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Photobiomodulation therapy for oral lesions: a bibliometric analysis

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ABSTRACT

Photobiomodulation therapy is a nonthermal light therapy with therapeutic properties for pain and inflammation relief, immune modulation, and tissue regeneration. Our goal was to provide a comprehensive overview of photobiomodulation therapy for oral lesions using visual mapping techniques. We used VOSViewer to analyze publications in the "photobiomodulation" and "oral lesion" categories from PubMed, Scopus, and Dimension AI databases, allowing us to track author contributions, journal, institutional affiliations, and contributions by country. A total of 373 publications from 1991 to 2022 were gathered. Notably, Brazil, the United States, and France emerged as major contributors in this field. The College of Dentistry at the University of Florida (US) ranked first with 515 citations. Jan Magnus Bjordal was the most prolific author, receiving 207 total citations. Supportive Care in Cancer and Photomedicine and Laser Surgery were identified as the two most promising journals. The intellectual structure was divided into four clusters: cluster one for 'lllt', cluster two for 'head and neck cancer', cluster three for 'olp', and cluster four for 'inflammatory mediators'. Overall, there has been a significant increase in research on photobiomodulation, particularly over the last decade. The study identified four distinct research clusters: low-level light therapy, head and neck cancer, oral lichen planus, and inflammatory mediators. These findings highlight the need for further research into photobiomodulation in the treatment of various oral diseases. This trend may indicate an increase in the use of low-level light therapy to treat oral lesions in the population, as well as the potential for alternative treatments.

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Key words: photobiomodulation; recurrent aphthous stomatitis; oral lichen planus; mucositis; bibliometric.

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Introduction

The North American Association for Photobiomodulation Therapy and the World Association for Laser Therapy have defined photobiomodulation therapy as a non-thermal light treatment with therapeutic properties, including pain and inflammation reduction, immunomodulation, and tissue healing and regeneration enhancement.[1] This treatment method has diverse clinical applications and has been utilized in various medical and dental procedures.[2] In the medical field, photobiomodulation therapy has been employed in the treatment of conditions such as diabetes, neurology, dermatology, radiation therapy complications, osteoarthritis, fibromyalgia, hip arthroplasty, neck pain, and lower back pain.[3] In dentistry, it is often used to alleviate pain and promote wound healing, with reported effectiveness in cases such as nerve pain, ulceration, and post-herpetic neuralgia.[4,5] It has been reported in several studies that light stimulation is significantly effective in various fields of dentistry, including periodontology, orthodontics, temporomandibular disorder (TMD), and oral pathology encompassing various types of oral lesions.[3,4] These oral lesions include recurrent aphthous stomatitis, oral lichen planus, pemphigus vulgaris, mucous membrane pemphigoid, and oral mucositis.[6,7] However, despite the extensive research in these areas, there is a lack of clear publication analysis about the use of photobiomodulation therapy in treating oral lesions.

This study aims to evaluate: i) what are the key growth trends in the publication on photomodulation therapy of oral lesions? ii) What performance analysis (author, institutions, journal, documents, country) from emerging regions has had the greatest influence on photobiomodulation therapy of oral lesions? iii) What topics in the photobiomodulation therapy on oral lesions publication have been studied with the greatest frequency and have attracted the greatest attention?

Materials and Methods

Search strategy

The PICO-S bibliometric determination involves the human population (P), specifically patients with recurrent aphthous stomatitis, oral lichen planus, pemphigus vulgaris, mucous membrane pemphigoid, or oral mucositis undergoing photobiomodulation therapy. The intervention (I) includes the administration of photobiomodulation therapy, encompassing laser, LEDs, and broad-band light, while the comparison (C) focuses on evaluating literature outcomes for each type of photobiomodulation therapy for oral ulceration. The desired research outcomes (O) consist of publication trends, performance analysis, and the intellectual structure of photobiomodulation therapy for oral ulceration. To achieve this, a Boolean search strategy will be formulated to obtain literature results matching the objective, covering publications from 1991 to June 2023. PROSPERO registration number: CRD42023418025.

On May 4, 2023, a search was conducted using the following keywords: "Low-level light therapy, low-level light therapies, LLLT, light therapy, light therapies, laser therapy, laser therapies, laser biostimulation, laser phototherapy, laser irradiation, photoradiation, visible radiation, aphthous stomatitis, aphthous ulcer, aphthae, oral lichen planus, oral lichenoid reaction, oral lichenoid lesion, pemphigus vulgaris, oral mucositis, chemotherapy-induced oral mucositis, radiotherapy-induced oral mucositis, radiation-induced oral mucositis, chemoradiotherapy-induced oral mucositis, chemoradiation-induced oral mucositis."

Data extraction

To determine who contributed the most, the bibliometric parameters (*i.e.*, title, keywords, journal, publication year, citations, author, institution, and country) were extracted and imported into Microsoft Excel 2019 (Redmond, Washington, United States) and VOSviewer 1.6.17 (Leiden University, Leiden, The Netherlands).[8] In VOSviewer, node size is positively related to the number of articles. The co-authorship study assessed the collaboration between various countries, authors, and institutions (Figure 1). Cooperation strength is positively correlated with the total link strength between the two nodes.[9] Using VOSviewer, the co-occurrence, and reference analysis keywords were visualized. An independent investigator examined the data extraction for any bias in the scientometric analysis in three phases.

Result

General data

From Scopus (n=151) and Dimension AI (n=222) databases, there were 373 publications obtained for this

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study. The excluded publications were about only one duplication (n=372). The first publication in photobiomodulation was described in 1991. Figure 2 showed publication trends of photobiomodulation therapy for thirty-one years. As shown in Figure 2, fewer than 20 articles were published in the first two decades. The highest number of articles (n=42) was published in 2021. The highest number of citations were in 2012 (n=783). The total number of citations was 7.567 and the number of citations per article was 20.96.

Country citation analysis

Prior to the bibliometric analysis, exclusion of publication was conducted due to abstract/letter (n=55), no author (n=36), and no specific keyword for oral lesion (n=168). A total number of 113 publications were analyzed (Figure 1). Figure 3 showed the performance analysis based on countries. The country with the highest number of publications is Brazil (n=51), followed by the United States (n=9), France (n=8), and India (n=8).

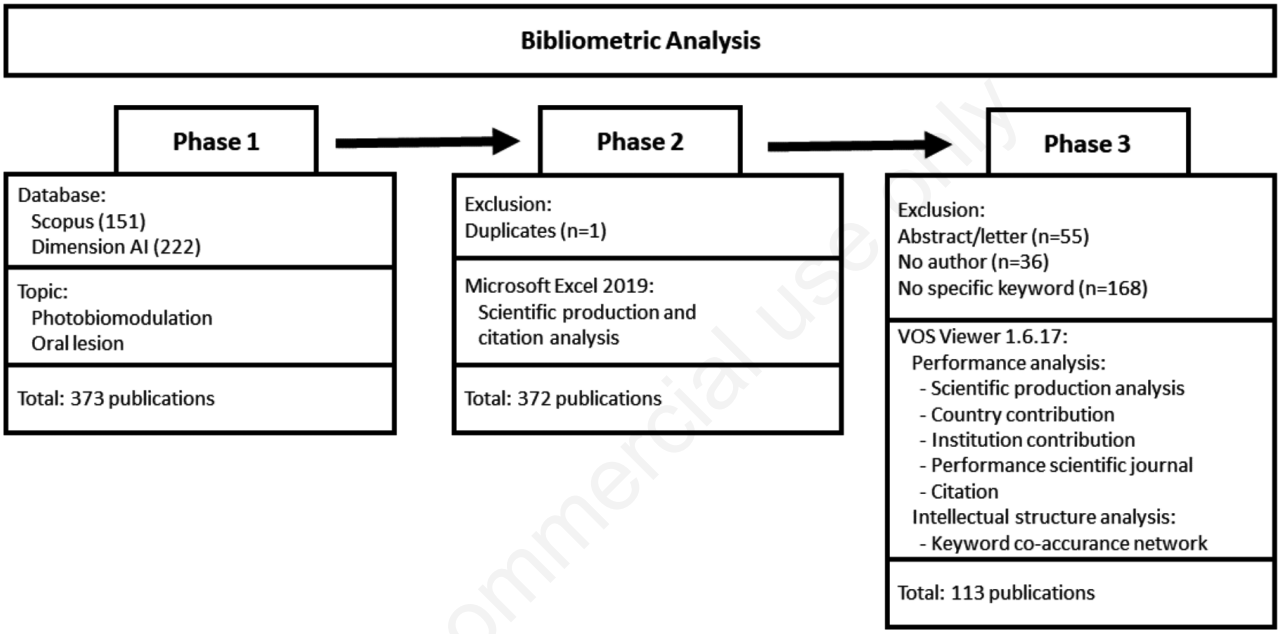


Figure 1. Flow diagram of bibliometric process.

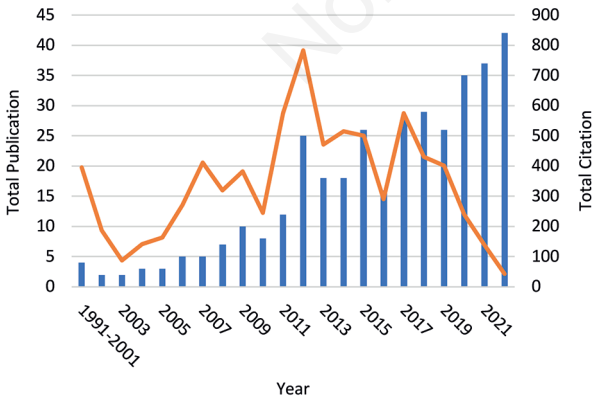
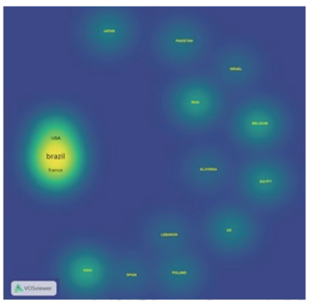


Figure 2. Publication trend (blue color) and citation (orange color) regarding photobiomodulation therapy from 1991 until 2022.



No	Country	Total Publication	Weighted Citations (wc)
1	Brazil	51	1369
2	United States	9	530
3	France	8	382
4	India	8	354
5	Iran	6	185
6	United Kingdom	4	22
7	Belgium	4	142
8	Egypt	4	48
9	Lebanon	2	31
10	Spain	1	26

Figure 3. Visual density of citations based on country.

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Institutions, journals, and document analysis

Table 1 showed the performance analysis based on institutions. The highest citations were found at the College of Dentistry, University of Florida (United States), followed by the Samuel Oschin Comprehensive Cancer Institute, Cedars Sinai Hospital System (United States), and the Department of Oral Surgery and Pathology, Federal University of Minas Gerais (Brazil).

Table 2 presents the journals with the highest citations regarding photobiomodulation therapy for oral lesions. "Supportive Care in Cancer" shows as the top journal with the highest number of citations (n=1129). This journal also has the highest publications for photobiomodulation therapy for oral lesions (n=26). Nevertheless, the highest citation per publication was in the "Current Opinion in Oncology" journal with a score of 69. Only one journal, "Photobiomodulation Photomedicine and Laser Surgery," was ranked in the third quartile.

Table 3 showed publications with the highest citations regarding photobiomodulation therapy from 1995 to 2019. Only 10 articles were cited in more than 100 documents.

Table 1. Top 10 most cited institutions.

No	Institution, country	Average citation	Average normalized citation
1	College of Dentistry, University of Florida, Gainesville, FL, United States	515	28254
2	Samuel Oschin Comprehensive Cancer Institute, Cedars Sinai Hospital System, Los Angeles, CA, United States	22	14286
3	Department of Oral Surgery and Pathology, Dental School, Federal University of Minas Gerais, Belo Horizonte, Minas Gerais, Brazil	355	12748
4	Department of Stomatology (Oral Pathology), Dental School, Federal University of Goiás, Goiânia, Goiás, Brazil	355	12748
5	Hematopoietic Stem Cell Transplant Unit, Araújo Jorge Hospital, Associação De Combate Ao Câncer De Goiás, Goiânia, Goiás, Brazil	355	12748
6	Postgraduate Program in Biophotonics Applied to Health Sciences, Nove De Julho University, Uninove, São Paulo, Brazil	5	12407
7	Department Of Stomatology and General Pathology Department, School of Dentistry, University of São Paulo, São Paulo, Brazil	27925	10257
8	Unit of Bone Marrow Transplantation, Hospital Israelita Albert Einstein, São Paulo, Brazil	28	9956
9	Department of Dental Science, Faculty of Medicine, University of Liège, Liège, Belgium	155	6888
10	Orodental Division Department, National Research Centre, Cairo, Egypt	185	6578

Table 2. Top 10 top most cited journals.

No	Journal	Total citations	Publication	CPP	SNIP[a] 2022	SJR[b] 2022	Scimago Quartile
1	Supportive Care in Cancer	1129	26	43.42	0.984	1.316	2
2	Photomedicine and Laser Surgery	669	17	39.35	1.496[c]	0.469[c]	-
3	Lasers in Medical Science	541	23	23.52	1.184	0.529	2
4	Lasers in Surgery and Medicine	330	6	55.00	1.281	0.665	1
5	Oral Oncology	303	7	43.29	1.497	1.271	1
6	International Journal of Radiation Oncology Biology Physics	277	5	55.40	1.776	2.090	1
7	Photodiagnosis and Photodynamic Therapy	267	15	17.80	0.965	0.633	2
8	Current Opinion in Oncology	207	3	69.00	1.025	0.971	2
9	Photobiomodulation Photomedicine and Laser Surgery	205	9	22.78	0.927	0.439	3
10	Radiotherapy and Oncology	155	5	31.00	1.715	1.834	1

[a]provided by Scopus; [b]provided by ScimagoJR; [c]data 2021; CPP, citation per publication; SNIP, source normalized impact per paper; SJR, SCImago journal Rank.

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The most frequently cited author was Jan Magnus Bjordal at the Department of Global Public Health and Primary Care, University of Bergen, with a total citation of 207 in the "Supportive Care in Cancer" journal.

Intellectual structure of author keywords

Figure 4 shows the intellectual structure of photobiomodulation therapy for oral ulcers. There are 4 clusters, with cluster 1 related to 'lllt', cluster 2 related to 'head and neck cancer', cluster 3 related to 'olp', and cluster 4 related to 'inflammatory mediators.'

Discussion

The use of photobiomodulation therapy in various fields has been reported since the first LASER was discovered in 1917. The development of photobiomodulation therapy has made it one of the therapeutic treatment options for managing various inflammatory, traumatic, infectious, and autoimmune lesions. Photobiomodulation therapy has become a supportive treatment in managing cancer patients, such as in dealing with oral mucositis, neuropathy, and lymphedema.[7,20] Furthermore, in subsequent developments, photobiomodulation therapy has been reported to yield satisfying results in addressing one of the global health issues, namely diabetes mellitus. The use of photobiomodulation therapy on the salivary glands of diabetic rats can lower blood sugar levels and insulin resistance.[21,22] In the field of dentistry, in addition to treating oral ulcers, photobiomodulation therapy has shown satisfactory results in orthodontic tooth movement[23], postgingivectomy healing[24], reduction of swelling and trismus post-odontectomy[25], management of dentin hypersensitivity[26], and healing of oral ulcers.

Maiman introduced the laser that could be used in the field of dentistry, namely the Helium-Neon (He-Ne)

Table 3. Top 10 most cited documents.

No	Author	Title	Journal	Type	TC
1	Bjordal *et al.* (2011)[10]	A systematic review with meta-analysis of the effect of low-level laser therapy (LLLT) in cancer therapy-induced oral mucositis	Supportive Care in Cancer	Review	207
2	Cowen *et al.* (1997)[11]	Low energy Helium-Neon laser in the prevention of oral mucositis in patients undergoing bone marrow transplant: Results of a double-blind randomized trial	International Journal of Radiation Oncology Biology Physics	Research	195
3	Migliorati *et al.* (2012)[12]	Systematic review of laser and other light therapy for the management of oral mucositis in cancer patients	Supportive Care in Cancer	Review	183
4	Schubert *et al.* (2007)[13]	A phase III randomized double-blind placebo-controlled clinical trial to determine the efficacy of low-level laser therapy for the prevention of oral mucositis in patients undergoing hematopoietic cell transplantation	Supportive Care in Cancer	Research	171
5	Zadik *et al.* (2019)[14]	Systematic review of photobiomodulation for the management of oral mucositis in cancer patients and clinical practice guidelines	Supportive Care in Cancer	Review	157
6	Whelan *et al.* (2002)[15]	NASA light-emitting diodes for the Prevention of oral mucositis in Pediatric bone Marrow Transplant Patients	Photobiomodulation Photomedicine and Laser Surgery	Research	127
7	Barasch *et al.* (1995)[16]	Helium neon laser effects on conditioning induced oral mucositis in bone marrow transplantation patients	Cancer	Research	121
8	Oberoi *et al.* (2014)[17]	Effect of prophylactic low-level laser therapy on oral mucositis: A systematic review and meta-analysis	PLoS ONE	Review	115
9	Antunes *et al.* (2007)[18]	Low-power laser in the prevention of induced oral mucositis in bone marrow transplantation patients: A randomized trial	Blood	Research	112
10	Bensadoun *et al.* (2012)[19]	Low-level laser therapy in the prevention and treatment of cancer therapy-induced mucositis	Current Opinion in Oncology	Research	110

TC, total citations.

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mixed laser. Since the discovery of the He-Ne laser, subsequent lasers have undergone more rapid development, such as the discovery of the Nd:YAG laser (Yttrium-Aluminum-Garnet coated with 1-3% Neodymium) in 1961, the argon laser in 1962, the ruby laser in 1963, and the CO2 laser in 1964.[27] Subsequently, in the 1990s, the Nd:YAG laser was specifically designed for the field of dentistry along with the diode laser. The period from 1991 to 2001 marked the first recording of photobiomodulation therapy as one of the treatment options for oral ulcers, including SAR, OLP, and oral mucositis.[20] During this period, publications on photobiomodulation therapy for oral ulcers were very limited, with the use of photobiomodulation therapy only covering gas-based lasers, namely the CO2 laser and the He-Ne laser. The time span between 1960 and 1991 indicates a gap of approximately 30 years between the discovery of the laser and the first recording of the application of photobiomodulation therapy for oral ulcers.

The increase in publications and significant citations in 2012 compared to 2011 and 2013 is depicted in Figure 02. During this period, the red laser was most frequently used, followed by the infrared laser, the He-Ne laser, the CO2 laser, the GaAlAs laser, and the Er:YAG laser. Figure 02 shows a similar time gap from 1991 to 2012. Despite the introduction of lasers in the field of dentistry, it still took a considerable amount of time for researchers to utilize lasers in their research.

The two-time gaps could be due to the limited understanding of the mechanisms of laser usage. Developments over time, such as the manner of laser usage, the indications for laser therapy, the most optimal laser wavelength, and the adjustment of laser usage protocols related to human factors, can influence why it took so long for lasers to be accepted in the field of dentistry. The human factors mentioned, such as differences in race among populations and the human desire to always seek the best, may have played a role. When the lasers developed during that period became the best, that period could be the point at which lasers were introduced into the field of dentistry. The factors mentioned could serve as reasons for researchers to conduct preclinical research and clinical trials before lasers were established as one of the therapeutic therapies for various fields in dentistry.[28,29,30] This condition need for thor-

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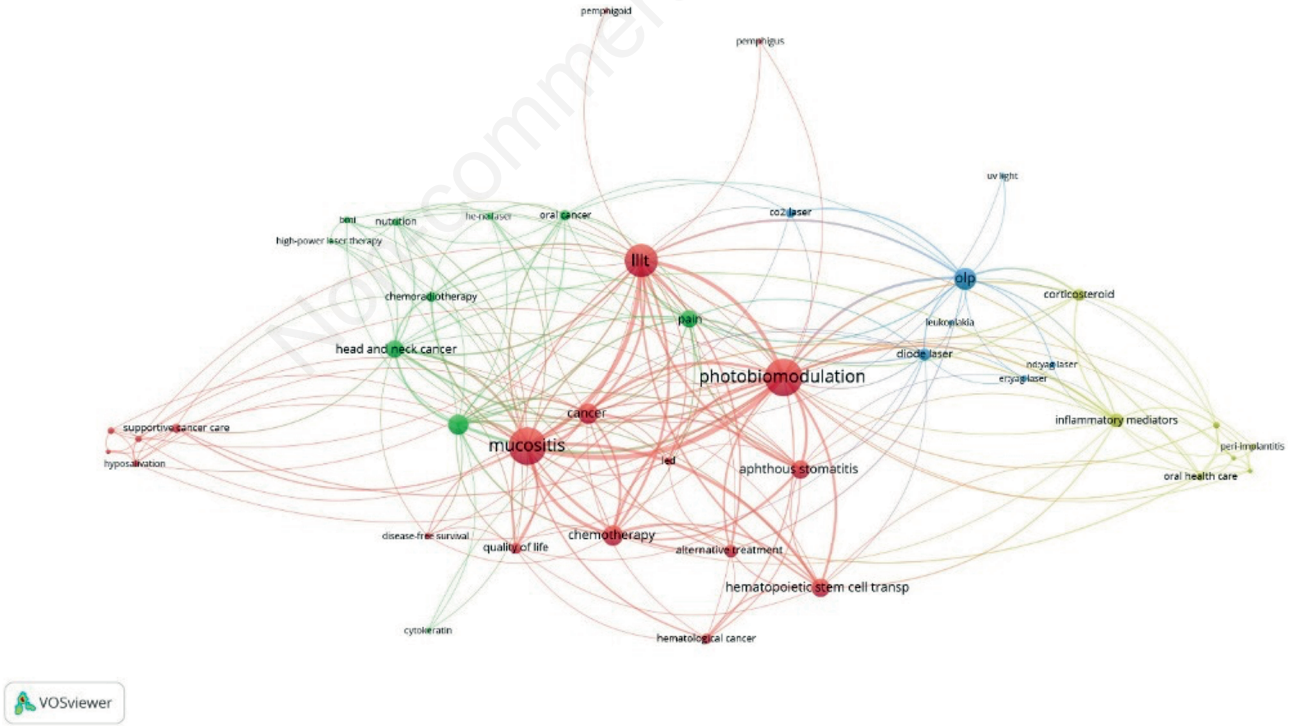

Figure 4. Intellectual structure based on author keyword.

ough research and testing may account for the time gaps between 1960 and 1991, and between 2001 and 2012, as preclinical research and clinical trials were necessary to ensure lasers could be effectively and optimally used in dentistry and for treating oral ulcerations. Indeed, the need for preclinical research and clinical trials before lasers could be used effectively and optimally in the field of dentistry and for the treatment of oral ulcers could explain the time gap between 1960 and 1991, as well as between 2001 and 2012.

Figure 3 illustrates the distribution of citations by country. Brazil emerged as the leader with 51 publications, garnering a total of 1,396 citations, followed by the United States with 9 articles and 530 citations. France secured the third position with 8 articles and 382 citations, while India occupied the fourth spot with 8 articles and 356 citations. Other countries contributed fewer than 8 articles, each receiving fewer than 150 citations. These findings align with the substantial presence of Brazilian researchers, as indicated in Table 3.

In Table 3, the preponderance of the leading 10 journals were positioned within the first and second quartiles, as per the SCImago journal rankings. Particularly noteworthy is the dominance of "Supportive Care in Cancer" with 26 publications and a citation per publication score of 43.42. The third quartile encompassed a sole journal, "Photobiomodulation Photomedicine and Laser Surgery".

As indicated in Table 3, 10 articles garnered over 100 citations. Remarkably, Jan Magnus Bjordal, associated with the Department of Global Public Health and Primary Care at the University of Bergen, emerged as the foremost author, amassing 207 citations.

Keywords were automatically extracted to construct a network based on bibliography co-occurrence. The full counting method was employed to tally the keywords. To eliminate duplications, a manual process of assessment and revision was undertaken to craft a tailored thesaurus. Within this data analysis, author keywords were established with a minimum occurrence of one, and 220 articles fulfilled this requirement. The depicted network in Figure 5 encompassed multiple nodes representing keywords, along with correlated edges. The proximity between nodes denoted the intensity of the correlation. Comparable keywords were grouped into clusters. Cluster 1 consists of 'alternative treatment', 'aphthous stomatitis', 'cancer', 'cancer complications', 'chemotherapy', 'disease-free survival', 'dysgeusia', 'dysphagia', 'hematological cancer', 'hematopoietic stem cell', 'hyposalivation', 'led', 'mucositis', 'pemphigoid', 'pemphigus', 'photobiomodulation', 'quality of life', and 'supportive cancer care.' Cluster 2 consists of 'bmi', 'chemoradiotherapy', 'cytokeratin', 'he-ne laser', 'high-power laser therapy', 'nutrition', 'oral cancer', 'pain', and 'radiotherapy.' Cluster 3 consists of 'co2 laser', 'diode laser', 'er:yag laser', 'leuoplakia', 'nd:yag laser', and 'uv light.' The last cluster, cluster 4, consists of 'corticosteroid', 'dental implants', 'oral health care', 'peri-implantitis', 'periodontal therapy', and 'saliva biomarker.'

Limitation of this study was the database used in this bibliometric analysis does not provide the option of author metadata, which no longer offers this metadata for performance analysis. For future bibliometric endeavors, it is advised to utilize alternative databases that offer author metadata, such as Dimension AI.

Conclusions

The bibliometric analysis conducted in this study presents insights into the research concerning the photobiomodulation of oral lesions published from 1991 to 2021. The findings revealed the presence of four distinct research clusters: low level light therapy, head and neck cancer, oral lichen planus, and inflammatory mediators. These results suggest the need for further exploration of photobiomodulation in the therapeutic treatment of various oral diseases. Overall, there has been a notable surge in research on photobiomodulation, particularly in the past decade. This trend may indicate the growing utilization of low-level light therapy for treating oral lesions within the population and the potential for alternative treatments for such conditions.

Contributions

CWW, IG, RA, conceptualization; CWW, IG, data curation, investigation, project administration, visualization; IG, formal analysis, resources, software; IG, RA, methodology; IG, RA, MSD, supervision; MSD, validation; CWW, writing–original draft; EFS, writing–review editing. All authors have read the final manuscript draft and agreed to be accountable for all aspects of the work.

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Conflict of interest

The authors declare no potential conflict of interest, and all authors confirm accuracy.

Ethics approval

Not applicable.

Informed consent

Not applicable.

Availability of data and materials

All data generated or analyzed durinng the study are avaible upon request.

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