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Review

Global Research Trends and Hotspots in Meibomian Gland Dysfunction (2014–2023): A Comprehensive Bibliometric and Visualization Analysis

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Abstract: This study aimed to explore the global research landscape, emerging hotspots, and advancements in Meibomian Gland Dysfunction (MGD) over the last decade through a bibliometric and visualization analysis for regenerative medicine strategy to treat MGD patients. Data were collected from the Web of Science Core Collection, covering the period from 2014 to 2023. VOSviewer and CiteSpace were used to analyze and visualize publication trends, contributions by countries and institutions, co-authorship analysis, journal impact, and keyword co-occurrence. Emerging topics were identified using keyword citation burst analysis. A total of 1271 publications were included. Four major research hotspots were identified: (1) etiology and pathogenesis, (2) advancements in diagnostic technologies, (3) therapeutic innovations, and (4) epidemiological trends. The United States and Yonsei University were the leading contributors in terms of publication and citation counts. *Ocular Surface*, *Cornea*, and *Investigative Ophthalmology & Visual Science* were the top journals by productivity and impact. The study revealed significant progress in MGD research and highlighted key areas requiring further investigation, including the establishment of global diagnostic standards and targeted therapies in regenerative medicine. These findings provide a roadmap for future collaborative efforts and strategic research directions in regenerative medicine of the field.

Keywords: meibomian gland dysfunction; bibliometric analysis; research trends; VOSviewer; CiteSpace

1. Introduction

The meibomian glands, located along the upper and lower margins, are integral to ocular surface health. These glands produce meibum, a lipid-rich secretion forming the outermost layer of the tear film [1,2]. This layer prevents excessive evaporation, ensuring tear film stability. Meibomian Gland Dysfunction (MGD), a prevalent disorder, disrupts meibum secretion, resulting in tear film instability, ocular surface inflammation, and symptoms of dry eye disease [3].

Since the *Tear Film and Ocular Surface Society* (TFOS) hosted its first workshop on MGD in 2011, research interest in this condition has surged, reflecting its clinical and economic impact on global eye health [4,5]. However, the vast and rapidly growing body of literature on MGD presents challenges in identifying key advancements and research priorities in regenerative medicine.

Bibliometric analysis, a quantitative approach to evaluating research trends, offers valuable insights into the growth, collaboration, and thematic focus of a field [6,7]. Tools like VOSviewer (https://www.vosviewer.com/) and CiteSpace (https://citespace.podia.com/) enable researchers to visualize relationships between institutions and keywords, as well as identify emerging research hotspots [8–14].

Despite the clinical importance of MGD, no comprehensive bibliometric analysis of MGD research exists to date. This study addresses this gap by evaluating the global research landscape of MGD from 2014 to 2023, uncovering key trends, identifying influential contributors, and mapping future research directions to treat MGD patients in regenerative medicine.

2. Methods

2.1. Data Collection and Retrieval Strategy

Data were retrieved from the Web of Science Core Collection, which is widely recognized for its comprehensive coverage of high-quality, peer-reviewed literature, particularly in the field of Medicine. The retrieval method shown in Figure 1, which included the following criteria:

(1) Topic = “meibomian gland dysfunction”;
(2) Timespan: “2014-01-01 to 2023-12-31”;
(3) Language: English;
(4) Document type: “article”; and
(5) Full records of each retrieved publication, including authors, organizations, countries, publications, keywords, journals, citations, and cited references, were collected.

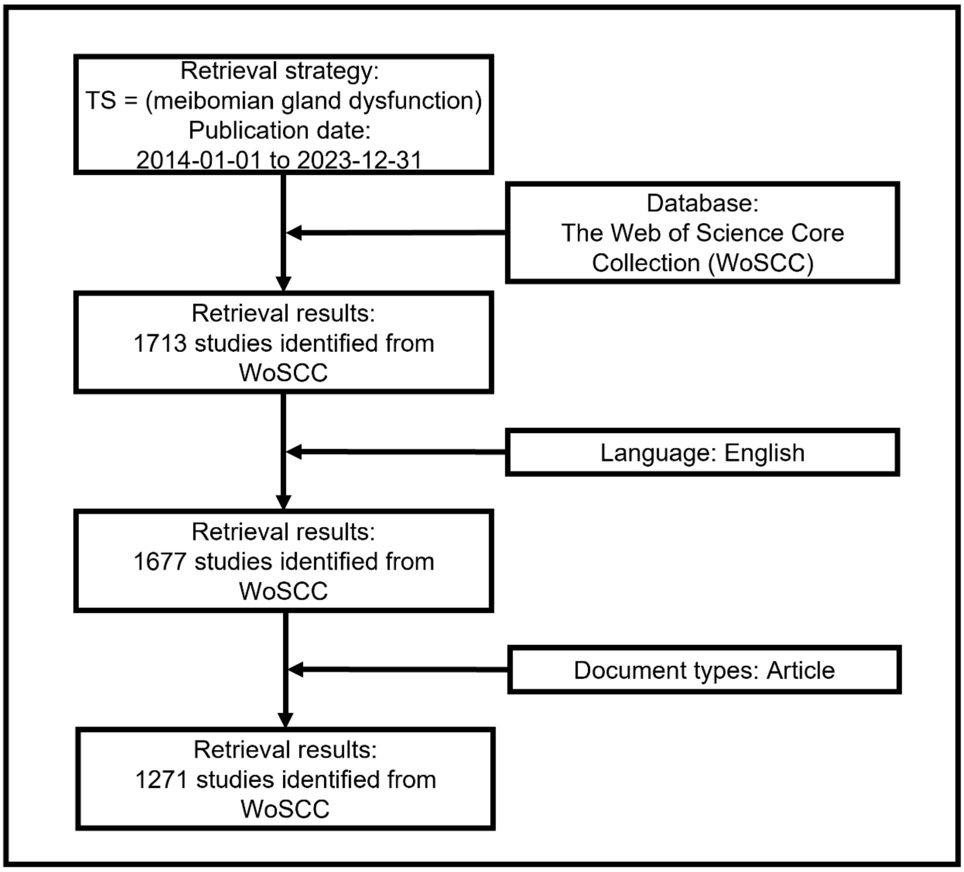

Figure 1. The retrieval strategy and the data collection process in this study.

2.2. Data Analysis and Thesaurus Replacement

Keywords with similar meanings were combined into one in the keyword co-occurrence analysis. Specifically, synonymous keywords were found, are listed in Supplementary Table S1, and were replaced before the visualization analysis. For instance, the keyword "intense pulsed-light" was combined into the keywords "intense pulsed light" using the formula "label…replace by".

2.3. Visualized Analysis

VOSviewer1.6.19 (www.vosviewer.com) and CiteSpace 6.3.1.0 (https://citespace.podia.com/) [15] were applied for the visualization evaluation in the study. Specifically, visualization of annual publications, countries/regions, organizations/institutions, journals, and keyword co-occurrence was conducted. In this study, each node in the visualization image represents the corresponding item/component that is aimed to be analyzed. The bigger the node is, the more the weight. The string between different nodes represents their links. The thicker the string is, the stronger the links. In addition, nodes with the same color belong to the same group or cluster. In addition, we employed the open-source graphing library Plotly (https://plotly.com/graphing-libraries/) to create Choropleth maps for data visualization of the distribution of countries/regions. The color map was specifically indexed to the logarithmic values of the number of publications for each country/region, allowing for an enhanced representation of the data distribution across regions.

3. Results

3.1. Annual Publications and Top Ten Articles Regarding MGD Research

A total of 1271 papers associated with MGD research, which were published from 2014 to 2023 were extracted. Figure 2A shows the annual distributions of papers on MGD. The number of annual papers showed a stable growth trend that increased significantly and consistently in the last decade, from 59 (2014) to 158 (2023). The number of annual publications on MGD research was less than 100 before 2018, after which the outputs increased stably and reached a maximum of 224 in 2022. Table 1 lists the top ten most cited papers on MGD research among the 1271 papers. "New Perspectives on Dry Eye Definition and Diagnosis: A Consensus Report by the Asia Dry Eye Society", which was published in 2017 in *Ocular Surface*, was the most frequently cited publication, with 358 citations. The number of citations of the remaining top 9 most cited publications ranged from 123 to 347.

Table 1. The top ten meibomian gland dysfunction (MGD) research papers with the most citation frequency over the past decade.

Rank	Title	Source Title	Publication Year	Citations	References
1	New Perspectives on Dry Eye Definition and Diagnosis: A Consensus Report by the Asia Dry Eye Society	Ocular Surface	2017	358	[16]
2	The Pathophysiology, Diagnosis, and Treatment of Dry Eye Disease	Deutsches Arzteblatt International	2015	347	[17]
3	Meibomian Gland Disease the Role of Gland Dysfunction in Dry Eye Disease	Ophthalmology	2017	209	[18]
4	Prospective Trial of Intense Pulsed Light for the Treatment of Meibomian Gland Dysfunction	Investigative Ophthalmology & Visual Science	2015	174	[19]
5	Intense Pulsed Light Treatment for Dry Eye Disease Due to Meibomian Gland Dysfunction; A 3-Year Retrospective Study	Photomedicine And Laser Surgery	2015	172	[20]
6	Rethinking Dry Eye Disease: A Perspective on Clinical Implications	Ocular Surface	2014	169	[21]
7	n-3 Fatty Acid Supplementation for the Treatment of Dry Eye Disease	New England Journal of Medicine	2018	150	[22]
8	Clinical Guidelines for Management of Dry Eye Associated with Sjogren Disease	Ocular Surface	2015	138	[23]
9	Inflammatory Response in Dry Eye	Investigative Ophthalmology & Visual Science	2018	125	[24]
10	Analysis of Cytokine Levels in Tears and Clinical Correlations After Intense Pulsed Light Treating Meibomian Gland Dysfunction	American Journal of Ophthalmology	2017	123	[25]
10	Dysfunctional tear syndrome: dry eye disease and associated tear film disorders—new strategies for diagnosis and treatment	Current Opinion in Ophthalmology	2017	123	[26]

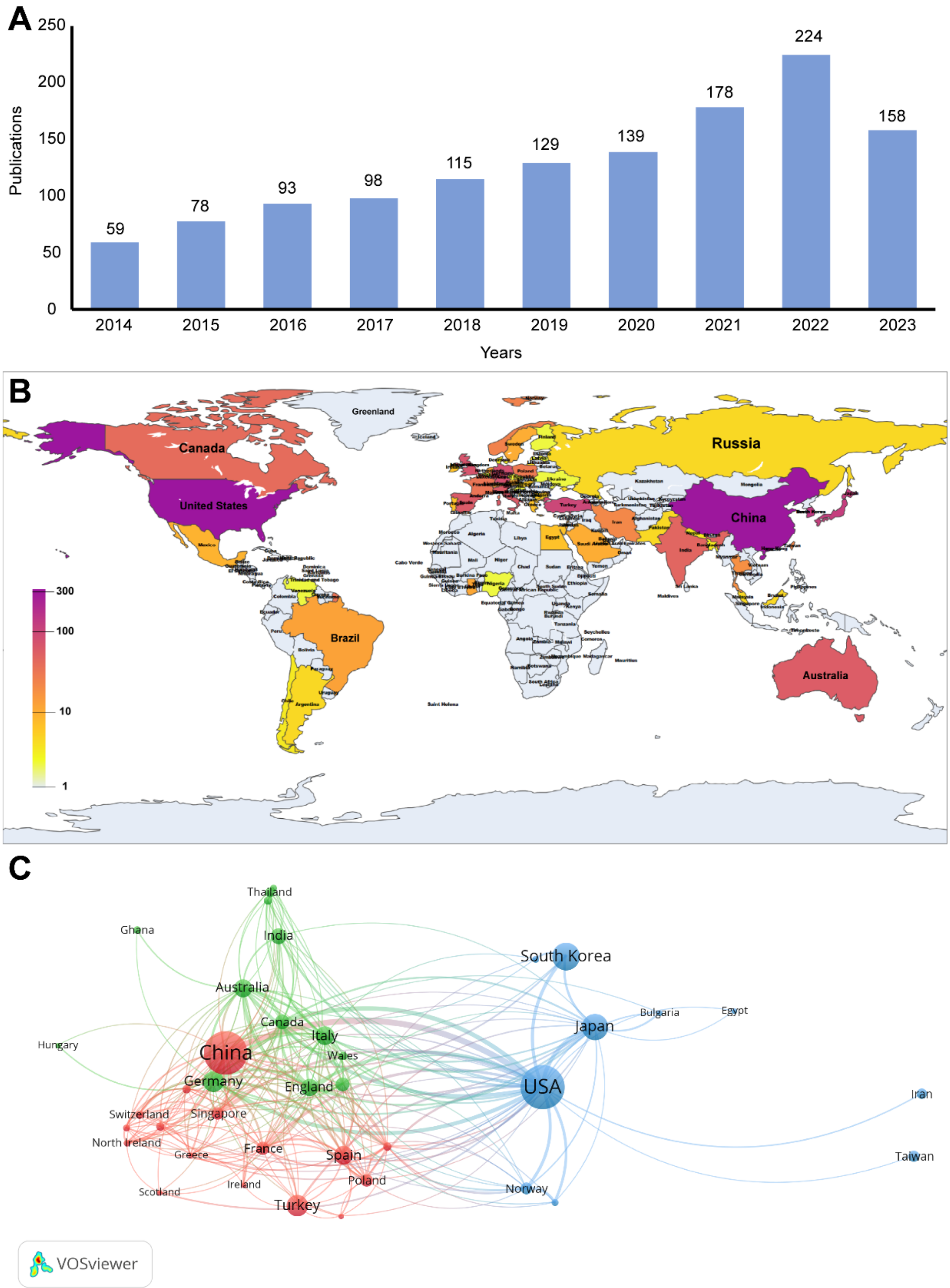

Figure 2. Distribution of Publications. (**A**) Annual publications on meibomian gland dysfunction (MGD) study from 2014 to 2023. (**B**) Distribution of countries/regions. (**C**) The co-authorship map of countries/regions regarding MGD research, 2014–2023. Connected countries/regions (39 of 66) with at least 8 publications are shown in the co-authorship network map.

3.2. Analysis of Countries/Regions Regarding MGD Research

A total of 66 countries/regions were included in the MGD study worldwide as shown in Figure 2B. Supplementary Table S2 lists the top ten countries/regions with the most papers. Among them, the United States (USA) was the first with 308 publications and 7040 citations, followed by China with 297 publications and 3821 citations, and South Korea with 124 publications and 2217 citations.

In addition, the co-authorship network map with nodes and lines was sketched (Figure 2C) to explore the latent connections among different countries/regions. As shown in Figure 2C, 39 connected countries/regions whose number of publications was above 8, which were formed three clusters with different colors (red, green, and blue) shown in the co-authorship network map. The largest group (in red), comprising 16 countries/regions, focused on China, Turkey, and Spain. The cluster in green comprises 13 countries/regions and was led by Germany, Italy, and Australia. The cluster in blue comprised 10 countries/regions, which was focusing on the USA, South Korea, and Japan. In addition, the USA had the strongest weight (n = 35) of cooperation with other countries/regions, followed by Germany (n = 28) and China (n = 28).

3.3. Analysis of Organizations/Institutions Involved in MGD Research

Totally, 1479 organizations/institutions were included in the MGD study worldwide. Supplementary Table S3 lists the top ten organizations/institutions with the most papers. Among them, Yonsei University (South Korea) ranked first with 41 publications and 1290 citations, followed by Harvard Medical School (USA) with 37 publications and 609 citations, and Fudan University (China) with 36 publications and 513 citations. The remaining top 10 organizations were located in China (n = 2), Japan (n = 2), the USA (n = 1), Canada (n = 1), and New Zealand (n = 1).

Moreover, the co-authorship network map of organizations/institutions (Figure 3) demonstrates cooperation among 140 organizations/institutions whose number of publications was above 5 and connected to form five clusters with different colors (red, green, blue, yellow, and purple). The largest group (in red, cluster 1), comprising 51 organizations/institutions, focused on the University of Alabama at Birmingham, the University of Auckland, and the University of Waterloo. The cluster in green (cluster 2) comprised 27 organizations/institutions led by Yonsei University, Keio University, and Itoh Clinic. The cluster in blue (cluster 3), comprising 23 organizations/institutions, concentrated on Oslo University Hospital, University of Oslo, and Norwegian Dry Eye Clinic. The cluster in yellow (cluster 4) consists of 20 organizations/institutions led by Fudan University, Wenzhou Medical University, and Capital Medical University. The cluster in purple (cluster 5) consists of 19 organizations/institutions centered around Harvard Medical School, Xiamen University, and Sun Yat-Sen University. Furthermore, Harvard Medical School had the strongest weight (n = 35) of cooperation with other organizations/institutions, followed by Keio University (26) and Wenzhou Medical University (26).

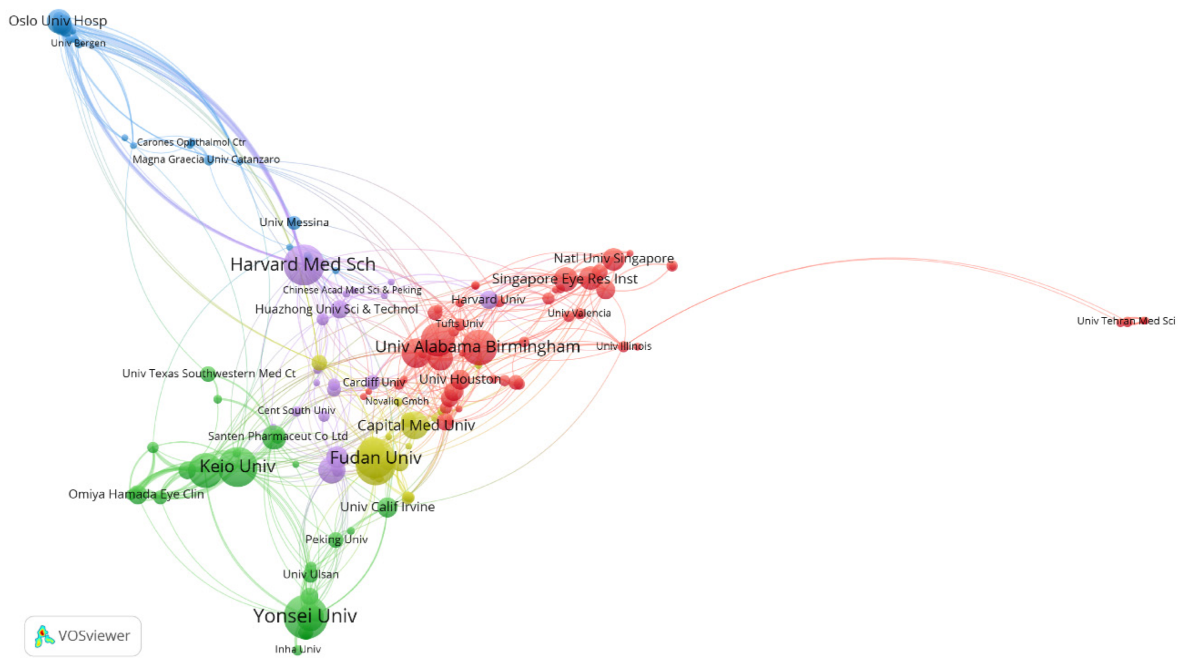

Figure 3. The co-authorship map of organizations/institutions involved in the MGD study, 2014–2023. Connected organizations/institutions (140 of 1479) with at least 5 publications are shown in the co-authorship map.

3.4. Analysis of Journals on MGD Research

The extracted papers on MGD study were found in 216 journals. Table 2 lists the main journals (32 of 216) with at least 10 MGD-related publications over the last decade. Totally, 959 of 1271 (75.45%) retrieved publications were published in the 32 listed journals, which contained approximately three-quarters of all publications. *Ocular Surface* had the most papers on MGD study (106, 8.3%), followed by *Cornea* (101, 7.9%) and *Investigative Ophthalmology & Visual Science* (71, 5.6%) among all journals. In addition, the top 3 journals had the most number of citations, with 2932, 2157, and 2003, respectively. Figure 4A highlights the journals with the most publications by the color red in the density visualization map of journals, which corresponds to the results in Table 2. In addition, with the increasing density, the blue color (background color) is gradually switched to cyan, green, yellow, orange, and red in Figure 4A. Furthermore, Figure 4B reveals the average publication year (APY) of the papers published by the journals, which noted several emerging journals in the MGD field, such as *Ophthalmology and Therapy* (APY: 2022.30), *Ocular immunology and inflammation* (APY: 2021.82), *European Journal of Ophthalmology* (APY: 2021.81), *Frontiers in Medicine* (APY: 2021.67), *Journal of Clinical Medicine* (APY: 2021.57), *Graefes Archive for Clinical and Experimental Ophthalmology* (APY: 2021.39), and *International Journal of Molecular Sciences* (APY: 2021.18).

Table 2. The main journals in meibomian gland dysfunction (MGD) research from 2014 to 2023.

Rank	Journal	IF (2023)	Count	Count%	Citations
1	Ocular Surface	5.9	106	8.3%	2932
2	Cornea	1.9	101	7.9%	2157
3	Investigative Ophthalmology & Visual Science	5.0	71	5.6%	2003
4	Contact Lens & Anterior Eye	4.1	49	3.9%	648
5	Eye & Contact Lens-Science and Clinical Practice	2.0	43	3.4%	608
6	Bmc Ophthalmology	1.7	38	3.0%	415
7	International Ophthalmology	1.4	38	3.0%	368
8	Scientific Reports	3.8	36	2.8%	411
9	Current Eye Research	1.7	35	2.8%	615
10	Journal of Clinical Medicine	3.0	35	2.8%	137
11	Experimental Eye Research	3.0	31	2.4%	521
12	Frontiers in Medicine	3.1	27	2.1%	138
13	Optometry and Vision Science	1.6	27	2.1%	513
14	PLoS ONE	2.9	27	2.1%	487
15	American Journal of Ophthalmology	4.1	26	2.0%	857
16	Indian Journal of Ophthalmology	2.1	25	2.0%	131
17	Journal of Ophthalmology	1.8	25	2.0%	306
18	International Journal of Ophthalmology	1.9	24	1.9%	259
19	British Journal of Ophthalmology	3.7	22	1.7%	552
20	International Journal of Molecular Sciences	4.9	17	1.3%	161
21	Ophthalmology	13.1	17	1.3%	1029
22	Ophthalmology and Therapy	2.6	17	1.3%	47
23	European Journal of Ophthalmology	1.4	16	1.3%	94
24	Acta Ophthalmologica	3.0	13	1.0%	166
25	Eye	2.8	13	1.0%	167
26	Graefes Archive for Clinical and Experimental Ophthalmology	2.4	13	1.0%	78
27	Clinical and Experimental Optometry	1.7	12	0.9%	190
28	Photobiomodulation Photomedicine and Laser Surgery	1.8	12	0.9%	162
29	Translational Vision Science & Technology	2.6	12	0.9%	139
30	Ocular Immunology and Inflammation	2.6	11	0.9%	52
31	Journal of Ocular Pharmacology and Therapeutics	1.9	10	0.8%	136
32	Ophthalmic Plastic and Reconstructive Surgery	1.2	10	0.8%	84

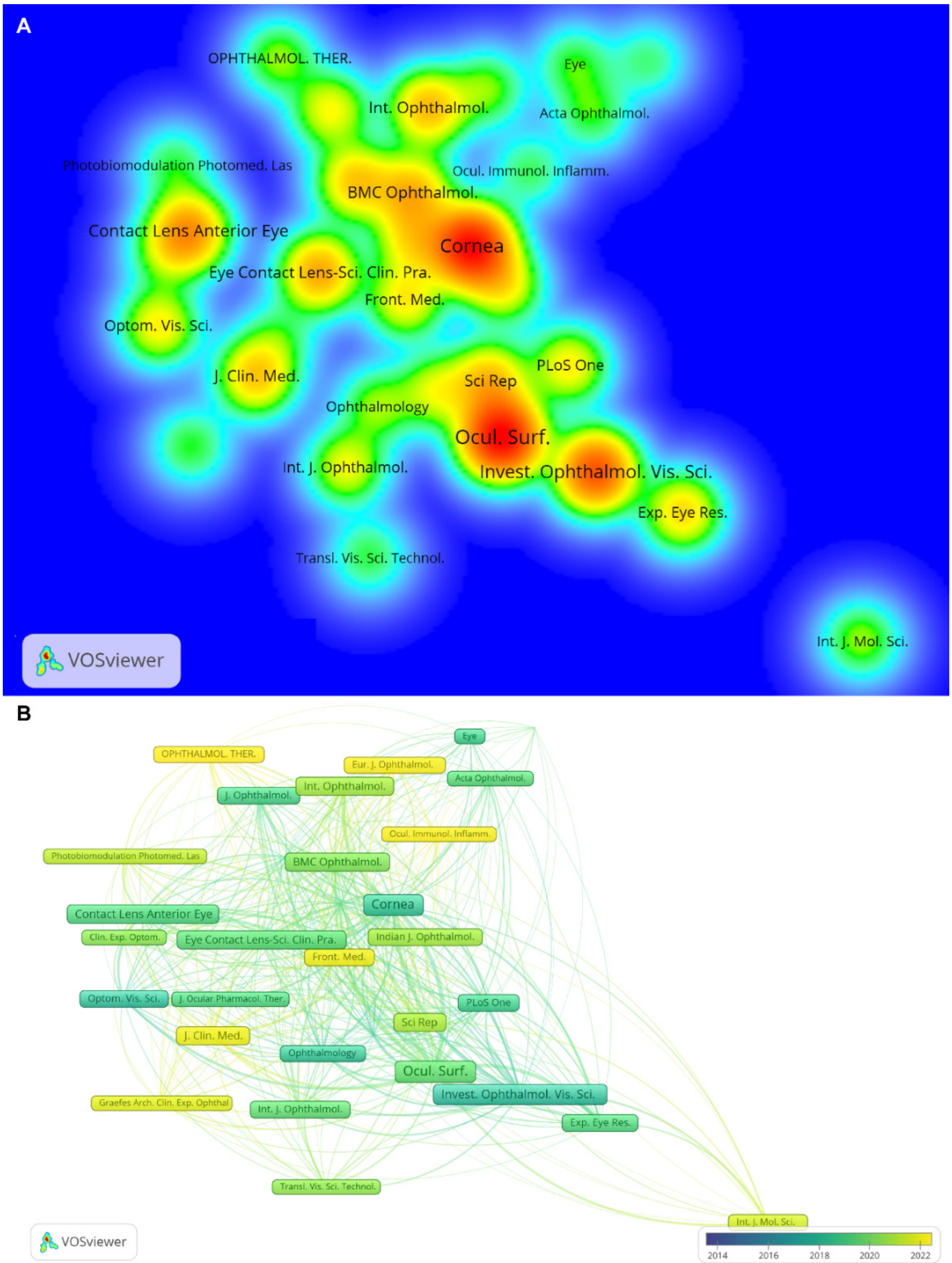

Figure 4. The visualized map of journals on MGD research, 2014–2023. (**A**) The density visualization map of journals. (**B**). The overlay visualization map of journals. Journals (32 of 216) with at least 10 MGD-related publications are shown on the map.

3.5. Analysis of Keyword Co-Occurrence and Citation Bursts in MGD Research

Totally 3395 keywords associated with the MGD study were extracted. The keywords with high frequencies (≥10) were visualized by VOSviewer; 163 of 3395 keywords met the threshold. The map of keyword co-occurrence analysis composed 4 clusters showing in four different colors, which included cluster 1 (red), cluster 2 (green), cluster 3 (blue), and cluster 4 (yellow) (Figure 5). The cluster in red (cluster 1), consisting of 47 keywords, represents the underlying etiology or pathogenesis of MGD; the cluster in green (cluster 2), comprising 41 keywords, represents the testing and diagnosis of MGD; the cluster in blue (cluster 3), containing 40 keywords, represents therapy for MGD; the cluster in yellow (cluster 4), including 35 keywords, represents the epidemiology of MGD. Keywords within the same cluster had the same color, where the different clusters indicated different hotspots of the MGD study, which are described in detail in the Discussion section. The top 163 keywords with their occurrences are shown in Supplementary Table S4.

Keywords citation bursts detection is the other method to uncover hot topics, which reflects the change of research hotspot over time. CiteSpace was used to detect keywords citation bursts in MGD research field from 2014 to 2023 in this study. The top 25 keywords with the strongest citation bursts were identified using keyword burst analysis, where the keyword "in vivo confocal microscopy" showed the latest citation bursts from 2021 to 2023 (Figure 6).

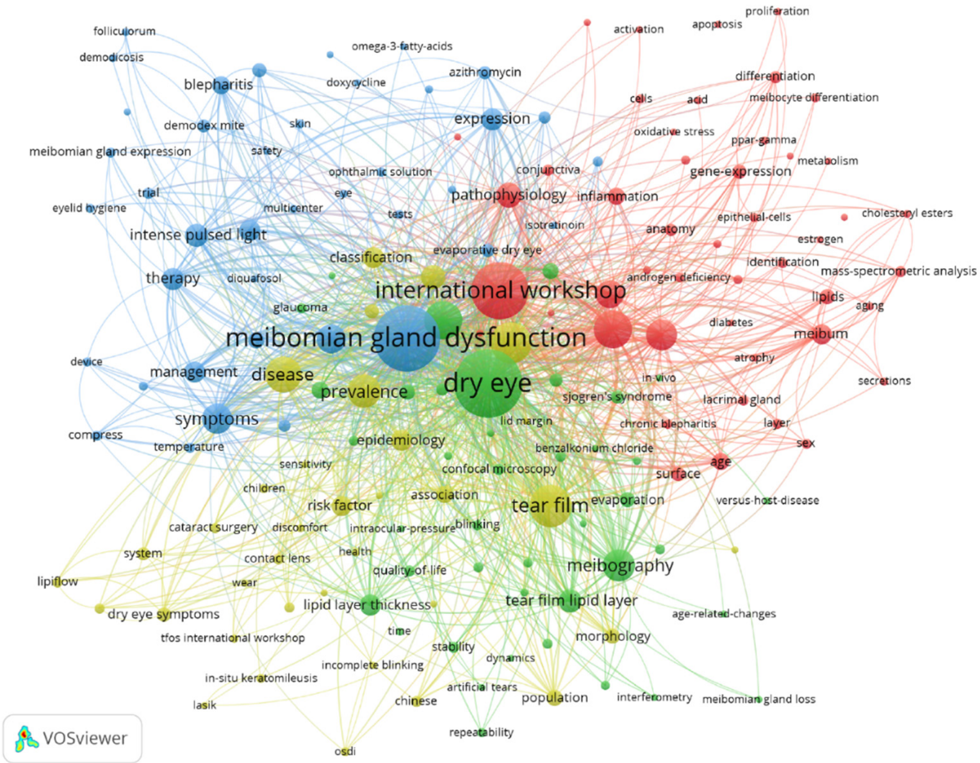

Figure 5. The visualized map of keywords in MGD research, 2014–2023. Keywords (163 of 3395) with at least 10 occurrences are shown on the map.

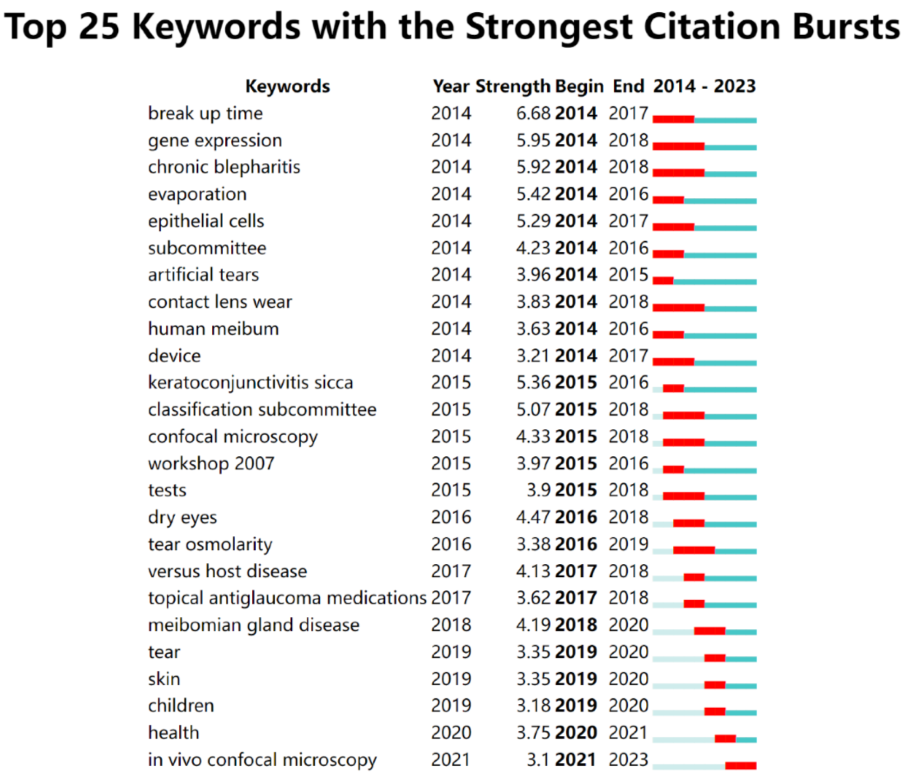

Figure 6. The top 25 keywords with the strongest citation bursts in MGD research, 2014–2023.

4. Discussion

4.1. Emerging Trends in MGD Research

The rapid increase in MGD-related publications over the past decade reflects its rising prominence as a critical area in ophthalmology. This trend mirrors the growing burden of MGD-related conditions on global healthcare systems, as well as advancements in diagnostic tools and therapeutic interventions.

The USA's dominant position in both publication volume and collaboration networks highlights its central role in shaping the research agenda. The contributions of China and South Korea further emphasize the increasing globalization of MGD research, with Asian countries playing an ever-growing role in advancing the field.

4.2. Research Hotspots and Persistent Challenges

Keywords play an essential function in figuring out the most imperative information from papers. Co-occurrence analysis of keywords uncover the hotspots of research, as assessed based on their frequencies. Totally, 4 clusters revealed 4 research hotpots, which are discussed in detail in the following paragraphs.

Cluster 1 # in red manifested the potential etiology or pathogenesis of MGD according to the key phrases "pathophysiology", "meibum/lipids/cholesteryl esters", "inflammation/chronic blepharitis/microbiome/ocular surface inflammation", "age/aging", "gene-expression", "differentiation/meibocyte differentiation/ppar-gamma", "sex/androgen deficiency/estrogen", "oxidative stress", "apoptosis", "atrophy", and "diabetes".

Meibum/lipids/cholesteryl esters—The quality, quantity, and composition of meibum that MG secreted is important for the homeostasis and health of the ocular surface [27–29]. The abnormality of meibum is one of the main features of MGD [30,31]. Variations in meibum composition/increased meibum viscosity might lead to MGD [32,33], because the appropriate constituents and proper ratio of the meibum make a guarantee of well-balanced flow. Alterations in the constituents of the meibum change the viscosity of the meibum and alter the osmolarity of the tear, which results in the accumulation of the meibum and the instability of the tear film. In addition, inspissated lipid secretions may develop in conjunction with duct hyper-keratinization, and eventually, the meibomian glands may drop out [34]. Therefore, the factors that disturb the normal secretion of meibum may be the potential etiology of MGD. In addition, abnormal lipoprotein levels were reported in some MGD patients in clinical studies [35–37]. Moreover, the closely associated relationship between MGD and hyperlipidemia/dyslipidemia was also confirmed in the basic study [1,38].

Inflammation/chronic blepharitis/microbiome/ocular surface inflammation—Patients with MGD usually had elevated levels of phospholipase A2, which is required for the manufacture of inflammatory mediators, suggesting a connection between MGD and inflammation [39]. The meibomian gland entrancement may become keratinization as a result of certain inflammatory cytokines [40,41]. In addition, an increasing inflammatory cell infiltration was also found in MGD [42]. Furthermore, an increase in commensal bacterial species occurs, and the lipids secreted by the meibomian gland may be dissolved by the lipases generated by these bacteria [43].

Age/aging—Aging is an important factor that has influenced the onset of many eye-related disorders, such as the well-known age-related macular degeneration (AMD) [44], and age-related MGD (ARMGD) [45]. MG went through a variety of age-related alterations, such as the decreased proliferation of acinar basal cells, the atrophy and drop-out of MG, and the increasing inflammatory cell infiltration with age [46]. Therefore, aging is highly related to the onset of MGD [47].

Gene-expression—The differential gene expression profile between the MGD patient and the normal control can reveal the potential pathogenic pathway, and shed light on the investigation of mechanisms of MGD [48]. A recent study uncovered the gene expression signatures of MGD patients, and the following pathways were activated, such as the differentiation signaling pathways for T helper-17 (Th-17), B cell receptor, T cell receptor, immunometabolism, MHC class I/II, and IFN I/II [49].

Differentiation/meibocyte differentiation/ppar-gamma—The decreased differentiation of meibocyte was found in MGD, which was confirmed to be related to the decreased expression of ppar-gama (peroxisome proliferator-activated receptor gamma) [50]. The ppar-gamma is predominant expressed in adipose cells, and regulates the lipogenesis gene expression [51]. ppar-gamma also expressed in MG and regulated the meibum synthesis and meibocyte differentiation [52,53]. However, the molecular mechanisms governing ppar-gamma-related meibocyte differentiation remain unclear. In addition, desiccating stress, characterized with the aid of dry conditions and described as exterior stress, might also cause MGD due to the effect on the differentiation and renewal of meibocytes [54].

Others—Additional factors that may play a role in MGD are pointed out in cluster 1 with the exacted keywords, such as "sex/androgen deficiency/estrogen" [55–57], "oxidative stress" [58,59], "apoptosis", "atrophy" [60], and "diabetes" [61], which are also investigated and confirmed in other studies.

In short, despite significant progress in understanding the molecular and biochemical mechanisms of MGD, many questions remain unanswered. For example, the precise roles of lipid metabolism, hormonal influences, and inflammatory pathways need further elucidation. Future studies could focus on integrating multi-omics approaches to uncover novel therapeutic targets.

Cluster 2 # (in green) represented the testing and diagnosis of MGD. The keywords "meibography", "lipid layer thickness", "confocal microscopy", "osmolarity", "break-up time", "optical coherence tomography", "keratograph", "tear film stability", "interferometry", and "kinetic-analysis" were fetched. Recent innovations, such as confocal microscopy and meibography, have improved the accuracy and reliability of MGD diagnoses. However, the absence of standardized diagnostic criteria complicates global comparisons and hampers the development of universally accepted management guidelines [62,63]. Optical coherence tomography (OCT) [64–67], in vivo confocal microscopy (IVCM) [68–71], and meibography [72–76] are new diagnostic methods that are frequently employed to analyze meibomian glands recently. Establishing consensus-based standards should be a priority for future research initiatives.

Cluster 3 # (in blue) revealed the hotspots of MGD therapy with the extracted keywords "intense pulsed light", "meibomian gland expression"/"compress", "azithromycin", "temperature", "ophthalmic solution", "eyelid hygiene", "omega-3-fatty-acids", "diquafosol", and "doxycycline". More specifically, the treatments for MGD regarding the potential etiology of MGD can be summarized as follows based on the extracted keywords.

Hygiene, massage, and eyelid warming are basic and essential remedies for treatment of MGD patients as regenerative medicine [77–83]. Regarding anti-inflammatory agents and antibiotics [84], they were proven to relieve symptoms effectively in those suffering from MGD.

Regarding lubricants/artificial tears, because MGD is the typical case of evaporative dry eye diseases, treatments such as lubricants and artificial tears are also effective for the treatment of MGD. Regarding autologous serum-based eye drops [85], the latest research has indicated that these eyedrops might be useful as regenerative medicine for severe symptoms or with damage to corneal epithelial. Whereas, the accessibility, safety, and fee of these eyedrops still need further studies.

The latest research has shown the function of intense pulsed light (IPL) remedy [25,86–88] in lowering inflammation, *Demodex*, and telangiectatic blood vessels. Lipiflow [89], a thermodynamic treatment, improved the subjective and objective parameters of MGD in patients according to a recent report [90]. Additional remedies like intraductal meibomian gland probing [91], diquafosol instillation [92], and nutritional supplements (such as vitamin D3 analog ointment [93], omega-3-fatty-acids [94,95], and essential fatty acid [96]), were also reported as regenerative medicine. However, these therapies require validation through large-scale, multicenter clinical trials to ensure their safety, efficacy, and cost-effectiveness.

Cluster 4 # (in yellow) focused on the epidemiology of MGD, with fetched keywords containing "prevalence", "epidemiology", "risk factors", "contact lens", "population", and "incomplete blinking". The prevalence of MGD has also been highlighted by the increased concern related to MGD. The latest research found that 35.8% of people have MGD [97]. In addition, Craig et al. [98] state that MGD symptoms manifested earlier in the natural history of the disorder progression, even in individuals in their 20s, demonstrating the widespread detrimental impacts of MGD. Furthermore, given that MGD was more common in East Asian ethnic groups [99,100], it is probably not surprising that the USA and Yonsei University in Korea have made the greatest contributions to the area of MGD among the countries/regions, and organizations/institutions. The latest cross-sectional research [101] has indicated that the risk factors for MGD include East Asian ethnicity, oral contraceptive therapy, migraine headaches, and thyroid disease. Overall, the observed disparities in MGD prevalence across different populations highlight the need for large-scale, cross-regional epidemiological studies. Understanding these differences could inform tailored interventions and guide resource allocation for managing MGD in diverse settings.

5. Conclusions

This study underscores the importance of international collaboration in addressing the challenges posed by MGD. The establishment of globally standardized diagnostic and treatment protocols would not only enhance the comparability of research findings but also improve patient outcomes worldwide. Additionally, fostering cross-regional partnerships could help bridge research gaps and promote equitable access to innovations in MGD management. While this study highlights key advancements in MGD research, particularly in etiology, diagnostics, and therapeutic innovations. The unmet therapeutic strategies present an urgent need for regenerative medicine in future. Given that MGD is primarily associated with glandular dysfunction and structural deterioration, regenerative approaches—such as stem cell therapy, tissue engineering, and bioengineered glandular restoration—could offer novel treatment pathways.

6. Strengths and Limitations of This Study

- This study provides a comprehensive bibliometric analysis of Meibomian Gland Dysfunction (MGD) research over the past decade, leveraging VOSviewer and CiteSpace for visualization and hotspot identification for future treatment of MGD patients.
- The Web of Science Core Collection was used as a robust and widely recognized database, ensuring the inclusion of high-quality and impactful publications.
- Analysis of keyword citation bursts and co-authorship networks highlights emerging research areas and collaboration trends, offering valuable insights for future MGD studies in regenerative medicine.
- A limitation of this study is the inclusion of only English-language publications, which may exclude relevant research published in other languages.

Supplementary Materials

The additional data and information can be downloaded at: https://www.sciltp.com/journals/rmd/2025/1/714/s1. Table S1: Synonym substitution. Table S2: Top ten leading countries/regions regarding MGD research from 2014 to 2023. Table S3: Top ten leading organizations/institutions in MGD research from 2014 to 2023. Table S4: Top 163 keywords in keywords co-occurrence analysis regarding MGD research.

Author Contributions

Q.L.: Conceptualization, visualization, methodology, writing, and revising the manuscript; F.Z.: Conceptualization, and revising the manuscript; J.L., M.G., C.J., T.W. and T.-C.S.: Data collection, and data analysis; T.Y.: Figure drawing, methodology; J.K.: Supervision; A.H.: Funding acquisition, supervision, and revising the manuscript. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Data Availability Statement

All relevant data are available within the article or from the corresponding author upon reasonable request.

Conflicts of Interest

The authors have no conflicts of interest to declare.

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