Observational Study

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Knowledge mapping of posterior capsular opacification from 2011 to 2023

A bibliometric analysis

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Abstract

This bibliometric analysis explores the current status and trends of global research on posterior capsular opacification (PCO). A search of the Web of Science Core Collection (WoSCC) database was conducted to identify publications on PCO from 2011 to 2023. Bibliometric analysis was used to explore publication trends in PCO-related research. VOSviewer v.1.6.20 was used to visualize country, institution and author productivity and collaborations, as well as research hotspots. CiteSpace 6.3.R1 was applied to extract the burst references and keywords. A total of 988 PCO-related documents were included. The largest number of publications (283) and citations (3538) were from China. Of these, the largest number of publications (41) and citations (655) were from Wenzhou Medical University. Quankui Lin published 31 articles and was the most productive author. The journal with the highest productivity (121 publications) was the Journal of Cataract and Refractive Surgery. The top 3 cited references mainly presented intraocular lens (IOL) optic material/design and surgical technique on the development of PCO; the mechanism of PCO formation. The keywords mainly formed 5 clusters: the prevalence and risk factors for PCO; the mechanism of PCO formation; the material and design of IOLs and their application in the prevention of PCO; the application of IOLs surface modification and drug delivery in the prevention of PCO; and complications associated with Nd:YAG laser capsulotomy. Based on the raw data from WoSCC, analyzing research hotspots can offer valuable insights into PCO studies.

Abbreviations: EMT = epithelial-mesenchymal transition, HSM = heparin-surface-modified, IOL = intraocular len, LECs = lens epithelial cells, PCO = posterior capsular opacification, PEG = polyethylene glycol, PMMA = polymethylmethacrylate, RD = retinal detachment, SCIE = science citation index expanded, SI-RAFT = surface-initiated reversible addition-fragmentation chain-transfer, WoSCC = Web of Science Core Collection.

Keywords: bibliometric analysis, CiteSpace, posterior capsular opacification, VOSviewer

1. Introduction

Posterior capsule opacification (PCO) is one of the most common complications leading to vision loss after cataract surgery.[1] In the past few decades, how to prevent and treat PCO has been a hot topic in ophthalmology research. In order to comprehensively analyze the current status and development trends of PCO research, we used bibliometrics and visualization mapping methods.

Bibliometrics is a method of evaluating the current state of research in a certain field and predicting trends on its development by quantitatively analyzing and describing published literature using mathematical and statistical methods. Various tools, such as CiteSpace and VOSviewer, are widely used to generate knowledge maps.

This study examines the growth of publications, distribution among countries, collaborations between institutions and authors, journal areas, citations, and keyword co-occurrence in the field of PCO research. Analyzing research trends is crucial for researchers to pinpoint areas that require further investigation in future studies. Hence, our study aims to comprehensively evaluate the current status and trends in PCO research through the application of bibliometric techniques.

2. Materials and methods

2.1. Data source and research process

The literature for this study was obtained from the science citation index expanded within the Web of Science Core Collection

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(WoSCC). The search formula used for this study was TS = ("PCO") OR TS = ("posterior capsule opacification"). The publication date was restricted to the period from January 1, 2011, to December 30, 2023. Only documents classified as "Article" were included in the study, while other document types were excluded. The data in this research comes from public databases, so it does not involve ethical approval.

2.2. Analytical tool and method

This study utilized bibliometric methods to provide an overview of literature related to PCO. VOSviewer (version 1.6.20), created by van Eck and Waltman, is utilized for the visual analysis of bibliometric data.[2] The present study utilized VOSviewer to analyze the citation of countries in the PCO field, conduct co-authorship analysis of institutions and authors, and perform co-occurrence analysis of keywords. Citespace (6.3.R1), developed by Zhuomei Chen et al at Drexel University, is a tool specifically created to aid in the examination of emerging trends within various knowledge domains.[3] The time period is set from 2011 to 2023, and each time slice is set to 1. Perform burstness analysis on keywords and references, and display the top 25 results, while covering dual maps of journals.

3. Results

3.1. Yearly quantitative analysis of literature

Based on the selection criteria, 988 articles on PCO were indexed in WoSCC from 2011 to 2023. As shown in Figure 1A, the number of publications showed fluctuations, with research hotspots. Depending on the citation bursts (shown in Figure 1B), the boost of publications in the years 2014, 2018, and 2021 may have been due to the hot topics of "regeneration", "intraocular lens (IOL)", "quality", "protein", "acrylic IOL", etc.

3.2. Country distribution and influence

According to the retrieved results from WoSCC, the 988 articles originated from 62 different countries (Fig. 2). Table 1 shows the top 10 countries contributing to PCO research, with a total of 892 articles accounting for 90.3% of the total number of publications. China contributed the most publications (283, 28.6%), followed by the United States (206, 20.9%) and India (94, 9.5%). Citation analysis was used to generate the knowledge domain map of the main countries that contributed to research in the PCO field. Figure 3 illustrates the distribution of PCO research influence across various countries. China leads with 3538 citations (33.3%), followed by the United States with 3448 (32.4%), and the United Kingdom with 1175 (11.1%).

3.3. Attribution and collaboration of organizations

A total of 1231 organizations have published literature related to PCO. As illustrated in Table 2, the top 10 most productive organizations in this field collectively published 236 papers, which represents 23.9% of the total publications. The top 3 most productive research institutions were Wenzhou Medical University (China, with 41 publications and 655 citations), Sun Yat-sen University (China, with 34 publications and 536 citations), and The University of Utah (USA, with 31 publications and 426 citations). The analysis of institutional co-authorship is depicted in Figure 4, revealing 16 clusters. Each cluster consists of institutions that collaborate closely, with The University of Utah demonstrating the highest level of cooperation with other institutions (total link strength = 17).

3.4. Attribution and collaboration of authors

According to the data retrieved from WoSCC, over 3965 authors contributed to PCO research during the studied period. Among the top 10 authors, Quankui Lin (Wenzhou Medical University, 31 publications) ranked first, followed by Liliana Werner (The University of Utah, 26 publications), and Yuemei Han (Wenzhou Medical University, 23 publications; Table 3). Figure 5 illustrates the co-authorship network corresponding to authors who have published more than 5 articles.

3.5. Number of publications and dual-map overlay of journals

Web of Science Core Collection yielded a total of 265 journals that published articles related to PCO. Table 4 displays the top 10 most productive Journals in the field. The top 3 most productive journals are the Journal of Cataract and Refractive Surgery (121 publications, impact factor 2.8), Experimental Eye Research (32 publications, impact factor 3.4), and Investigative Ophthalmology and Visual Science (31 publications, impact factor 4.4). The dual-map overlay analysis of journals in the PCO field is depicted in Figure 6. The left side of the map represents the subject of the citing journal, while the label on the right represents the subject of the cited journal. The diagram illustrates 3 primary types of reference paths, with cited journals predominantly covering topics related to neurology, sports, and ophthalmology. The cited journals mainly focus on molecular biology and genetics and ophthalmology, ophthalmic, and ophthalmologica.

3.6. Knowledge base analysis

The collection of 21,056 reference citations from publications in this field can be viewed as a scientific knowledge base, with the top 10 most cited references being presented in Table 5. Co-citation bursts indicate significant changes in references over time. Figure 7 displays the top 25 references with citation bursts between 2011 and 2023. The reference topics with high co-citation intensity in recent years mainly focus on the role of IOL materials and surface modification in PCO.

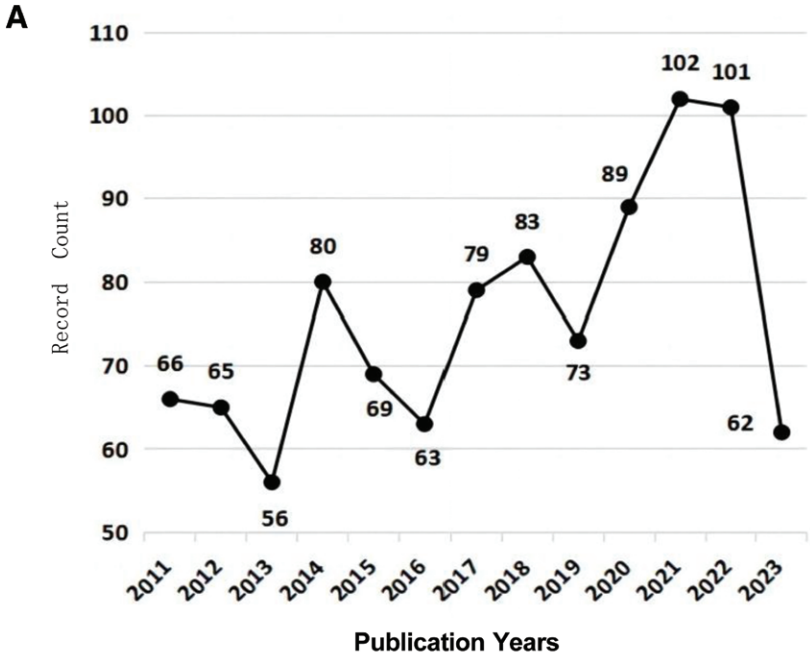
3.7. Keywords co-occurrence analysis

A total of 3228 keywords were listed in PCO research. Cluster analysis of high-frequency keywords can help identify distinct research directions within the field of PCO. Figure 8 illustrates the application of co-occurrence analysis in the generation of the keywords co-occurrence network. A total of 164 high-frequency keywords formed 5 main clusters and are denoted by blue, red, green, purple, and yellow colors, respectively. The 5 main clusters included the prevalence and risk factors for PCO; the mechanism of PCO formation; the material and design of IOLs and their application in the prevention of PCO; the application of IOLs surface modification and drug delivery in the prevention of PCO; and complications associated with Nd:YAG laser capsulotomy.

4. Discussion

4.1. Global trends in research on PCO

Quantity variation in the number of academic papers is an important research index, which can reflect the development trend of the field. As shown in Figure 1A, a total of 988 articles were retrieved on PCO from 2011 to 2023, and the annual research output fluctuated with time. Burst keywords are considered as indicators of emerging trends over time. Figure 1B shows the citation bursts of the extracted keywords.



B

Citation Bursts

Keywords	Year	Strength	Begin	End	2011-2023
rabbit eye	2011	4.5	2011	2015	
contrast sensitivity	2011	4.43	2011	2012	
aberration	2011	3.34	2011	2016	
eye	2011	3.26	2011	2013	
differentiation	2011	3.19	2011	2013	
optic edge	2011	3.1	2011	2015	
visual impairment	2011	3.06	2011	2013	
bag	2011	3.73	2012	2013	
aqueous humor	2011	3.24	2012	2016	
edge	2011	3.19	2012	2013	
growth factor beta	2011	4.2	2013	2018	
rabbit	2011	3.29	2013	2015	
followup	2011	3.16	2013	2015	
regeneration	2011	3.21	2014	2016	
acrylic intraocular lense	2011	3.2	2014	2016	
optical coherence tomography	2011	3.73	2015	2017	
vitrectomy	2011	4.15	2016	2020	
congenital cataract	2011	3.39	2016	2019	
epithelial-mesenchymal transition	2011	4.56	2017	2018	
cataract extraction	2011	3.04	2017	2019	
quality	2011	3.09	2018	2020	
to mesenchymal transition	2011	3.12	2019	2021	
sharp	2011	3.05	2019	2020	
protein	2011	4.4	2021	2023	
iol	2011	3.47	2021	2023	

Figure 1. (A) Annual number of publications describing research on PCO from 2011 to 2023. (B) Burst analysis of keywords. PCO = posterior capsular opacification.

Keywords like "regeneration", "acrylic intraocular lens", "quality", "protein", and "IOL" emerged in 2014, 2018, and 2021. Through the citation burst analysis of these keywords, we found that the research focus of PCO has gradually shifted from the material and design of IOL to visual quality, and then to the study of the mechanism of PCO, which may be the reason for the increase in the number of articles published in each time period.

In the analysis of influential countries, those with larger nodes occupy central positions. Figure 3 illustrates the prominent

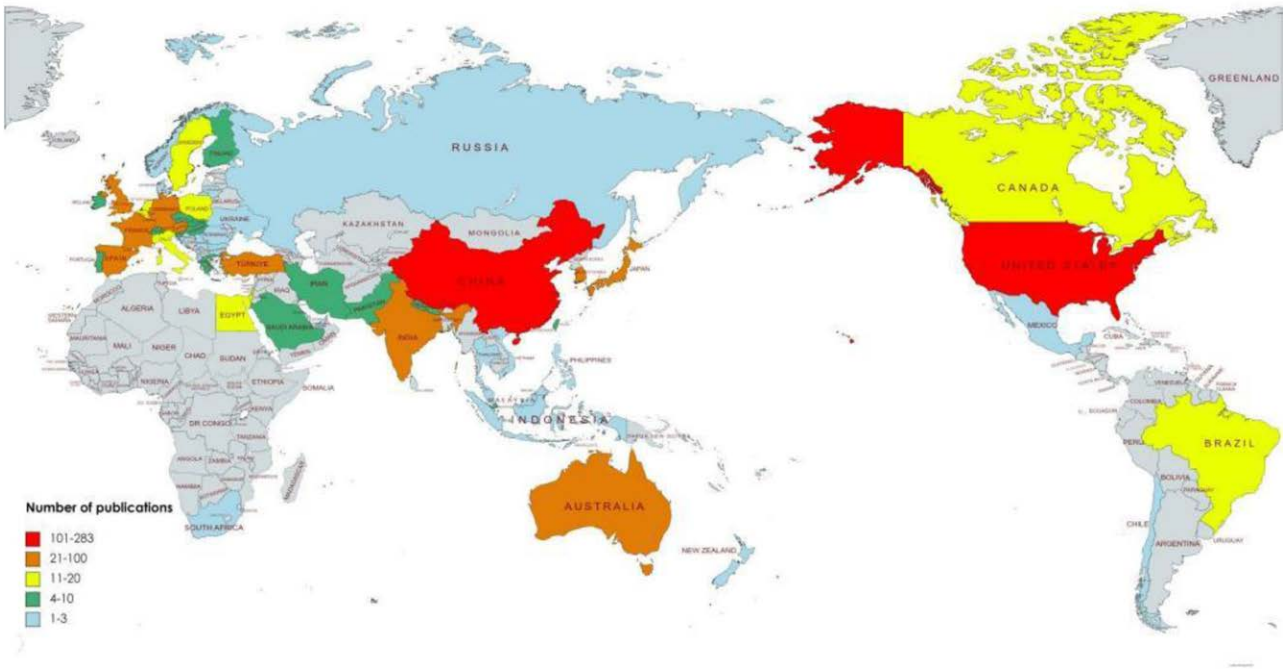


Figure 2. Distribution of main countries contributing research results in the PCO field. PCO = posterior capsular opacification.

Table 1

Top 10 most productive/influential countries in PCO research, 2011 to 2023.

Rank	Countries	Documents	Rank	Countries	Citations
1	China	283 (28.6%)	**1**	China	3538 (33.3%)
2	USA	206 (20.9%)	**2**	USA	3448 (32.4%)
3	India	94 (9.5%)	**3**	UK	1175 (11.1%)
4	UK	69 (7.0%)	**4**	India	936 (8.8%)
5	Germany	57 (5.8%)	**5**	Germany	880 (8.3%)
6	Austria	44 (4.5%)	**6**	Austria	583 (5.5%)
7	Japan	44 (4.5%)	**7**	Australia	559 (5.3%)
8	Turkey	38 (3.9%)	**8**	Japan	530 (5.0%)
9	Australia	30 (3.0%)	**9**	Netherlands	466 (4.4%)
10	South Korea	27 (2.7%)	**10**	Canada	329 (3.1%)

PCO = posterior capsular opacification.

positions of China and the United States as international scientific centers for PCO research, highlighting their significant roles within the global cooperation network. Notably, the 4 institutions with the highest productivity and influence are all located in China and the United States, underscoring their leadership in this research domain.

Through the distribution analysis of research organizations, the most productive and influential organizations can be identified. According to the results in Table 2, Wenzhou Medical University stands out for its significant contributions in terms of publications and citations, establishing itself as the most authoritative organization in this particular research field. In the visualization diagram, the nodes represent the number of publications, and links between nodes represent collaborations. Figure 4 demonstrates that The University of Utah (total link strength = 17) has the highest number of connections, suggesting extensive collaborations with other institutions.

Constructing the knowledge map of authors can provide valuable information for individual researchers to seek cooperation opportunities. According to Table 3, Professor Quankui Lin contributed 31 publications, which were cited 579 times; therefore, making him a leading figure in this research field. The co-authorship analysis of authors revealed that 6 clusters in which closer collaboration between authors was evident, indicated by the same color in Figure 5: The red group with Prof Quankui Lin (Wenzhou Medical University, China) as the core; the green and cyan groups with Prof Yizhi Liu (Sun Yat-sen University, China) as the core; the blue group with Prof Xiuhua Wan (Capital Medical University, China) as the core; the yellow group with Prof Jun Kong (Peking University, China) as the core; the purple group with Prof Ke Yao (Zhejiang University, China) as the core; and the orange group with Prof Yune Zhao (Wenzhou Medical University, China) as the core.

Analysis of journal productivity and research fields can offer valuable insights for researchers when choosing journals to publish their research. The Journal of Cataract and Refractive Surgery stands out as the leading publication in the field of PCO, with the highest productivity (121 publications). The top 10 most productive journals predominantly focus on ophthalmology, aligning with the findings of the dual-map overlay of journals.

4.2. Intellectual base

Through co-citation analysis, a large number of cited references can effectively show the background of the study. As shown in Table 5, the top 3 co-cited references mainly discussed the IOL optic material and design, as well as surgical technique on the development of PCO. These 3 references were ranked on top both in frequency count and link weight, which demonstrates their core position in the knowledge network. The total number of citations and total link strength for the co-cited articles, which were ranked 6, 7, and 8, were 146 and 1562, respectively. This high-weight attribute demonstrates the prominent position of the 3 cited references in the visualization of the currently active map. This demonstrates that the mechanism of PCO is at the core position in the knowledge background.

4.3. Research frontiers

Keywords summarize the general theme of a paper, and their frequency can reflect the hot spots and development trends in the research field. As shown in Figure 8, the keywords used in

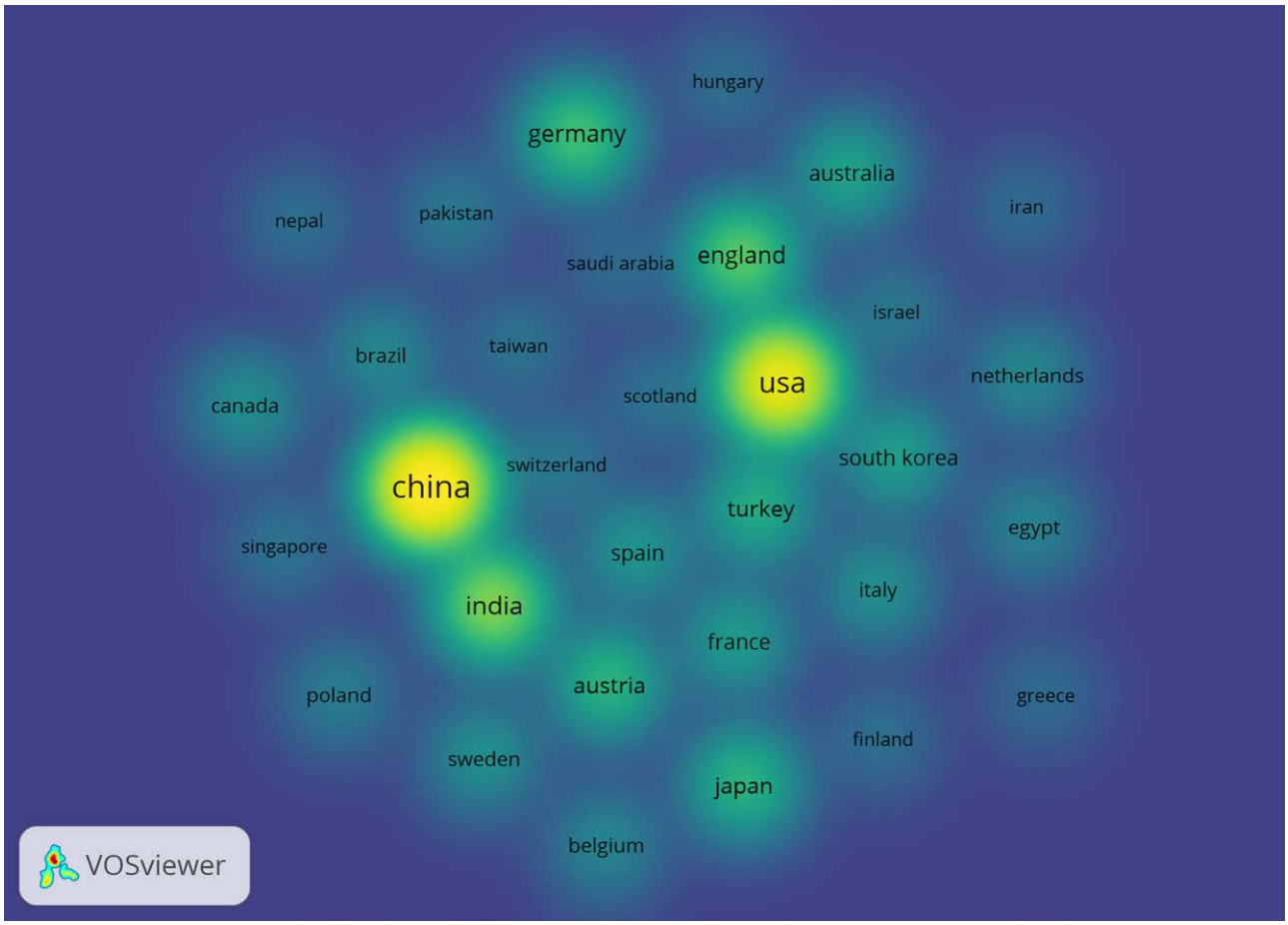


Figure 3. Citation network of countries in the PCO field. The minimum number of publications from a particular country was set as 5. Of the 62 countries that are involved in PCO research, 32 met the threshold. PCO = posterior capsular opacification.

Table 2

Top 10 most productive/influential organizations in PCO research, 2011 to 2023.

Rank	Organization (Country)	Documents	Rank	Organization (Country)	Citations
1	Wenzhou Medical University (China)	41 (4.2%)	**1**	Wenzhou Medical University (China)	655 (6.8%)
2	Sun Yat-sen University (China)	34 (3.4%)	**2**	Sun Yat-sen University (China)	536 (5.6%)
3	The University of Utah (USA)	31 (3.1%)	**3**	The University of Utah (USA)	426 (4.4%)
4	Tianjin Medical University (China)	22 (2.2%)	**4**	Tianjin Medical University (China)	420 (4.4%)
5	University of Colorado (USA)	21 (2.1%)	**5**	University of Sydney (Australia)	353 (3.7%)
6	Fudan University (China)	19 (1.9%)	**6**	University of Colorado (USA)	346 (3.6%)
7	Xi'an Jiaotong University (China)	19 (1.9%)	**7**	University of East Anglia (England)	288 (3.0%)
8	Zhejiang University (China)	17 (1.7%)	**8**	Hanusch Hospital (Austria)	267 (2.8%)
9	Hanusch Hospital (Austria)	16 (1.6%)	**9**	Capital Medical University (China)	255 (2.7%)
10	China Medical University (China)	16 (1.6%)	**10**	Moorfields Eye Hospital NHS Foundation Trust (United Kingdom)	247 (2.6%)

PCO = posterior capsular opacification.

publications in the PCO field can be divided into 5 main clusters, and those in the same cluster often represent similar research topics. We characterized these 5 clusters as follows: Cluster #1 (blue-colored): keywords related to the prevalence and risk factors for PCO. High-frequency co-occurrent keywords included "cataract surgery", "complications", "outcomes", "children", "vitrectomy", "management", "prevalence", "risk factors", "visual acuity", and "pediatric cataracts". After cataract surgery, PCO was the most common long-term complication. Previous studies have reported that PCOs with different morphology and severity showed different degrees of visual function impairment, including visual acuity and contrast sensitivity.[4] The reported incidence rates of PCO at 1, 2, 3, and 4 years after cataract surgery were 11.8%, 14.8%, 21.2%, and 28.6%, respectively.[5,6] Within 2 months to 5 years postoperatively, the overall incidence rate in adults was 50%, whereas this figure can reach as high as 100% in pediatric cases.[7] He et al[8] reported that PCO was more severe in highly myopic eyes after cataract surgery and that a longer axial length was an independent risk factor for the development of PCO. The incomplete capsular-artificial lens interaction in high myopia, caused by a larger capsular bag and thinner IOL, weakens the barrier effect during the migration of lens epithelial cells (LECs). In addition to these factors, various studies have demonstrated the association of PCO with younger age, glaucoma, previous vitrectomy surgery, implantation of lower IOL powers, lens nucleus hardness of III

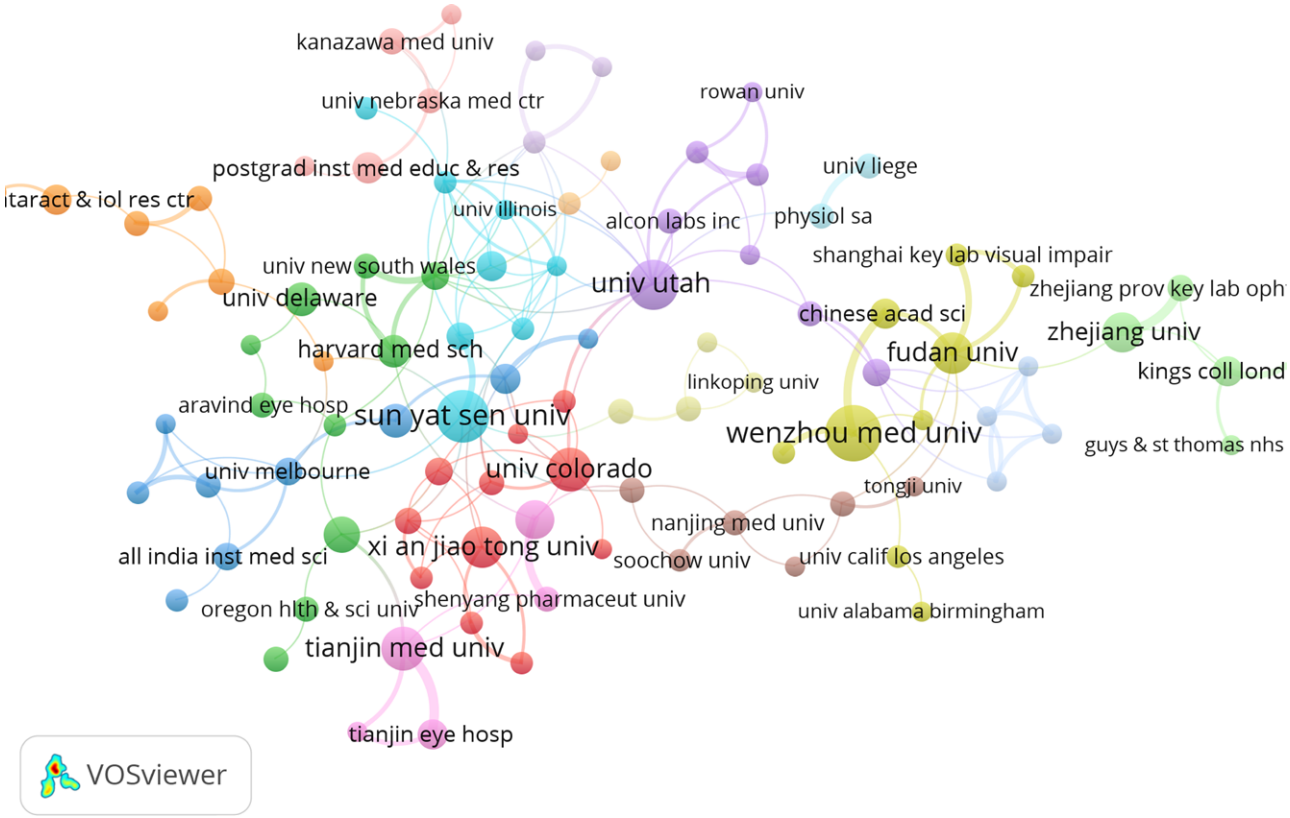


Figure 4. Co-authorship network of institutions in the PCO field. The minimum number of publications from a particular organization was set as 3. Of the 1234 organizations that are involved in PCO research, 145 met the threshold. PCO = posterior capsular opacification.

Table 3

Top 10 most productive authors in PCO research, 2011 to 2023.

Rank	Author	Countries	Documents	Citations	Average citation
1	Lin	China	31	579	18.7
2	Werner	USA	26	365	14.0
3	Han	China	23	462	20.1
4	Mamalis	USA	22	309	14.1
5	Chen	China	20	429	21.5
6	Li	China	18	191	10.6
7	Findl	Austria	16	267	16.7
8	Liu	China	15	306	20.4
9	Tang	China	15	412	27.5
10	Wormstone	England	15	389	25.9

PCO = posterior capsular opacification.

to V, extracapsular cataract extraction, diabetes, and hydrophilic IOL implantation.[1,9,10] These are considered as risk factors for PCO.

Cluster #2 (green-colored): keywords related to the mechanism of PCO. High-frequency co-occurring keywords included "expression", "proliferation", "epithelial-mesenchymal transition (EMT)", "TGF-β", "migration", "inhibition", "fibrosis", "LECs", "aqueous humor", and "aldose reductase". The migration and proliferation of LECs within the cystic capsule resulting from surgical trauma is the underlying mechanism for PCO. Fibrotic PCO is characterized by a series of fibrotic processes, including excessive proliferation, matrix shrinkage, matrix deposition, and EMT. In contrast, regenerative PCO occurs at a later stage, when lens fiber cells differentiate to form Soemmerring ring and Elschnig pearls.[11] EMT in LECs plays a significant role in the development of fibrotic PCO. Key features of transformed LECs include downregulation of E-cadherin and upregulation of α-SMA, all of which are known EMT markers. TGF-β has been detected in the aqueous humor of the anterior chamber of the eye and plays a pivotal role in EMT-driven fibrosis of LECs.[12] Aldose reductase promotes the development of PCO by inducing the migration of LECs and triggering epithelial-to-mesenchymal transition through the TGF-β/Smad signaling pathway.[13,14] Thus, studies on the mechanism of PCO may provide potential therapeutic benefits to cataract patients.

Cluster #3 (red-colored): keywords mainly related to the material and design of IOLs and their application in the prevention of PCO. High-frequency co-occurring keywords include "implantation", "silicone", "prevention", "rates", "epithelial cells", acrysof, "adhesion", "optic edge design", "single-piece", and "polymethylmethacrylate (PMMA)". The incidence of PCO is considered to be affected by the compatibility of IOLs. The main features of this compatibility are the materials, the optic edge design, and the lens surface modification.[15] Previous literature compared PCO incidence in patients with different materials for IOL implantation. Ursell et al[16] analyzed 2-year postoperative data in 90 eyes and reported that AcrySof lenses were associated with less PCO than silicone and PMMA lenses. The difference between PMMA and silicone lenses was not statistically significant. Rønbeck et al[17] compared the development of PCO associated with round-edged heparin-surface-modified (HSM) PMMA IOLs, round-edged silicone IOLs, and sharp-edged hydrophobic acrylic IOLs 12 years postoperatively. In the present study, no difference in PCO development was observed between acrylic and silicone IOLs. The HSM PMMA IOLs showed a higher rate of PCO than the silicone IOLs and lower Nd:YAG capsulotomy rates than the acrylic IOLs. However, the data regarding optic material was complicated by the fact that some studies compared round-edged with sharp-edged IOLs. Studies have demonstrated that the development of PCO

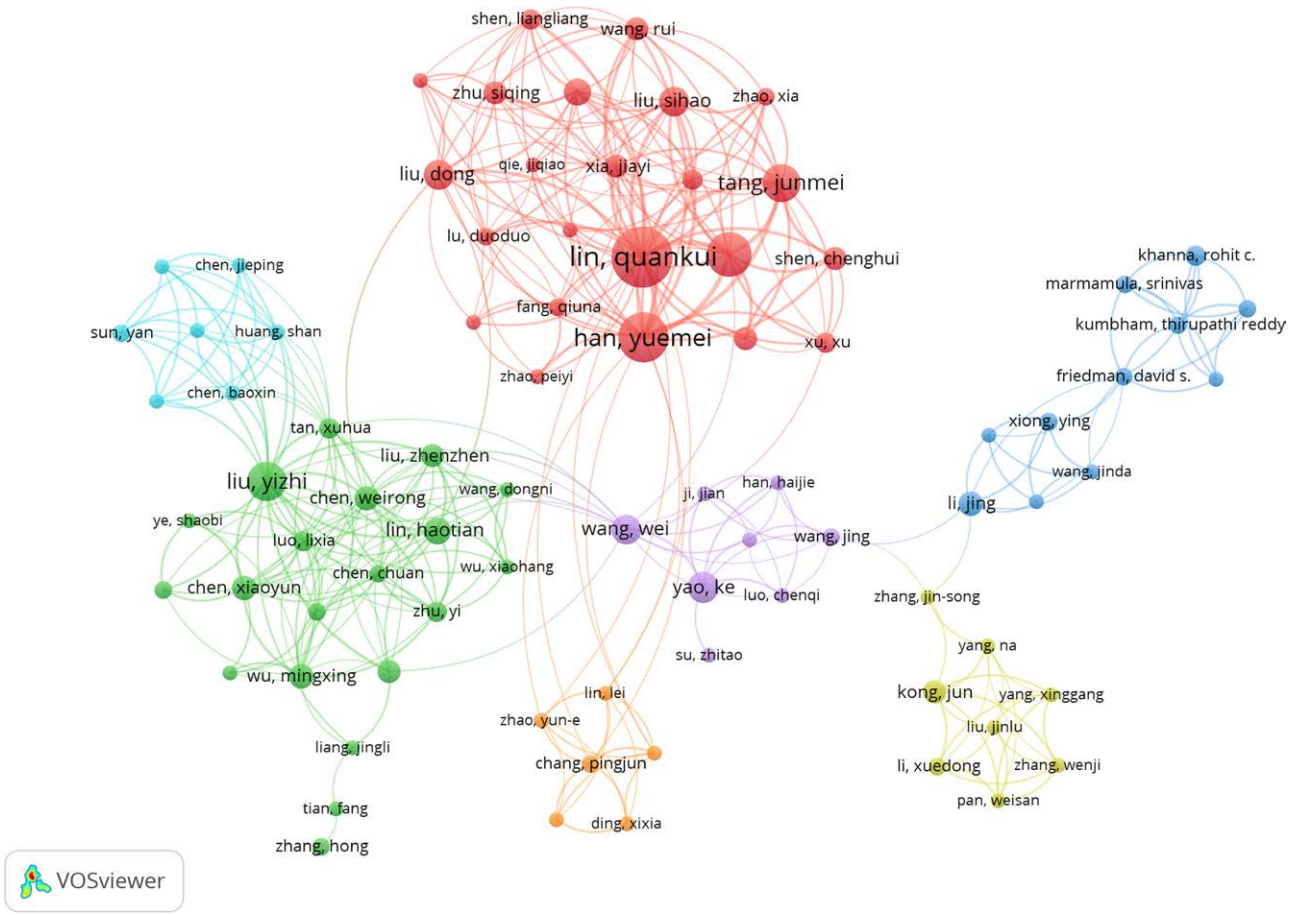


Figure 5. Co-authorship network of authors in the PCO field. The minimum number of publications from a particular author was set as 5. Of the 3981 authors that are involved in PCO research, 90 met the threshold). PCO = posterior capsular opacification.

Table 4

Top 10 most productive Journals in PCO research, 2011 to 2023.

Rank	Journal	Documents	Impact factor
1	Journal of Cataract and Refractive Surgery	121	2.8
2	Experimental Eye Research	32	3.4
3	Investigative Ophthalmology and Visual Science	31	4.4
4	Current Eye Research	30	2
5	Indian Journal of Ophthalmology	26	3.1
6	International Journal of Ophthalmology	26	1.4
7	Graefe Archive for Clinical and Experimental Ophthalmology	25	2.7
8	BMC Ophthalmology	23	2
9	European Journal of Ophthalmology	23	1.7
10	American Journal of Ophthalmology	22	4.2

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depends more on the optical edge design of the lens. A Cochrane study evaluated IOLs of sharp- and round-edged designs and revealed that a sharp-edged design acts as a barrier against the proliferation of LECs behind the IOL optic.[18] The impact of optical materials on PCO is complex, further complicated by the fact that certain studies have compared round-edged IOLs with sharp-edged ones. Long-term follow-up (over 6 years) demonstrated higher PCO values and Nd:YAG capsulotomy rates in the group with hydrophobic acrylic IOLs than those in the group with silicone IOLs.[19] The delayed proliferation of LECs eventually leads to the formation of a Soemmering ring, which in turn diminishes the barrier effect of the hydrophobic acrylic IOL with a sharp edge.[20] In the long run, the performance of the material itself has a greater impact on preventing PCO than the design of the edges. Apart from the materials and optic edge design, there are also other design factors to be considered. One study reported that 1-piece hydrophobic acrylic IOLs had a higher incidence of PCO,[21] but in other studies, the lens design (1-piece vs 3-piece) did not affect the PCO rate.[22] This cluster demonstrates that more precise studies should be conducted to better characterize the incidence rate and risk factors for PCO.

Cluster #4 (purple-colored): keywords related to the application of IOL surface modification and drug delivery for the prevention of PCO. High-frequency co-occurring keywords include "intraocular lens", "in vitro", "surface modification", "biocompatibility", "rabbit eyes", "nanoparticles", "release", "delivery", and "polymerization". Surface modification of the IOL can enhance the biocompatibility between the IOL and the posterior capsule, thereby reducing the occurrence of PCO.[23] This is a significant focus in cataract and IOL research. Previous studies investigated the role of various types of IOLs prepared with different surface modifications in the prevention of PCO. One promising approach is the use of antibiofouling IOLs that incorporate bioactive decontamination materials onto their surfaces. This material helps minimize the attachment of proteins, bacteria, and cells to the lens, thereby reducing the inflammatory response and inhibiting the development of PCO. Xu et al[24,25] applied plasma-assisted chemical grafting to fix hydrophilic polyethylene glycol (PEG) onto the IOL surface. This modification did not affect the optical performance compared to that of the original IOL. In vivo experiments conducted on rabbit eyes

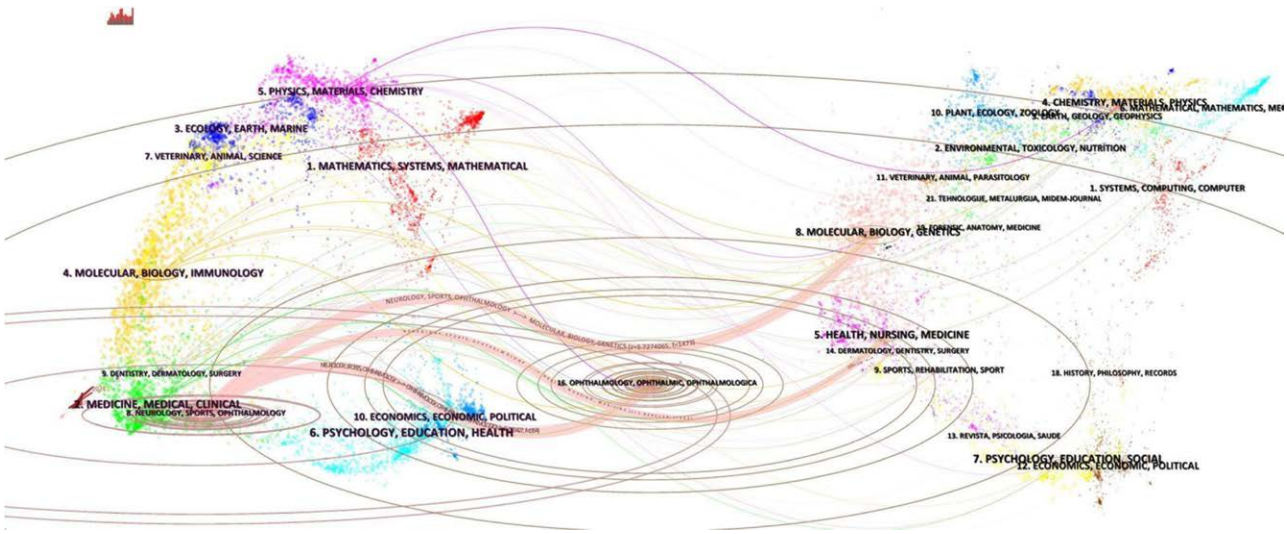

Figure 6. Dual-map overlay of journals.

Table 5

Top 10 most cited references in PCO research, 2011 to 2023.

Rank	Title	Citations	Year	Author
1	Posterior capsular opacification: a problem reduced but not yet eradicated (PMID: 19365040)	164	2009	Awasthi
2	Posterior capsule opacification (PMID: 19365040)	149	2008	Wormstone
3	Posterior capsule opacification (PMID: 1455302)	138	1992	Apple
4	Prevention of posterior capsular opacification (PMID: 25783492)	77	2015	Nibourg
5	A systematic overview of the incidence of posterior capsule opacification (PMID: 9663224)	77	1998	Schaumberg
6	Posterior capsule opacification: a cell biological perspective (PMID: 12014915)	74	2001	Wormstone
7	TGF-beta2-induced matrix modification and cell transdifferentiation in the human lens capsular bag (PMID: 12091431)	73	2002	Wormstone
8	Transforming growth factor-beta-induced epithelial-mesenchymal transition in the lens: a model for cataract formation (PMID: 15942192)	72	2005	de longh
9	Posterior capsular opacification: a problem reduced but not yet eradicated (PMID: 19365040)	64	2009	Awasthi
10	Eradication of posterior capsule opacification: documentation of a marked decrease in Nd:YAG laser posterior capsulotomy rates noted in an analysis of 5416 pseudophakic human eyes obtained postmortem (PMID: 11237905)	60	2001	Apple

PCO = posterior capsular opacification.

demonstrated that PEG-modified IOLs effectively prevented the occurrence of PCO. Additionally, the research team utilized surface-initiated reversible addition-fragmentation chain-transfer (SI-RAFT) polymerization technology to create PEG brushes on IOL materials. Subsequent in vivo experiments confirmed that the modified IOL exhibited excellent biocompatibility and significantly reduced PCO. Han et al[26] employed a bottom-up grafting procedure to develop 2-methacryloyloxyethyl phosphorylcholine brushes on the surface of the IOL. Through an experiment on live rabbit eyes, they successfully demonstrated a reduction in the severity of PCO. Seo et al[27] used femtosecond laser technology to fabricate micropatterned poly (HEMA) IOL samples. The results of in vivo experiments on rabbit eyes demonstrated that the implanted patterned IOLs effectively prevented PCO by promoting consistent migration of LEC from the periphery toward the center of the IOL. Qie et al[28,29] utilized polydopamine to attach chlorine 6 (Ce6) onto the surface of the IOL. The in vivo experiments demonstrated that the implanted modified IOL effectively prevented PCO. Subsequently, they employed spin-coating technology to fabricate a Ce6-loaded cyclic polylactide-co-glycolic acid coating-modified IOL. In vitro experiments revealed that the coating efficiently eliminated LECs during light treatment, and in vivo experiments further confirmed its favorable PCO-preventive effect and biocompatibility. Drug-loaded IOLs can deliver various drug types (including antiproliferative, anti-inflammatory, apoptosis-inducing, anti-migration, and anti-adhesion drugs) into the capsular bag.[30] This targeted drug delivery system aimed to prevent the occurrence of PCO. Several methods are currently available for storing and releasing drugs from IOLs. These methods include direct soaking in a drug solution, supercritical impregnation, attachment of the drug reservoir to the IOL, and surface modification. Huang et al[31] co-immobilized natural glucose oxidase and horseradish peroxidase on mesoporous silica nanoparticles to develop a cascade of catalytic platform IOLs. Both in vivo and in vitro evaluations demonstrated effective catalytic activity and notable inhibition of PCO. IOL surface modifications that target different aspects have great potential for the prevention and treatment of PCO.

Cluster #5 (yellow-colored): keywords related to complications associated with Nd:YAG laser capsulotomy. High-frequency co-occurring keywords include “neodymium”, “capsulorhexis”, “retinal detachment (RD) ”, “cystoid macular edema”, “risk”, “refraction”, “association”, “optical coherence tomography”, “anterior”, and “intraocular pressure”. Nd:YAG laser capsulotomy is a fast and noninvasive procedure for the treatment of PCO. However, it carries risks of complications, including the elevation of intraocular pressure (IOP), macular edema, lens dislocation or damage, uveitis, and RD, which is even sight-threatening.[5] The most common complication of this procedure is the increased IOP. There was a correlation between the increase in IOP after Nd:YAG laser

Top 25 References with the Strongest Citation Bursts

References	Year	Strength	Begin	End	2011 - 2023
Awasthi N, 2009, ARCH OPHTHALMOL-CHIC, V127, P555, DOI 10.1001/archophthalmol.2009.3, DOI	2009	19.52	2011	2014	
Wormstone IM, 2009, EXP EYE RES, V88, P257, DOI 10.1016/j.exer.2008.10.016, DOI	2009	16.21	2011	2014	
Findl O, 2010, COCHRANE DB SYST REV, V0, P0, DOI 10.1002/14651858.CD003738.pub3, DOI	2010	9.18	2011	2015	
Kohnen T, 2008, OPHTHALMOLOGY, V115, P1308, DOI 10.1016/j.ophtha.2008.01.002, DOI	2008	6.95	2011	2013	
Vock L, 2009, J CATARACT REFR SURG, V35, P459, DOI 10.1016/j.jcrs.2008.11.044, DOI	2009	5.65	2012	2014	
Liu HL, 2009, GRAEF ARCH CLIN EXP, V247, P801, DOI 10.1007/s00417-008-1007-0, DOI	2009	5.13	2012	2014	
Leishman L, 2012, J CATARACT REFR SURG, V38, P1664, DOI 10.1016/j.jcrs.2012.04.040, DOI	2012	6.76	2013	2016	
Vasavada AR, 2011, J CATARACT REFR SURG, V37, P1050, DOI 10.1016/j.jcrs.2010.12.060, DOI	2011	6.51	2013	2015	
Jun L, 2011, EXP EYE RES, V92, P173, DOI 10.1016/j.exer.2011.01.009, DOI	2011	5.85	2013	2016	
Kavoussi SC, 2011, J CATARACT REFR SURG, V37, P2194, DOI 10.1016/j.jcrs.2011.05.049, DOI	2011	5.74	2014	2016	
Mamuya FA, 2014, J CELL MOL MED, V18, P656, DOI 10.1111/jcmm.12213, DOI	2014	7.71	2015	2019	
Eldred JA, 2014, INVEST OPHTH VIS SCI, V55, P7057, DOI 10.1167/iovs.14-15302, DOI	2014	5.38	2015	2019	
Chang KC, 2015, INVEST OPHTH VIS SCI, V56, P4198, DOI 10.1167/iovs.15-16557, DOI	2015	5.34	2016	2019	
Nibourg LM, 2015, EXP EYE RES, V136, P100, DOI 10.1016/j.exer.2015.03.011, DOI	2015	18	2017	2020	
Wormstone IM, 2016, EXP EYE RES, V142, P2, DOI 10.1016/j.exer.2015.04.021, DOI	2016	11.49	2017	2021	
Karahan Eyyup, 2014, MED HYPOTHESIS DISCOV INNOV OPHTHALMOL, V3, P45	2014	5.95	2017	2019	
Wesolosky JD, 2017, J CATARACT REFR SURG, V43, P923, DOI 10.1016/j.jcrs.2017.03.046, DOI	2017	6.59	2019	2023	
Ursell PG, 2018, EYE, V32, P1579, DOI 10.1038/s41433-018-0131-2, DOI	2018	6.21	2020	2023	
Zhao Y, 2017, MEDICINE, V96, P0, DOI 10.1097/MD.0000000000008301, DOI	2017	6	2020	2023	
Wormstone IM, 2021, PROG RETIN EYE RES, V82, P0, DOI 10.1016/j.preteyeres.2020.100905, DOI	2021	14.39	2021	2023	
Ursell PG, 2020, EYE, V34, P960, DOI 10.1038/s41433-019-0630-9, DOI	2020	9.2	2021	2023	
Liu YC, 2017, LANCET, V390, P600, DOI 10.1016/S0140-6736(17)30544-5, DOI	2017	7.75	2021	2023	
Han YM, 2019, INT J NANOMED, V14, P9047, DOI 10.2147/IJN.S215802, DOI	2019	7.28	2021	2023	
Lin QK, 2017, COLLOID SURFACE B, V151, P271, DOI 10.1016/j.colsurfb.2016.12.028, DOI	2017	6.7	2021	2023	
Topete A, 2020, J CONTROL RELEASE, V326, P245, DOI 10.1016/j.jconrel.2020.07.020, DOI	2020	5.36	2021	2023	

Figure 7. Burst analysis of references.

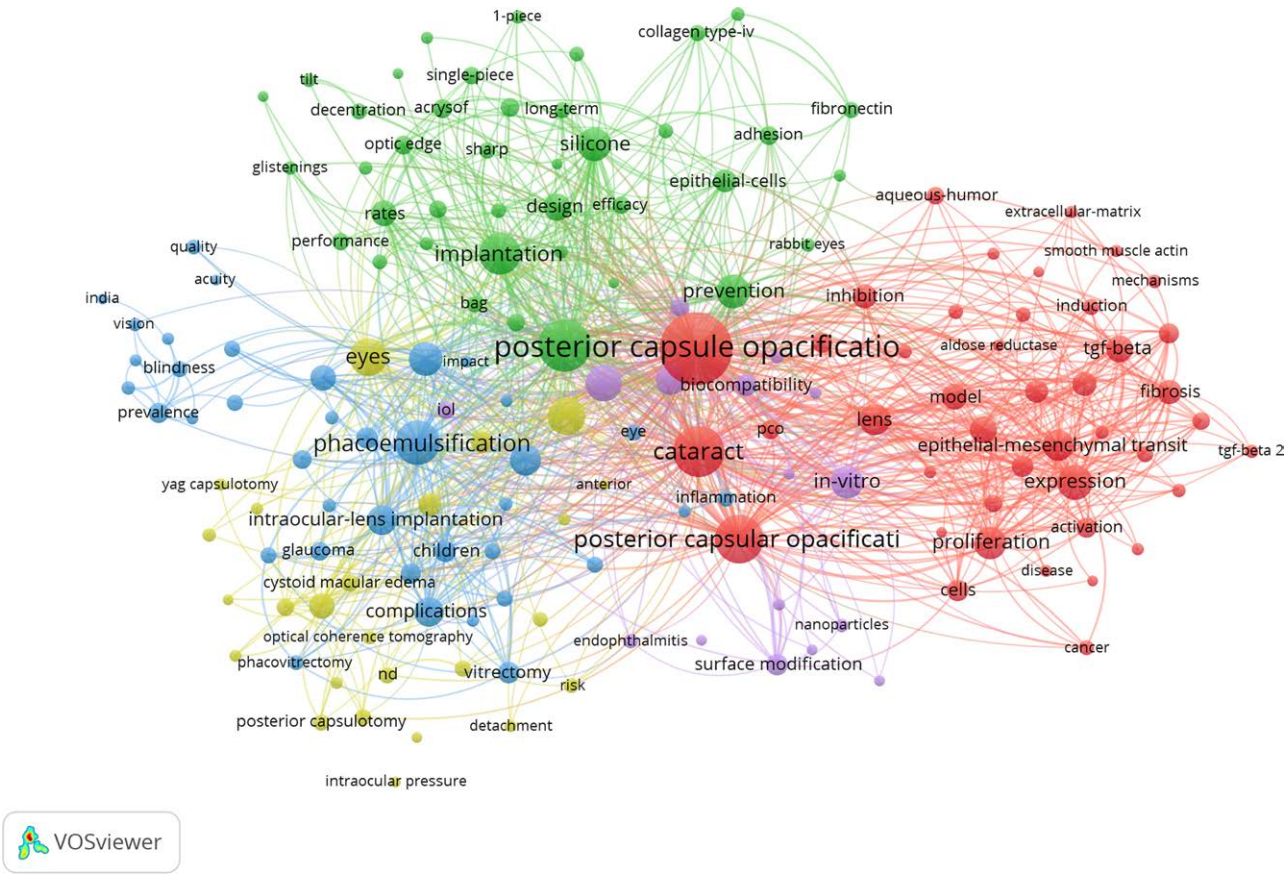

Figure 8. Co-occurrence network of keywords in the PCO field. The minimum number of occurrences of a particular keyword was set as 10. Of the 3228 keywords that were identified in publications related to PCO research, 164 met the threshold. PCO = posterior capsular opacification.

capsulotomy and the laser energy. It was observed that higher laser energy levels resulted in a longer time for IOP to return to its baseline level.[32,33] Researchers have provided different explanations for the raised IOP, including the debris deposits in the trabecular meshwork, pupillary block, or inflammatory swelling of the ciliary body.[34] Elmi Sadr et al[35] demonstrated that a single topical application of 0.5% betaxolol and 0.2% brimonidine, administered 1 hour prior to surgery, effectively prevented a notable increase in IOP following Nd:YAG laser posterior capsulotomy. Previous studies have investigated cystoid macular edema after Nd:YAG laser treatment. The probable etiology may be related to the fact that the movement of the vitreous body induces the release of inflammatory mediators. According to a recent study, regular preventive medications may not be necessary for postoperative macular thickness changes.[36] Another devastating outcome of capsulotomy is the occurrence of RD. Wesolosky et al[37] reported that a high risk of retinal tear and/or RD after Nd:YAG laser capsulotomy was observed in the first 5 months, and the rate of RD was 0.87%. The existing literature does not offer sufficient evidence to support a link between Nd:YAG capsulotomy and the development of RD.[38] Nevertheless, higher energy levels and anterior hyaloid damage may be associated with an elevated risk of RD after Nd:YAG laser capsulotomy. This cluster demonstrates that although Nd:YAG capsulotomy is accepted as standard treatment for PCO, more effective choices to reduce the incidence of complications associated to this laser capsulotomy should be considered.

5. Limitations

The extraction of records from the Web of Science Core Collection (WoSCC) between 2011 and 2023, along with the exclusion of non-English publications, may have restricted the scope of research related to PCO.It is important to note that this database is continuously updated; future analyses should consider integrating multiple databases, incorporating publications in additional languages, and exploring emerging themes. While bibliometric analysis in the field relies on software for objective data, interpreting results, especially regarding hot topics and research trends, can be influenced by subjective tendencies.

6. Conclusion

This study presents the first bibliometric analysis of the research on PCO conducted in the last decade. Through a visualization analysis, we characterized the yearly publication volume, countries, institutions, authors, journals, references, and keywords within the field. Future research trends are focused on the materials and design of IOLs, visual quality, and the mechanisms underlying PCO. Our findings serve as a valuable resource for identifying suitable journals, connecting with potential collaborators, pinpointing focal points for research, and gaining insight into the PCO field.

Author contributions

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Writing – review & editing: Lijun Zhang.

References

[1] Wu S, Tong N, Pan L, et al. Retrospective analyses of potential risk factors for posterior capsule opacification after cataract surgery. J Ophthalmol. 2018;2018:1–7.
[2] van Eck NJ, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics. 2010;84:523–38.
[3] Synnestvedt MB, Chen C, Holmes JH. CiteSpace II: visualization and knowledge discovery in bibliographic databases. AMIA. Annual Symposium proceedings/ AMIA Symposium AMIA Symposium. 2005.
[4] Lu C, Yu S, Song H, et al. Posterior capsular opacification comparison between morphology and objective visual function. BMC Ophthalmol. 2019;19:40.
[5] Elgohary MA, Dowler JG. Incidence and risk factors of Nd:YAG capsulotomy after phacoemulsification in non-diabetic and diabetic patients. Clin Exp Ophthalmol. 2006;34:526–34.
[6] González-Martín-Moro J, González-López JJ, Gómez-Sanz F, Zarallo-Gallardo J, Cobo-Soriano R. Posterior capsule opacification, capsular bag distension syndrome, and anterior capsular phimosis: a retrospective cohort study. Arch Soc Esp Oftalmol. 2015;90:69–75.
[7] Liu H, Wu L, Fu S, et al. Polylactide-glycoli acid and rapamycin coating intraocular lens prevent posterior capsular opacification in rabbit eyes. Graefes Arch Clin Exp Ophthalmol. 2009;247:801–7.
[8] He W, Cheng K, Zhao L, et al. Long-term outcomes of posterior capsular opacification in highly myopic eyes and its influencing factors. Ophthalmol Ther. 2023;12:1881–91.
[9] Tokko HA, Hussain F, Al-Awadi A, et al. Factors associated with the development of posterior capsule opacification requiring yttrium aluminum garnet capsulotomy. Optom Vis Sci. 2019;96:492–9.
[10] Donachie PHJ, Barnes BL, Olaitan M, Sparrow JM, Buchan JC. The Royal College of Ophthalmologists' national ophthalmology database study of cataract surgery: report 9, risk factors for posterior capsule opacification. Eye (Basingstoke). 2023;37:1633–9.
[11] Wormstone IM, Wormstone YM, Smith AJO, Eldred JA. Posterior capsule opacification: what's in the bag? Prog Retin Eye Res. 2021;82:100905.
[12] Taiyab A, Holms J, West-Mays JA. β-Catenin/Smad3 interaction regulates transforming growth factor-β-Induced epithelial to mesenchymal transition in the lens. Int J Mol Sci . 2019;20:2078.
[13] Chang KC, Petrash JM. Aldose reductase mediates transforming growth factor β2 (TGF-β2)–inducedmigration and epithelial-to-mesenchymal transition of lens-derived epithelial cells. Invest Ophthalmol Vis Sci. 2015;56:4198–210.
[14] Zukin LM, Pedler MG, Groman-Lupa S, Pantcheva M, Ammar DA, Petrash JM. Aldose reductase inhibition prevents development of posterior capsular opacification in an in vivo model of cataract surgery. Invest Ophthalmol Vis Sci. 2018;59:3591–8.
[15] Özyol P, Özyol E, Karel F. Biocompatibility of intraocular lenses. Turk Oftalmoloiji Dergisi. 2017;47:221–5.
[16] Ursell PG, Spalton DJ, Pande MV, et al. Relationship between intraocular lens biomaterials and posterior capsule opacification. J Cataract Refract Surg. 1998;24:352–60.
[17] Rønbeck M, Kugelberg M. Posterior capsule opacification with 3 intraocular lenses: 12-year prospective study. J Cataract Refract Surg. 2014;40:70–6.
[18] Maedel S, Evans JR, Harrer-Seely A, Findl O. Intraocular lens optic edge design for the prevention of posterior capsule opacification after cataract surgery. Cochrane Database Syst Rev. 20218:CD012516.
[19] Kwon YR, Hwang YN, Kim SM. Posterior capsule opacification after cataract surgery via implantation with hydrophobic acrylic lens compared with silicone intraocular lens: a systematic review and meta-analysis. J Ophthalmol. 2022;2022:3570399.
[20] Nishi O, Yamamoto N, Nishi K, Nishi Y. Contact inhibition of migrating lens epithelial cells at the capsular bend created by a sharp-edged intraocular lens after cataract surgery. J Cataract Refract Surg. 2007;33:1065–70.
[21] Wallin TR, Hinckley M, Nilson C, Olson RJ. A clinical comparison of single-piece and three-piece truncated hydrophobic acrylic intraocular lenses. Am J Ophthalmol. 2003;136:614–9.
[22] Duman R, Karel F, Özyol P, Ateş C. Effect of four different intraocular lenses on posterior capsule opacification. Int J Ophthalmol. 2015;8:118–21.

[23] Luo C, Wang H, Chen X, Xu J, Yin H, Yao K. Recent advances of intraocular lens materials and surface modification in cataract surgery. Front Bioeng Biotechnol. 2022;10:913383.
[24] Xu X, Tang JM, Han YM, Wang W, Chen H, Lin QK. Surface PEGylation of intraocular lens for PCO prevention: an in vivo evaluation. J Biomater Appl. 2016;31:68–76.
[25] Lin Q, Tang J, Han Y, Xu X, Hao X, Chen H. Hydrophilic modification of intraocular lens via surface initiated reversible addition-fragmentation chain transfer polymerization for reduced posterior capsular opacification. Colloids Surf B Biointerfaces. 2017;151:271–9.
[26] Han Y, Xu X, Tang J, Shen C, Lin Q, Chen H. Bottom-up fabrication of zwitterionic polymer brushes on intraocular lens for improved biocompatibility. Int J Nanomedicine. 2017;Volume 12:127–35.
[27] Seo Y, Kim S, Lee HS, et al. Femtosecond laser induced nano-textured micropatterning to regulate cell functions on implanted biomaterials. Acta Biomater. 2020;116:138–48.
[28] Qie J, Wen S, Han Y, et al. A polydopamine-based photodynamic coating on the intraocular lens surface for safer posterior capsule opacification conquering. Biomater Sci. 2022;10:2188–97.
[29] Lu D, Wang H, Feng C, et al. Spin-coating-based facile annular photodynamic intraocular lens fabrication for efficient and safer posterior capsular opacification prevention. ACS Appl Mater Interfaces. 2022;14:48341–55.
[30] Topete A, Saramago B, Serro AP. Intraocular lenses as drug delivery devices. Int J Pharm. 2021;602:120613.
[31] Huang H, Zhu S, Han Y, et al. Cascade catalytic platform modified intraocular lens for high-efficient posterior capsule opacification prevention. Chem Eng J. 2022;427:131553.
[32] Chawla H, Singh MD, Vohra V. Clinical implications of energy used in neodymium: yttrium aluminum garnet posterior capsulotomy on intraocular pressure. Indian J Ophthalmol. 2021;69:2717–20.
[33] Ari S, Cingu AK, Sahin A, Cinar Y, Caca I. The Effects of Nd:YAG laser posterior capsulotomy on macular thickness, intraocular pressure, and visual acuity. Ophthalmic Surg Lasers Imaging. 2012;43:395–400.
[34] Karahan E, Er D, Kaynak S. An overview of Nd:YAG laser capsulotomy. Med Hypothesis Discov Innov Ophthalmol. 2014;3:45–50.
[35] Elmi Sadr N, Saber E, Paknazar F. The prophylactic effect of betaxolol 0.5% versus brimonidine 0.2% on IOP elevation after Nd:YAG laser posterior capsulotomy. Clin Exp Optom. 2022;105:813–6.
[36] Parajuli A, Joshi P, Subedi P, Pradhan C. Effect of Nd:YAG laser posterior capsulotomy on intraocular pressure, refraction, anterior chamber depth, and macular thickness. Clin Ophthalmol. 2019;13:945–52.
[37] Wesolosky JD, Tennant M, Rudnisky CJ. Rate of retinal tear and detachment after neodymium:YAG capsulotomy. J Cataract Refract Surg. 2017;43:1618.
[38] Grzybowski A, Kanclerz P. Does Nd:YAG capsulotomy increase the risk of retinal detachment. Asia-Pacific J Ophthalmol. 2018;7:339–44.