Review Article

Periodontic-Orthodontic Interdisciplinary Research: A Bibliometric and Visualization Analysis

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Abstract - The bibliometric analysis aims to provide insights into the performance, trends, effectiveness, and future direction of research in a specific area. This bibliometric review was conducted to identify and analyze the orthodontic-periodontic relationship. A comprehensive literature search was performed using the Scopus database (Elsevier), with no restriction on language, publication year, or study design. A total of 103 articles relevant to the topic were included in the analysis. Bibliometric information from the full texts was extracted and analyzed using VOSviewer for data visualization and analysis. The citation counts for the articles ranged from 0 to 255. The most productive year was 2012, with 8 articles published. The majority of the articles (n=15) were published in the American Journal of Orthodontics and Dentofacial Orthopaedics, highlighting it as a significant source of research in this field. This bibliometric analysis highlights the research trends and productivity in the orthodontic-periodontic relationship. Despite the limited number of studies, the findings underscore the importance of continued research to enhance clinical practices and patient outcomes. Future research should focus on expanding the evidence-based and exploring new avenues within this interdisciplinary field.

Keywords - Periodontitis, Periodontic, Pathological tooth migration, Orthodontic, Interdisciplinary.

1. Introduction

Periodontal disease or periodontitis is a common chronic inflammatory disease characterized by the destruction of tooth-supporting structures, including the periodontal ligament, cementum, and alveolar bone [1]. This inflammatory disease is usually associated with dental plaque biofilm dysbiosis [2]. One of the most significant complications of advanced periodontal disease is Pathological Tooth Migration (PTM) [3], which is defined as tooth displacement following a disturbance of the equilibrium among the factors that maintain physiological tooth position [4]. According to the previous literature, one out of 10 periodontal patients seek periodontal treatment due to pathological tooth migration [3]. PTM may not only compromise a patient's dental function but also adversely affect aesthetics and, consequently, the quality of life of the affected individuals. PTM results from the destruction of periodontal support, causing teeth to shift from their normal positions, creating functional and aesthetic concerns that necessitate corrective orthodontic intervention. Further, PTM will lead to an escalating burden on the healthcare economy [5]. Orthodontic management of patients with periodontally-compromised dentition presents unique challenges and opportunities. The primary goal of orthodontic treatment in

such cases is to restore functional occlusion and enhance dental and facial aesthetics while ensuring the preservation and improvement of periodontal health. An interdisciplinary approach involving periodontists and orthodontists is essential to achieve optimal outcomes, necessitating careful assessment and treatment planning tailored to the individual needs of each patient. Studies have proved that orthodontic intervention in periodontally compromised patients is expected to improve their quality of life by improving their mastication function, appearance, self-confidence, and quality of life [5, 6]. In addition, there is an increasing number of adult patients with periodontitis seeking orthodontic treatment [7,8].

Despite the clinical significance of orthodontic management in periodontally compromised patients, there is a notable gap in the literature concerning the bibliometric analysis of this topic. Bibliometric analysis provides a quantitative assessment of research output, trends, and impacts, offering valuable insights into the development and focus areas of a given field [9]. To date, no comprehensive bibliometric analysis has been conducted to evaluate the research landscape related to orthodontic management in periodontally-compromised patients. Such an analysis is

crucial to identify research trends, gaps, and future directions, thereby guiding clinicians and researchers towards evidence-based practice and novel investigations in this interdisciplinary domain.

This study aims to address this gap by conducting a bibliometric analysis of the literature on orthodontic management in periodontally-compromised patients. The findings will contribute to a better understanding of the research trends and impacts in this field, providing a foundation for future studies and clinical advancements that enhance patient outcomes and quality of life.

2. Materials and Methods

An electronic search was performed using the Scopus database (Elsevier), which is known for its extensive coverage of scientific journals across various disciplines [10]. The advanced search strategy employed the following query: ((periodontic OR "periodontal disease" OR "periodontally compromised") AND (orthodontic OR intrusion OR extrusion) AND (interdisciplinary OR multidisciplinary OR relationship)) with a restriction to the field of Dentistry. This approach ensured the inclusion of relevant literature on the orthodontic-periodontic relationship.

This search focused on journal articles, reviews, book chapters, and conference papers. To minimize potential bias from daily database updates, data retrieval was completed within a single day.

Two reviewers independently screened the titles and abstracts of search results to exclude literature not related to periodontology and orthodontics. Any disagreements during the initial screening were resolved through a second stage of review to ensure consensus.

The records were exported to the plain text format and *.RIS format, ensuring that each entry contained all relevant information needed for the subsequent analysis, including title, author, keywords, and abstract. The VOSviewer software was utilized to visualize and analyze trends through bibliometric maps, which depicted publications, countries, and journals. The mapping was based on co-citation and keyword analysis, incorporating three types of data mapping: network, density, and visualization overlay.

The terms included in the VOS viewer overlay were carefully filtered according to the study's criteria. After considering all the selection criteria, the final dataset comprised 103 documents. The majority were journal articles (91.3%, followed by reviews (8.7%). This comprehensive bibliometric analysis provides valuable insights into the orthodontic-periodontic relationship, highlighting research trends and areas for future investigation.

3. Results

3.1. Publications Evolution

The initial search for the key terms resulted in 840 articles. After a thorough selection process, 737 articles were excluded, leaving 103 articles to be analyzed. The primary reasons for exclusion included duplication of articles and articles that were not related to the topic of discussion.

The analysis of the annual publication trends demonstrated that the first paper related to the "periodontal-orthodontic interdisciplinary" was published in the year 1973 in English. Between 1973 and 2023, October 10, a total of 103 publications and 2407 references related to the topic were indexed in the Scopus database. Despite some fluctuations during the period (Figure 1), the annual growth rate of the number of publications was 109.2%. Notable, the peak publication years were 2012 (8 documents), 2001, and 2014 (6 documents each).
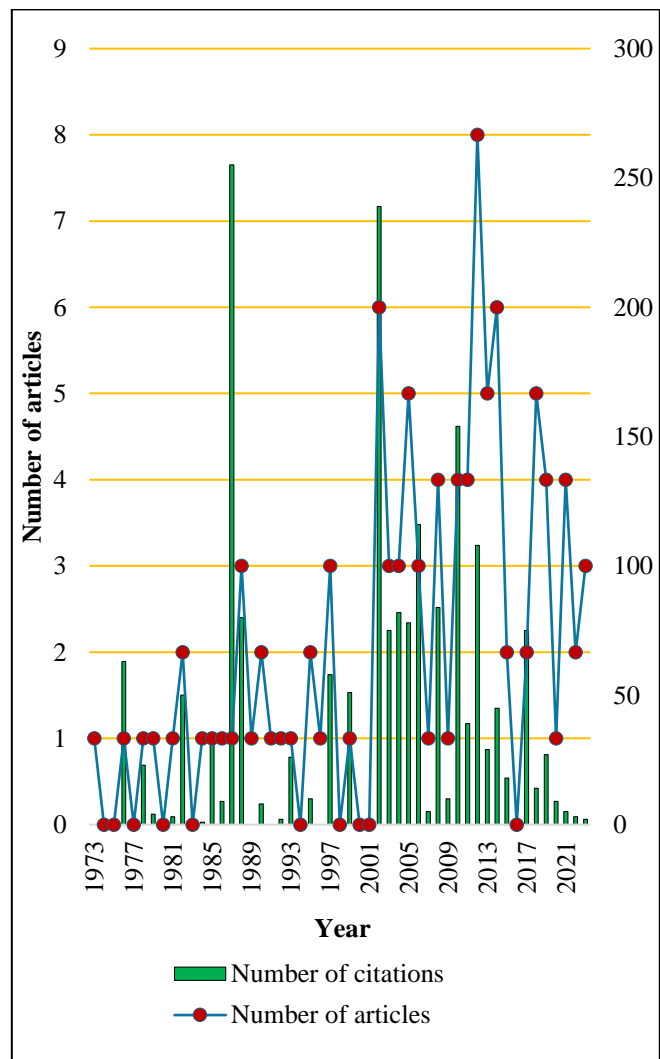

Fig. 1 The annual number of general publications on "periodontal-orthodontic interdisciplinary" published between 1973 and 2023 (50 years of publication)

Table 1. The top 10 most productive countries in terms of publication

Rank	Country	Total Documents	Total Citation	Average citation per document	Link	Total Link Strength (TLS)	% International Collaboration
1	USA	23	709	31	22	896	95.7
2	Brazil	10	84	8	16	89	160.0
3	Germany	9	96	11	18	204	200.0
4	Japan	8	136	17	15	186	187.5
5	Italy	7	89	13	15	97	214.3
6	India	7	20	3	14	106	200.0
7	Turkey	4	42	11	6	24	150.0
8	France	3	35	12	13	71	433.3
9	China	3	27	9	13	68	433.3
10	South Korea	3	21	7	12	99	400.0

The proportion of documents published in the past ten years (2014-2023) accounted for 28.2% of the total publications. The graph illustrates an increase in the publication on the "periodontal-orthodontic interdisciplinary" topic, with the highest number of publications recorded in the year 2012 (n=8) and these articles collectively receiving 108 citations (Figure 1). This trend indicates that the orthodontic treatment in periodontology has evolved, and further research in this area is likely to be explored.

In terms of citation analysis, the number of citations per year also exhibits variability. The citation counts ranged significantly, with some articles receiving minimal citations while others garnered substantial attention. The peak citation activity occurred in the early 2000s and around 2012, aligning with the periods of increased article publications.

3.2. Country/ International Cooperation Publications

These 103 cited documents originated from 35 countries, with the United States of America (USA) ranked first with 23 documents (22.3%). Brazil follows with 10 documents (9.7% of all documents), and Germany ranks third with 9 documents (8.7%). The top 10 productive countries ranked by the number of documents published are shown in Table 1.

Although the USA ranked first in the number of documents, total citation, average citation per document, link and Total Link Strength (TLS), it exhibits the lowest percentage of international collaboration among the top countries. Among the top 10 countries, the top three in terms of average citations per document were the USA (31), Japan (17) and Italy (13).

Brazil, which ranked second in the number of publications with 10 documents, garnered an average rate of only 8. This suggests that Brazil excels in the quantity of documents published. There is room for improvement in terms of the quality, accessibility, and attention these documents receive.

The proportion of international collaboration of the documents in all top 10 countries showed all had 100.0% and above, with the highest being China and France (433.3%) and the lowest being in Turkey (150.0%) except in the USA (95.7%).

This analysis underscores the significant contributions and collaborative efforts of various countries in the field of orthodontic-periodontic research. The high rates of international collaboration, particularly from France and China, highlight the global interest and cooperative nature of research in this interdisciplinary area.

Figure 2 shows an international collaboration network of highly cited documents in the field of orthodontics in periodontology. The nodes represent countries, while the size of the nodes indicates the number of documents published in each country. The connections between the nodes represent the collaboration between countries, with the thickness of the links indicating the frequency of collaboration.

Out of 35 countries, only 74.3% (26 countries) engaged in international collaboration. The figure highlights significant international collaboration among these countries in this research field. Each of these countries is connected with multiple others, showing a robust network of cooperative research efforts. The USA, represented by the largest node, stands out as a central hub of collaboration, connecting with various countries worldwide and contributing significantly to the global advancement of knowledge in orthodontics and periodontics.

3.3. Journal Distribution/ Authorship

The top five journals that published documents related to the field of orthodontics and periodontics are presented in Figure 3. This finding demonstrates that the American Journal of Orthodontic and Dentofacial Orthopaedics not only leads in the number of publications but also holds the highest Total Link Strength (TLS) and citation count, indicating its central role and influence in the field.
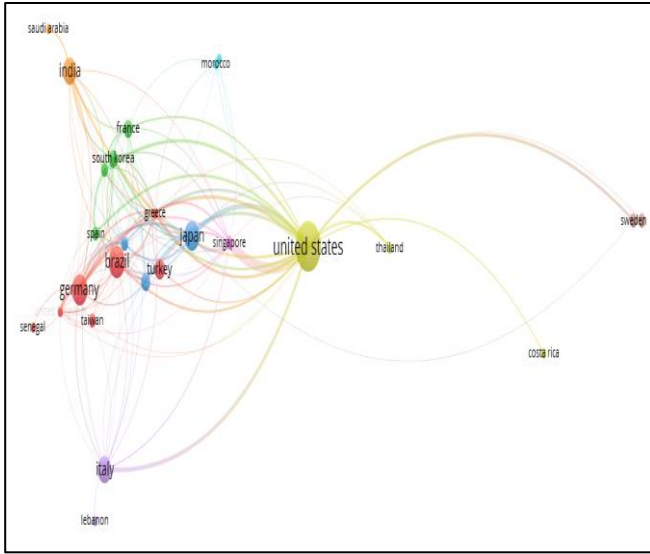
Fig. 2 International cooperation network of the highly cited paper

Other journals, such as the Angle Orthodontist and the Journal of Clinical Periodontology, have also made significant contributions. However, their impact varies when measured by different metrics such as TLS and total citations. This analysis underscores the prominence of certain journals in disseminating research in the interdisciplinary area of orthodontics and periodontology, highlighting the importance of both publication volume and research impact. Further analysis showed that the authorship network involved all 103 authors in the field of periodontal-orthodontic interdisciplinary research (Figure 4a). The network analysis identified 57 clusters, each represented by different colours. These clusters highlight the authors who have published in this field, though many are not interconnected. Figure 4b focuses on the collaboration network, showing that only 50 of the 103 authors are connected within 10 distinct clusters. This indicates that while there are numerous authors contributing to this research area, collaborative efforts are relatively limited.
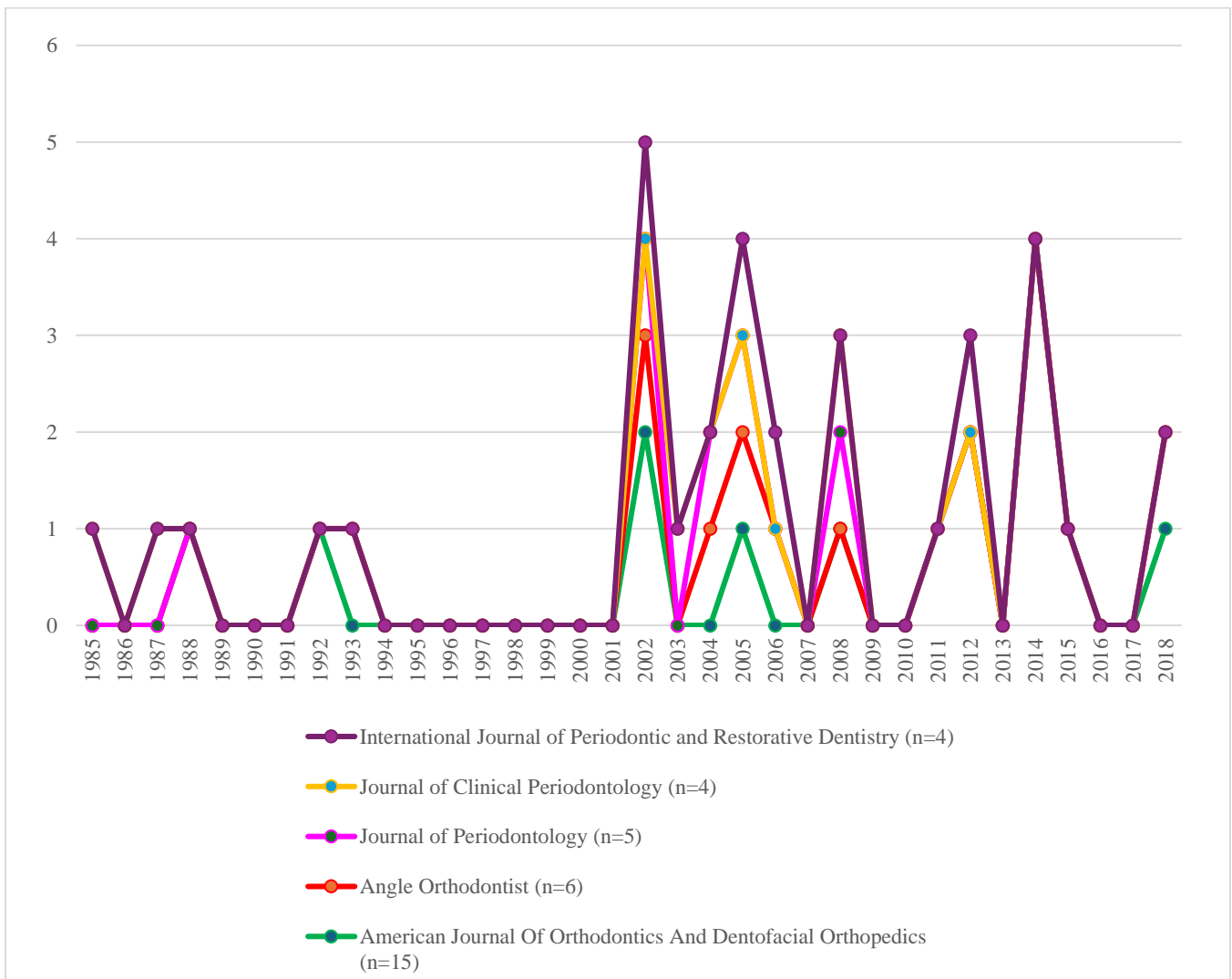

Legend:
- International Journal of Periodontic and Restorative Dentistry (n=4)
- Journal of Clinical Periodontology (n=4)
- Journal of Periodontology (n=5)
- Angle Orthodontist (n=6)
- American Journal Of Orthodontics And Dentofacial Orthopedics (n=15)

Fig. 3 Top 5 journals in terms of number of publications

Table 2. Most influential authors

| Number	Author	Document	Citation	Link	TLS
Based On Citation					
1	Wennstrom JL, Lindhe J, Sinclair F, Thilander B	1	255	1	2
2	Gkantidis N, Christou P, Topouzelis N	1	127	32	107
3	Ong MMA, Wang HL	2	84	29	129
4	Toms SR, Lemons JE, Bartolucci AA, Eberhardt AW	1	81	1	1
5	Engstrőm C, Granstrőm G, Thilander B	1	76	0	0
Based On TLS (Collaboration)					
1	Ong MMA, Wang HL	2	84	29	129
2	Antoun JS, Mei L, Gibbs K, Farella M	1	74	27	113
3	Gkantidis N, Christou P, Topouzelis N	1	127	32	107
4	Reichert C, Hanger M, Jepsen S, Jãger A	1	16	26	75
5	Hazan-Molina H, Levin L, Einy S, Aizenbud D	1	13	24	64
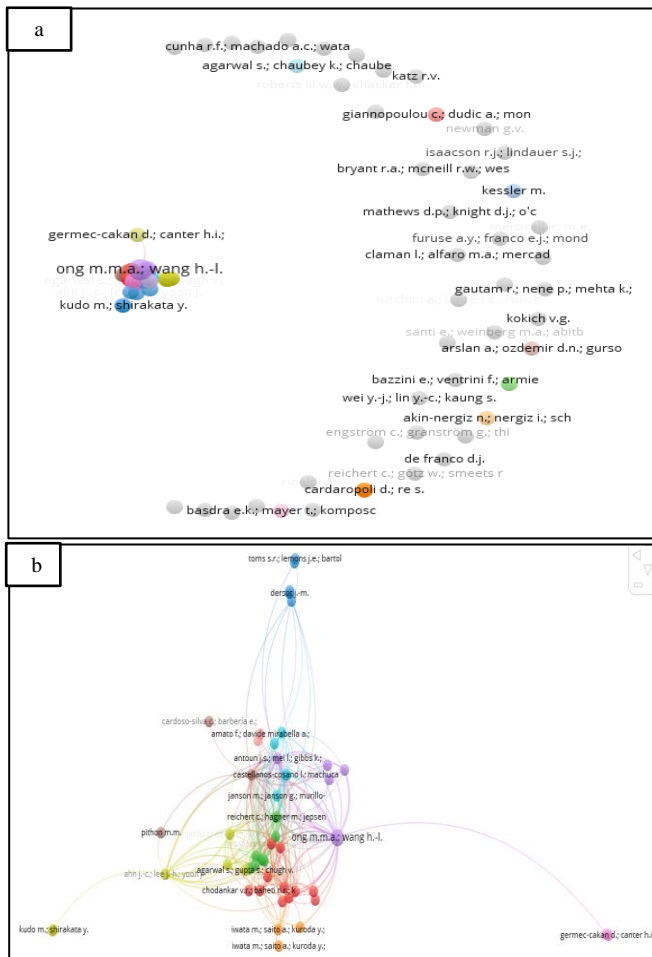
Fig. 4 Authorship network of "orthodontic therapy and periodontic therapy". (a) All 103 authors. (b) Authors with collaboration

Among the 50 connected authors, only one author pair, 'Ong MMA, Wang HL', had published more than a paper, totalling two publications with 84 citations and 127 TLS (Table 2).

The data highlighted a notable amount of research on the periodontal-orthodontics interdisciplinary field, yet the expected level of collaboration and interconnected research interest is lacking. High publication counts do not necessarily equate to being the most influential, as seen in the comparison between citation counts and TLS. This analysis reveals that while high publication and citation counts are important indicators of research impact, collaboration strength, as measured by TLS, plays a crucial role in advancing interdisciplinary research.

3.4. Most Influential Institutions/ Organizations

There were 223 organizations or institutions that published papers related to the field of periodontal-orthodontic interdisciplinary research between the years 1973 and 2023. The top ten most productive organizations, each with 4 to 7 documents published, are presented in Table 3. These institutions demonstrate varying levels of impact based on citation counts and citations per article.
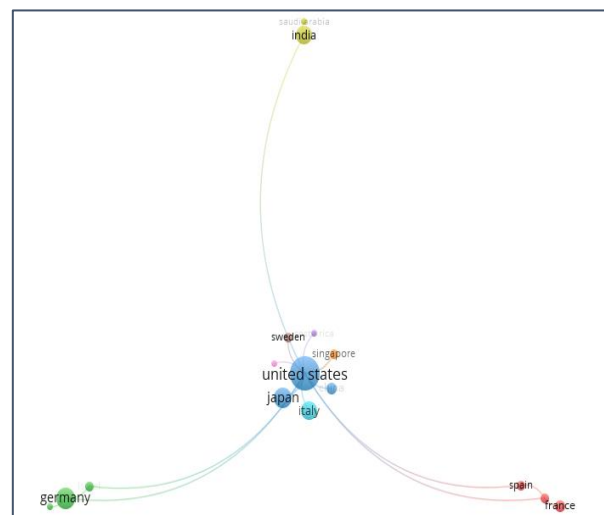
Fig. 5 Author's collaboration within countries

Table 3. Top five organizations/ institutions

Institution	Country	Number of articles	Number of citations	Citation per article
University of Bonn	Germany	6	94	15.7
Yeditepe University	Turkey	5	31	6.2
University of Michigan	USA	4	173	43.3
University of Geneva	Switzerland	4	40	10.0
University of Alabama	USA	4	324	81.0
Taipei Veterans General Hospital	Taiwan	4	56	14.0
State University of São Paulo	Brazil	7	88	12.6
Okayama University	Japan	4	58	14.5
Ohio State University	USA	4	115	28.8
Government Dental Collage and Hospital Maharashtra	India	4	0	0.0

3.5. Keywords Co-occurrence Trends Analysis

The analysis of keyword co-occurrence is crucial for exploring the relationships between keywords in the field of periodontal-orthodontic interdisciplinary research. This analysis uncovers prevalent themes and helps scholars understand current scientific concerns. Keywords in publications represent overall knowledge concepts and are used to reveal the knowledge structure of research domains [11].

In this study, a total of 10991 keywords were investigated, with 321 of them appearing more than ten times. The nodes in different colours represented different clusters, and node sizes indicated the number of keyword occurrences, and thick connection lines or links represented a close relationship between two items. These keywords were divided into four clusters (Figure 6a). Clusters were developed based on the distance between keywords, grouping the most related keywords [12]. The top 5 keywords were 'relationship' with 384 occurrences, 'patient' with 358 occurrences, 'treatment' with 338 occurrences, 'teeth' with 232 occurrences, and 'study' with 215 occurrences.

Figure 6a reveals that recent research trends, indicated by yellow lines, are moving towards interdisciplinary approaches, addressing periodontal disease, and understanding pathological tooth migration. However, the small size of the circles for these emerging topics suggests that they are still underrepresented in the literature. The keyword density visualization, as presented in Figure 6b, further confirms these trends, highlighting areas with the highest research activity and suggesting potential gaps for future research. High-frequency keywords like "relationship", "patient", "treatment", "teeth, and "study" are predominantly displayed. This analysis helps identify key areas of interest and opportunities for further exploration within the periodontal-orthodontic interdisciplinary research domain.
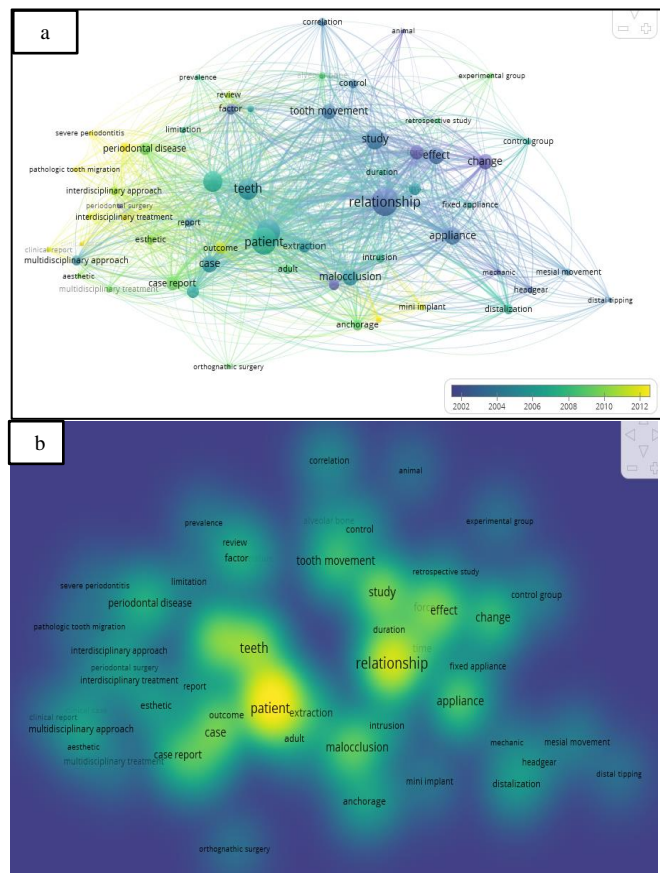

Fig. 6 Network visualization of keywords (59) co-occurrence. (a) Most occurrences of keywords networks. (b) Keyword density visualization

The article 'Some periodontal tissue reactions to orthodontic tooth movement in monkeys' by Wennström, J.L., Lindhe, J., Sinclair, F., Thilander, B. is the most cited with 255 citations, indicating the most influential paper. This is followed by 'The orthodontic-periodontic interrelationship in integrated treatment challenges: A systematic review' by Gkantidis, N., Christou, P., Topouzelis, N. with 127 citations (Table 4).

Table 4. The top 10 most cited publications

Author	Title	Year	Source	Citation
Wennström, J.L., Lindhe, J., Sinclair, F., Thilander, B. [13] (Wennström et al., 1987)	Some periodontal tissue reactions to orthodontic tooth movement in monkeys	1987	Journal of Clinical Periodontology	255
Gkantidis, N., Christou, P., Topouzelis, N. [14] (Gkantidis et al., 2010)	The orthodontic-periodontic interrelationship in integrated treatment challenges: A systematic review	2010	Journal of Oral Rehabilitation	127
Ong MMA, Wang HL [15] (Ong & Wang, 2002)	Periodontic and orthodontic treatment in adults	2002	American Journal of Orthodontics and Dentofacial Orthopedics	84
Toms SR, Lemons JE, Bartolucci AA, Eberhardt AW [16] (Toms et al., 2002)	Non-linear stress-strain behaviour of periodontal ligament under orthodontic loading	2002	American Journal of Orthodontics and Dentofacial Orthopedics	81
Engstrőm C, Granstrőm G, Thilander B [17] (Engström et al., 1988)	Effect of orthodontic force on periodontal tissue metabolism a histologic and biochemical study in normal and hypocalcemic young rats	1988	American Journal of Orthodontics and Dentofacial Orthopedics	76
Antoun JS, Mei L, Gibbs K, Farella M [18] (Antoun et al., 2017)	Effect of orthodontic treatment on the periodontal tissues	2017	Periodontology 2000	74
Von Bőhl M, Maltha J, Von Den Hoff H, Kuijpers-jagtman AM [19] (Von Böhl et al., 2004)	Changes in the periodontal ligament after experimental tooth movement using high and low continuous forces in beagle dogs	2004	Angle Orthodontist	70
Kessler M [20] (Kessler, 1976)	Interrelationships between orthodontics and periodontics	1976	American Journal of Orthodontics	63
Yamaguchi M, Yoshii M, Kasai K [21] (Yamaguchi et al., 2005)	Relationship between substance P and interleukin-1β in gingival crevicular fluid during orthodontic tooth movement in adults	2006	European Journal of Orthodontics	55
Sanders NL [22] (Sanders, 1999)	Evidence-based care in orthodontics and periodontics: A review of the literature	1999	Journal of the American Dental Association	51

The citation analysis underscores the impact and influence of specific studies in shaping the understanding and advancement of periodontal-orthodontic interdisciplinary research. High citation counts reflect the foundational nature and wide recognition of these studies within the scientific community. The diversity in research topics among the top-cited articles highlights the comprehensive approach taken by researchers to explore various facets of the periodontal and orthodontic relationship.

4. Discussion

Orthodontic intervention has been widely utilized in dentistry, not only for correcting misaligned teeth but also as an adjunctive treatment for periodontal conditions. This study employed VOSviewer visualization software to perform a bibliometric analysis of orthodontics in periodontology over the past 50 years, offering a comprehensive perspective on the field. The analysis systematically outlined evaluation trends and identified future research hotspots, aiding researchers in understanding the current research status and guiding topic selection for future studies.

The analysis of publication trends revealed distinct phases in the development of periodontal-orthodontic research:
- Early years phase (1973-1989): Sporadic publications with low citation counts, indicating emerging interest and foundational research in the field.
- Growth phase (1990-2005): A gradual increase in both publications and citations, reflecting growing academic interest and the establishment of interdisciplinary studies.
- Peak phase (2006-2013): A surge in publications and

citations, with 2012 standing out as the year with the highest number of published articles, signalling a peak in research activity.

- Recent trends (2014-2023): Although there was a decline in the number of publications, citation activity remained sustained, suggesting continued relevance and ongoing research interest.

In general, the analysis of publication trends revealed fluctuation in the number of publications on orthodontics in periodontology, with an annual growth rate of publication less than 109.2%. This indicates a developing field with increasing engagement from countries and researchers worldwide. The USA emerged as the nation with the highest number of publications on "orthodontic intervention and periodontal therapy." Despite this, the USA's citation counts and international collaboration were lower compared to other countries. Nevertheless, institutions in the USA, such as the University of Alabama and the University of Michigan, were leading in both the number of publications and citation counts, underscoring the country's significant position in the field.

The citation analysis emphasized the USA's dominant role, with the highest citation counts indicating strong professional recognition of its scientific contributions. However, the relatively low percentage of international collaboration (27.4%) suggests potential areas for improvement in global research partnerships. On the other hand, countries like China, despite having a high number of publications, showed low citation counts, highlighting the need to enhance the quality and impact of their research.

The analysis of authorship and journals revealed key contributors and influential publications. Authors such as Wennström, J.L., Lindhe, J., and Sinclair, F., along with institutions like the University of Alabama, were prominent in the field. The most cited articles, such as "Some periodontal tissue reactions to orthodontic tooth movement in monkeys" and "The periodontic-orthodontic interrelationship in intergrade treatment challenges: A systematic review," have significantly shaped the research landscape.

The cluster analysis of keywords identified major research themes and potential future hotspots. Keywords such as "orthodontic intrusion", "orthodontic extrusion", "efficacy", "pathological tooth migration", and "intra-bony defect" emerged as areas needing further exploration. The density visualization showed high-frequency keywords, indicating established research areas, while the smaller cluster pointed to emerging topics that could gain prominence.

The study utilized the Scopus database, recognized for its comprehensive coverage and advanced analysis tools, providing a robust foundation for bibliometric research [10].

Scopus offers significant advantages, including the exclusion of self-citations and broader coverage compared to the Web of Sciences [23]. However, it is essential to acknowledge the limitations of this study, including the exclusion of non-English documents and other scholarly indexes by databases like Google Scholar [24].

This study was subjected to certain limitations. It only evaluated the most relevant documents within 30 years. The Scopus database retrieves citations mainly from articles of only peer-reviewed journals, whereas Google Scholar includes citations from books, theses, dissertations, open-access online journals, and non-scholarly sources [25]. Therefore, this study did not include citations from books, journals written in other languages or dissertations. Evaluating longer periods, such as 100 years, could provide more substantial insights into the trends over time [24].

This study achieved superior results by leveraging comprehensive data collection from the Scopus database, which is known for its extensive coverage of peer-reviewed journals across diverse research fields and exclusion of self-citation. Utilizing VOSviewer software for sophisticated visualization and mapping allowed us to identify complex relationships between keywords, authors, and institutions, providing clearer insights into the structure and dynamics of the research field.

By spanning our analysis over 50 years, we were able to identify long-term trends and patterns in publication activity, citations, and research development, offering a complete picture of the field's evolution. Detailed keyword and cluster analysis pinpointed emerging research hotspots, while network analysis mapped international collaborations, revealing the extent and impact of global partnerships. Furthermore, the versatility of Scopus and its advanced document analyzer offered a robust and holistic view of the research landscape. Transparent acknowledgement of limitations, such as the exclusion of non-English documents, ensured a clear understanding of our findings' scope.

5. Conclusion

The research of orthodontics intervention in periodontology is still in the initial stages but is growing, with increasing studies in recent years. Despite comprehensive insights provided by the Scopus database, limitations include the exclusion of non-English documents and contributions from books and dissertations. In conclusion, this bibliometric analysis provides insight into the orthodontics intervention in periodontology research, highlighting key trends, influential contributors, and future research directions. This study underscores the evolving nature of periodontal-orthodontic interdisciplinary research. Enhancing international collaboration and focusing on emerging research areas will be crucial for advancing the field and improving patient outcomes.

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