anticancer research using herbal medicine: a scientometric analysis. *Scientometrics*. 2017;110:1375–96.

[15] Zhu K-X, Wu M, Bian Z-L, Han S-L, Fang L-M, Ge F-F, *et al.* Growing attention on the toxicity of Chinese herbal medicine: a bibliometric analysis from 2013 to 2022. *Front Pharmacol*. 2024;15:1293468.

[16] Shah R, Gayathri G, Mehta DS. Application of herbal products in management of periodontal diseases: a mini review. *Int J Oral Health Sci*. 2015;5(1):38–44.

[17] Островська Г, Сидоренко А, Луценко Р, Петрова Т, Чечотіна С, Розколупа Н, *et al.* Herbal medicine in dentistry: past, present, and future. Актуальні проблеми сучасної медицини: Вісник Української медичної стоматологічної академії. 2024;24(3):173–8.

[18] da Silva Junior EJ, de Santana RJ, da Silva Filho NJ, de Abreu LM, Melo AP, de Oliveira Sabino MEB, *et al.* Evidências do uso de fitoterápicos na odontologia: uma revisão de literatura. *Res Soc Dev*. 2021;10(10):e113101018167–e.

[19] Pai PG, Dayakar M, Nath AR, Ashwini G. Phytotherapeutics in the management of periodontal disease—A review. *SRM J Res in Dent Sci*. 2019;10(2):82–9.

[20] Muntean I, Roi C, Rusu L, Rivis M, Mihai L, Puscas A, *et al.* The implications of phytotherapy in the management of periodontal disease. *Med in Evol*. 2023;29(3):324–36.

[21] Chen Y-J, Xie M-R, Zhou S-Q, Liu F. Research state of the herbal medicine Huangqi (Radix Astragali): a global and bibliometric study. *Medicine*. 2024;103(8):e37277.

[22] Hassan G, Ghafoor S. Herbal medicines: an adjunct to current treatment modalities for periodontal diseases. *Biomedica*. 2020;36(1):15–22.

[23] Pandita V, Patthi B, Singla A, Singh S, Malhi R, Vashishtha V. Dentistry meets nature-role of herbs in periodontal care: a systematic review. *J Indian Assoc Public Health Dent*. 2014;12(3):148–56.

[24] Huang X, Liu X, Shang Y, Qiao F, Chen G. Current trends in research on bone regeneration: a bibliometric analysis. *Biomed Res Int*. 2020;2020(1):8787394.

[25] Ahuja A, Tyagi PK, Kumar M, Sharma N, Prakash S, Radha, *et al.* Botanicals and oral stem cell mediated regeneration: a paradigm shift from artificial to biological replacement. *Cells*. 2022;11(18):2792.

[26] Nguyen-Thi T-D, Nguyen-Huynh B-H, Vo-Hoang T-T, Nguyen-Thanh T. Stem cell therapies for periodontal tissue regeneration: a meta-analysis of clinical trials. *J Oral Biol Craniofac Res*. 2023;13(5):589–97.
[27] Xue W, Yu J, Chen W. Plants and their bioactive constituents in mesenchymal stem cell-based periodontal regeneration: a novel prospective. *Biomed Res Int*. 2018;2018(1):7571363.
[28] Yang H, Wen Q, Xue J, Ding Y. Alveolar bone regeneration potential of a traditional Chinese medicine, B u-S hen-G u-C hi-W an, in experimental periodontitis. *J Periodont Res*. 2014;49(3):382–9.
[29] Ai S, Li Y, Zheng H, Zhang M, Tao J, Liu W, *et al.* Collision of herbal medicine and nanotechnology: a bibliometric analysis of herbal nanoparticles from 2004 to 2023. *J Nanobiotechnol*. 2024;22(1):140.
[30] Seo Y, Park H-S, Kim H, Kim K-W, Cho J-H, Chung W-S, *et al.* A bibliometric analysis of research on herbal medicine for obesity over the past 20 years. *Medicine*. 2022;101(23):e29240.
[31] Tang J-L, Liu B-Y, Ma K-W. Traditional Chinese medicine. *The Lancet*. 2008;372(9654):1938–40.
[32] Calixto JB. The role of natural products in modern drug discovery. *Anais da Academia Brasileira de Ciências*. 2019;91(Suppl 3):e20190105.
[33] Newman DJ, Cragg GM. Natural products as sources of new drugs over the nearly four decades from 01/1981 to 09/2019. *J Nat Prod*. 2020;83(3):770–803.
[34] Hirsch JE. An index to quantify an individual's scientific research output. *Proc Natl Acad Sci USA*. 2005;102(46):16569–72.
[35] Bornmann L, Daniel HD. What do citation counts measure? A review of studies on citing behavior. *J Doc*. 2008;64(1):45–80.
[36] Ioannidis JP. Why most published research findings are false. *PLoS Med*. 2005;2(8):e124.
[37] Fanelli D. Negative results are disappearing from most disciplines and countries. *Scientometrics*. 2012;90(3):891–904.
[38] Franco A, Malhotra N, Simonovits G. Publication bias in the social sciences: unlocking the file drawer. *Science*. 2014;345(6203):1502–5.
[39] Waltman L, Van Eck NJ, Noyons EC. A unified approach to mapping and clustering of bibliometric networks. *J Informetr*. 2010;4(4):629–35.
[40] Leydesdorft L, Wagner C. International collaboration in science and the formation of a core group. *J Informetr*. 2008;2(4):317–25.
[41] Zhou P, Leydesdorff L. The emergence of China as a leading nation in science. *Res Policy*. 2006;35(1):83–104.
[42] Glänzel W, Schubert A. *Analysing Scientific Networks through Co-Authorship. Handbook of Quantitative Science and Technology Research: The Use of Publication and Patent Statistics in Studies of S&T Systems*. Springer; 2004. p. 257–76 .