Evolution and trends of high myopia research from 2002 to 2021: a scientometric analysis

Yuan Tan[1#], Weining Zhu[1,2#], Yingshi Zou[1], Bowen Zhang[1,2], Yinglin Yu[1], Wei Li[1,2], Chaoqun Xu[1], Leyi Hu[1], Guangming Jin[1], Zhenzhen Liu[1^]

[1]State Key Laboratory of Ophthalmology, Zhongshan Ophthalmic Center, Sun Yat-sen University, Guangdong Provincial Key Laboratory of Ophthalmology and Visual Science, Guangdong Provincial Clinical Research Center for Ocular Diseases, Guangzhou, China; [2]Zhongshan Medical School, Sun Yat-sen University, Guangzhou, China

Contributions: (I) Conception and design: Z Liu, G Jin; (II) Administrative support: Z Liu, G Jin; (III) Provision of study materials or patients: Z Liu, G Jin; (IV) Collection and assembly of data: Y Tan, W Zhu; (V) Data analysis and interpretation: Y Tan, W Zhu; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

[#]These authors contributed equally to this work and should be considered as co-first authors.

Correspondence to: Zhenzhen Liu, MD, PhD; Guangming Jin, MD, PhD. State Key Laboratory of Ophthalmology, Zhongshan Ophthalmic Center, Sun Yat-sen University, Guangdong Provincial Key Laboratory of Ophthalmology and Visual Science, Guangdong Provincial Clinical Research Center for Ocular Diseases, No. 7 Jinsui Rd., Guangzhou 510060, China. Email: liuzhenzhen@gzzoc.com; jingm@mail2.sysu.edu.cn.

Background: Research on high myopia has gradually formed a complex network of knowledge, but a panorama of evolutionary trends is lacking. By conducting a scientometric analysis, we can gain a deeper understanding of the development and evolution of this field.

Methods: The global literature on high myopia published from 2002 to 2021 was extracted from the Science Citation Index Expanded in the Web of Science Core Collection. Microsoft Excel, VOSviewer, and CiteSpace were used to analyse and visualize the bibliometric data. Publication-related information, including countries, journals, authors, citations, subject categories, and its' time trends, was analysed.

Results: A total of 4,226 included publications showed an annually increasing trend during the past 20 years. The high myopia research hotspots were refractive error correction, epidemiology, ocular biometry, drug and laser treatment of myopic fundus lesions, and surgical treatment of myopic fundus lesions. Co-citation analysis showed that high myopia genetics and myopic fundus lesion research were the research frontiers. A total of 116 disciplines were involved in high myopia research. Ophthalmology (n=3,338) was the most dominant subject category. Engineering (betweenness centrality =0.65) was the discipline with the most obvious bridge role. Science & technology—other topics (burst years: 2015–2021; strength =14.88) had the greatest strength as of 2021, which was the hottest subject category.

Conclusions: High myopia genetics and myopic fundus lesion research showed a potential for breakthroughs. Medical-engineering cross-innovation is a cutting-edge technology trend.

Keywords: High myopia; theme change; evolution; research hotspot

Received: 17 May 2023; Accepted: 25 August 2023; Published online: 04 September 2023.

doi: 10.21037/aes-23-35

View this article at: https://dx.doi.org/10.21037/aes-23-35

^ ORCID: 0000-0002-4853-2474.

Introduction

The global prevalence of high myopia continues to increase, with nearly one billion people expected to be highly myopic by 2050 worldwide, making high myopia a global public health problem (1). During the past years, a large number of systematic reviews on different high myopia-related topics have been published, including topics such as complications and refraction correction (2,3). But the purpose of conducting systematic reviews and meta-analyses was to answer a specific scientific question. It is not feasible to analyse the overall overview of the field of high myopia and to explore its research hotspots and trends with a systematic review, which is not conducive to the development of the field.

The scientometric approaches are the methods for studying science from a quantitative perspective (4). When using the scientometric approach, the contributions of predominant actors and the dynamic changes in the area over time can be quantitatively analysed, and the development of the academic field can be clearly presented (5). However, no study has specifically and objectively investigated the evolution of scientific research in the high myopia field with a sufficient time interval so far.

Therefore, we performed this scientometric study to explore the dynamic changes related to time factors in high myopia research within a 20-year interval. This information will be of use to researchers deciding research directions and undeciding problems in the high myopia field. Scientific policies aimed at improving public health in relation to high myopia will also benefit from the current research knowledge.

Highlight box

Key findings

- Research on high myopia could make significant strides in two areas: genetics and fundus lesions.

What is known and what is new?

- The increasing prevalence of high myopia and its association with blindness is of research importance, and research results have gradually formed a complex network of knowledge, but a panorama of evolutionary trends is lacking.
- Genetics and fundus lesions are potential key points for breakthroughs in high myopia research, with medical-engineering cross-innovation representing a cutting-edge technology trend in the field.

What is the implication, and what should change now?

- The research knowledge on high myopia will be useful for researchers in determining their research directions and may help address some unresolved issues in the field.
- Additionally, it may contribute to the development of scientific regulations aimed at improving public health in relation to high myopia and reducing blindness.

Methods

Literature search and study selection

Original research articles and review articles on high myopia were retrieved from the Science Citation Index Expanded (SCIE) in the Web of Science Core Collection (Clarivate Analytics, Philadelphia, PA, USA) by searching for high myopia related keywords to construct a dataset of all eligible publications in the field. The document types that were excluded are meeting abstracts, corrections, letters, news items, and editorial materials. The literature search included articles published from 2002 to 2021 using the following keywords and terms: ("high grade myopia" OR "highmyopia" OR "high myopia" OR "high near-sighted" OR "high correction" OR "high myopic" OR "highly myopic" OR "excessive myopia" OR "pathological myopia"). The search terms were applied to the Title, Abstract, Author Keywords, and Keywords Plus fields. To avoid bias caused by frequent database updates, all literature searches and data downloads were completed on the same day (19 December 2021). The detailed study selection and analysis methods are shown in *Figure 1*.

Data extraction and collection

To calculate the annual number of article publications, citations, national publications, journal publications, and author publications, we downloaded the corresponding data from the Web of Science Core Collection. We then exported the full records of the retrieved publications and their references from the Web of Science Core Collection to plain text for analysis of keywords, cited references, and subject categories.

Statistical analysis

Holistic analysis

The publication volume and predominant actors, including countries, journals, and authors, were counted with Microsoft Excel 2019 (Microsoft Corporation, Redmond, WA, USA) and visualized with GraphPad Prism version 8.3.0 (GraphPad Software, La Jolla, CA, USA) (6). Co-

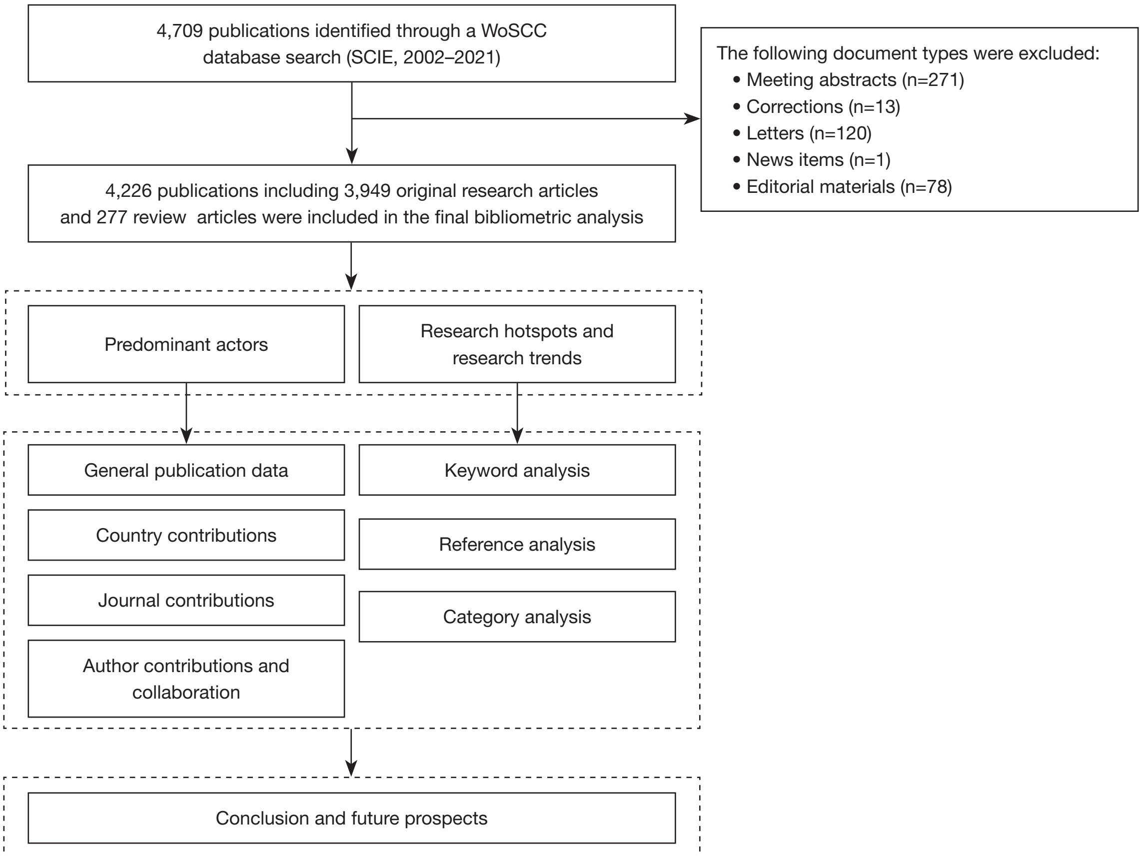


Figure 1 Flow chart of the study selection for publications related to high myopia, as well as the analysis steps. WoSCC, Web of Science Core Collection; SCIE, Science Citation Index Expanded.

authors were given the same weight. To calculate the year-on-year growth rates, the difference between the number of publications in a given year and the number of publications in the previous year was divided by the number of publications in the previous year. A negative year-on-year growth rate was considered no growth and was represented by a value of zero. A year of remarkable publication activity was defined as a year with ≥100 publications and a year-on-year growth rate of ≥10% (7,8).

VOSviewer version 1.6.5 (Leiden University's Centre for Science and Technology Studies, Leiden, Netherlands) was used to perform a co-occurrence analysis of high-frequency keywords and co-authorship analysis. VOSviewer is a software tool designed for constructing and visualizing scientometric networks. The research hotspots were identified based on co-occurrence analysis of high-frequency keywords to form clusters. Based on the shared characteristics of included keywords belonging to the same cluster, the research hotspots represented by that cluster were determined (9). The keywords in the keyword network map were weighted with the number of keyword occurrences to form clusters of high-frequency keywords. The author collaboration networks were identified based on co-authorship analysis of high-frequency co-authors to form clusters. The authors in the author's collaboration network map were weighted with the total number of links, indicating the strength of collaborations in the network. The lines between authors or between keywords reflected the associations, with thicker lines indicating stronger associations. To calculate the association scores, the full counting method was used. The total link strength of the links determined the association strength, indicating the number of publications in which two elements appeared together (10,11). The clusters of networks were labelled by the largest elements in the network respectively.

Analysis of dynamic changes over time

CiteSpace V version 5.8.R3 (Drexel University, Philadelphia, PA, USA) was used to perform co-citation analysis of cited references, co-occurrence analysis of networks of subject categories, and analysis of subject categories with strong citation bursts (12). CiteSpace is a Java-based application designed to visualize and analyze trends and patterns in scientific literature. To determine the frontiers in research topics, the cited references were clustered by relevance, and the state of research in a cluster was summarized based on the characteristics of the citing articles falling into the corresponding clusters. The most recent state of research was defined as the frontiers in research topics identified over the study period and showed potential to become continued frontiers to achieve breakthroughs.

Homogeneous clusters tended to have silhouette values close to one. Each network's modularity score measured the extent to which the elements in the network could be divided into groups such that elements within the same group were more closely connected than elements in different groups (13). The distance between elements within a cluster indicated the relevance of the cited references, with closer proximity indicating more frequent co-citation (13).

Top cited references indicated high levels of academic attention. Top frequent subject categories were defined as the dominant subject categories (occurrence >100). The determination of the cited references that were important turning points in the knowledge structure from the scientific literature, and subject categories serving as bridges between other subject categories were based on the calculation of the betweenness centrality (BC). Elements with a high BC (BC >0.1) were significant, represented by purple rings on the maps. Burst-detection algorithm was used for detecting sharp increases of interest in a speciality, which were denoted by burst strengths and burst periods. Burst till 2021 subject categories were defined as the hot subject categories (14).

Results

Predominant actors

Annual outputs

Figure S1A (top graph) shows the annual outputs and citations related to high myopia from 2002 to 2021. A total of 4,226 SCIE-indexed original research and review articles were published during the study period. The highest number of publications occurred in 2021 (n=384; 9.09%), whereas the lowest number occurred in 2002 (n=74; 1.75%). There was an overall upward trend, with more than five times as many publications in 2021 as in 2002. The total number of citations from 2002 to 2021 was 92,865, with an average of 21.97 citations per publication. The annual citation counts also showed an overall upward trend, with a peak in 2021 (n=12,478).

The year-on-year publication growth rates are shown in Figure S1A (bottom graph). There were 14 positive growth years (1.61–67.57%), with 2003, 2006, 2008, 2013, 2016, and 2020 identified as years of remarkable publication activity.

Countries

A total of 81 countries contributed to publications related to high myopia. China had the most publications (n=1,350; 31.95%), followed by the USA (n=763; 18.05%), Japan (n=501; 11.86%), Germany (n=353; 8.35%), the UK (n=316; 7.48%), Spain (n=254; 6.01%), Italy (n=214; 5.06%), South Korea (n=211; 4.99%), Australia (n=191; 4.52%), and France (n=168; 3.98%). Figure S1B shows the numbers of publications of the top 10 countries.

Journals

A total of 384 journals published articles related to high myopia during the study period. The Journal of Cataract and Refractive Surgery had the most publications (n=297; 7.03%), followed by Investigative Ophthalmology & Visual Science (n=239; 5.66%), American Journal of Ophthalmology (n=207; 4.90%), Journal of Refractive Surgery (n=201; 4.76%), and Retina (n=200; 4.73%). The top 10 journals published a total of 1,860 articles, accounting for 44.01% of the total output (Figure S1C).

Authors

A total of 15,131 authors contributed to high myopia research, with an average of 3.6 authors per study. The top 10 authors in terms of the number of publications are listed in Figure S2A. Kyoko Ohno-Matsui was the most prolific author (139 publications; 3.29%), followed by Jost B. Jonas (n=117; 2.77%) and Xingtao Zhou (n=51; 1.21%). Jost B. Jonas (35; 0.83%), Kazutaka Kamiya (21; 0.50%), and Kyoko Ohno-Matsui (20; 0.47%) had the most publications as first authors (Figure S2B). The top 12 authors with the highest number of publications as first authors are shown in Figure S2B.

With a threshold of ≥20 publications, the author collaboration network included 68 authors and 437 links. Well-published authors showed clear characteristics of a collaboration network, which consisted of four clusters

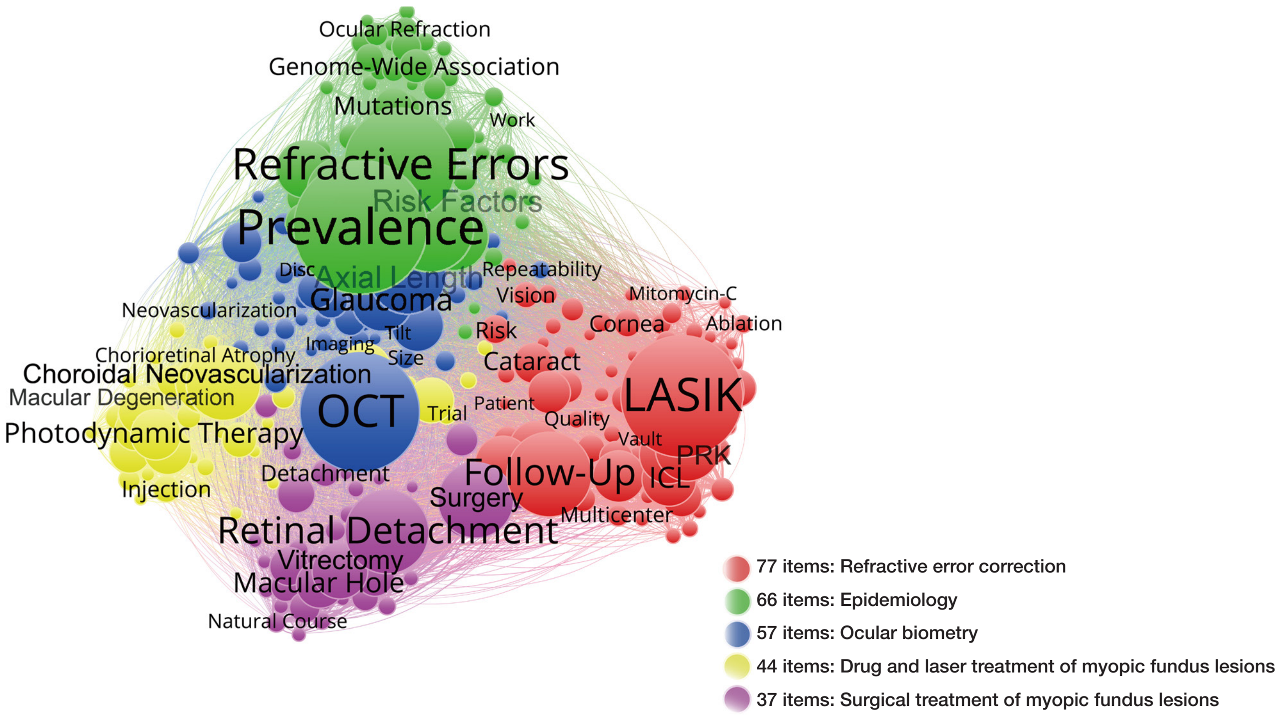


Figure 2 High myopia research hotspots based on keywords. Each node represents a different keyword. The larger the node, the more frequent the keyword. Clusters were formed based on a co-occurrence analysis. Closely related keyword nodes in a cluster are indicated by the same colour. LASIK, laser in situ keratomileusis; OCT, optical coherence tomography; ICL; implantable collamer lens; PRK, photorefractive keratectomy.

(Figure S2C): the cluster of Jost B. Jonas, including 23 authors; the cluster of Xingtao Zhou, including 17 authors; the cluster of Xueshan Xiao, including 16 authors; and the cluster of Kyoko Ohno-Matsui, including 12 authors.

Research hotspots and research trends

Hot research topics

In terms of hot topics, "prevalence" (n=634), "laser in situ keratomileusis (LASIK)" (n=554), and "optical coherence tomography (OCT)" (n=537) were the three most frequently occurring keywords. Setting the minimum frequency of keywords to 20 times, 313 high-frequency keywords were identified. These keywords belonged to five clusters (*Figure 2*): the "LASIK" cluster (red; 77 items); the "prevalence" cluster (green; 66 items); the "OCT" cluster (blue; 57 items); the "choroidal neovascularization" cluster (yellow; 44 items); and the "retinal detachment" cluster (purple; 37 items). After summarizing the contents of the keyword clusters, five research hotspots were identified: refractive error correction, epidemiology, ocular biometry, drug and laser treatment of myopic fundus lesions, and surgical treatment of myopic fundus lesions.

Frontiers in research topics

Figure 3 shows the cited reference clusters from 2002 to 2021. The cited references formed four clusters. The earliest cluster was the refractive surgery cluster (Cluster#0; 62 items; mean formation year: 1999), chronologically followed by the anti-vascular endothelial growth factor (anti-VEGF) therapy cluster (Cluster#2; 42 items; mean formation year: 2002), the high myopia genetics cluster (Cluster#3; 30 items; mean formation year: 2004), and the myopic maculopathy cluster (Cluster#1; 54 items; mean formation year: 2010). The proximity of the three most recently formed clusters (myopic maculopathy, high myopia genetics, and anti-VEGF therapy) indicated that the studies within these clusters, which were mainly related to genetic pathology and myopic fundus lesions, tended to be co-cited. Meanwhile, they were the latest research themes that had formed over the past 20 years, so they showed the potential to continue to be the future research frontiers.

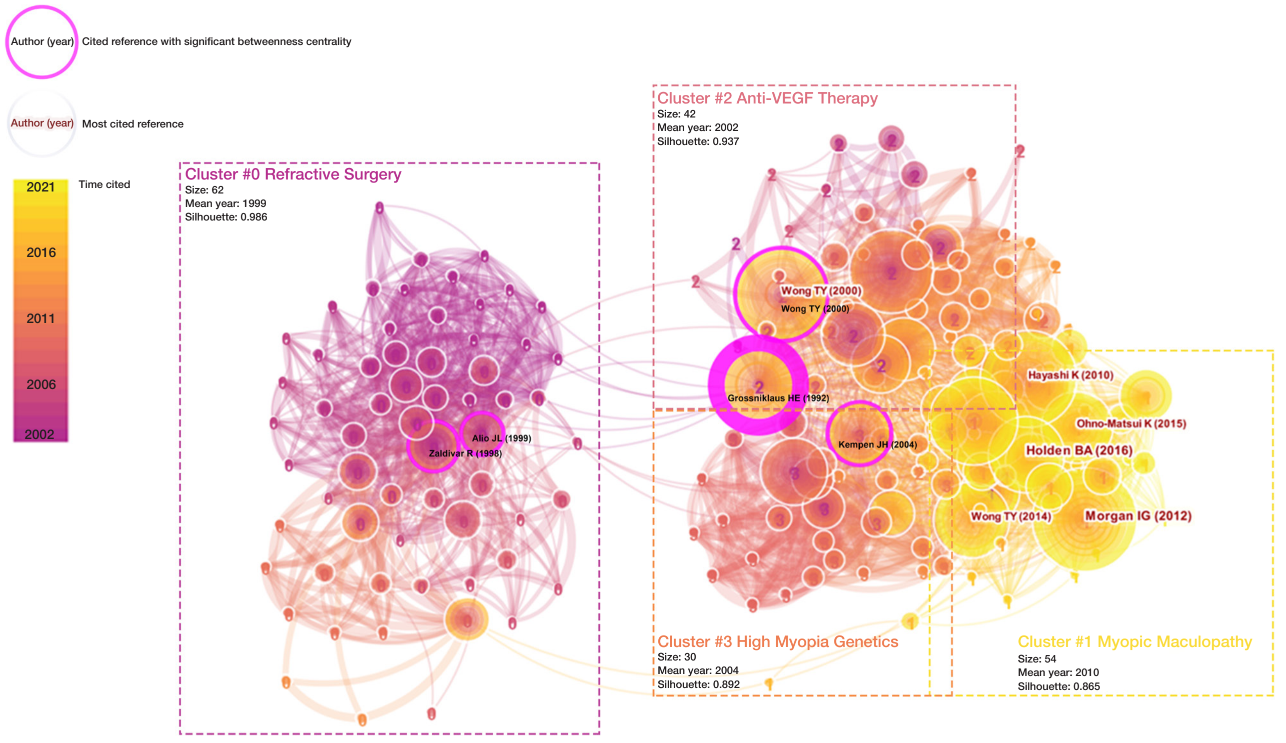


Figure 3 High myopia research frontiers over the period 2002–2021. The nodes represent cited references of high myopia studies. The larger the node, the more frequent the citation. Nodes with significant betweenness centralities, indicating a turning point role in shifts in research directions, are indicated by purple outer rings. The co-citation network was considered the knowledge base. The co-citation clusters are numbered #0–3 in descending cluster size order, with Cluster #0 having the largest cluster size. Terms derived from the citing articles were used to label the clusters as frontier research topics. The top six most cited studies and the five studies with significant contributions to research direction shifts are indicated. VEGF, vascular endothelial growth factor.

Table 1 shows the cited references and the citing articles in the clusters, as well as the temporal factors in the evolution of the clusters. The cited references were the references to the articles retrieved through our search strategies, encompassing a time frame that extends beyond the years 2002–2021. The citing articles were articles retrieved through our search strategies, within the years 2002–2021.

It also lists five studies (15-19) that were important turning points in the knowledge structure from the scientific literature (BC >0.1), with two studies (16,19) in the anti-VEGF therapy cluster, two (17,18) in the refractive surgery cluster, and one (15) in the high myopia genetics cluster. Furthermore, *Table 1* shows the top six most cited studies (1,16,20-23), five (1,20-23) in the myopic maculopathy cluster and one (16) in the anti-VEGF therapy cluster, representing the studies attracting the greatest academic interest. All articles in *Table 1* were cited in Table S1.

Frontiers of research subject categories

Among 116 myopia research subject categories, the categories with the highest occurrences were ophthalmology (n=3,338), surgery (n=557), and genetics & heredity (n=191). Engineering, surgery, and biochemistry & molecular biology had the highest BC values (0.65, 0.16, and 0.15; *Figure 4A*). Burst times continuing into 2021 were identified in the biotechnology & applied microbiology (2014–2021; strength =3.61), science & technology—other topics (2015–2021; strength =14.88), multidisciplinary sciences (2015–2021; strength =14.69), medicine, research & experimental (2018–2021; strength =6.26), research & experimental medicine (2018–2021; strength =6.26), and biochemical research methods (2019–2021; strength =3.08) categories (*Figure 4B*).

Table 1 The co-citation analysis of revealing the organization and time trends of high myopia research

Mean year	Frontier labels	Top five cited references with the highest citation in each cluster		Top five citing articles with the highest coverage in each cluster	
		Citations (n)	Author [year], title	Coverage (%)	Author [year], title
1999	#0, refractive surgery	69	Sanders [2004], United States Food and Drug Administration clinical trial of the Implantable Collamer Lens (ICL) for moderate to high myopia: three-year follow-up	18	Maloney [2002], Artisan phakic intraocular lens for myopia: short-term results of a prospective, multicenter study
		60	Zaldivar [1998], Posterior chamber phakic intraocular lens for myopia of -8 to -19 diopters[†]	13	Lovisolo [2005], Phakic intraocular lenses
		51	Sanders [2003], U.S. Food and Drug Administration clinical trial of the Implantable Contact Lens for moderate to high myopia	12	Sanders [2002], Incidence of lens opacities and clinically significant cataracts with the implantable contact lens: comparison of two lens designs
		43	Budo [2000], Multicenter study of the Artisan phakic intraocular lens	11	Alfonso [2010], Collagen copolymer toric posterior chamber phakic intraocular lens for myopic astigmatism: one-year follow-up
		42	Alió [1999], Phakic anterior chamber lenses for the correction of myopia: a 7-year cumulative analysis of complications in 263 cases[†]	11	Malecaze [2002], A randomized paired eye comparison of two techniques for treating moderately high myopia: LASIK and artisan phakic lens
2002	#2, anti-VEGF therapy	157	Wong [2000], Prevalence and risk factors for refractive errors in adult Chinese in Singapore[†‡]	18	Silva [2012], Myopic maculopathy: a review
		115	Blinder [2003], Verteporfin therapy of subfoveal choroidal neovascularization in pathologic myopia: 2-year results of a randomized clinical trial---VIP report no. 3	18	Neelam [2012], Choroidal neovascularization in pathological myopia
		111	Grossniklaus [1992], Pathologic findings in pathologic myopia[†]	17	Mitry [2012], Recent trends in the management of maculopathy secondary to pathological myopia
		96	Yoshida [2003], Myopic choroidal neovascularization: a 10-year follow-up	17	Ng [2012], Anti-vascular endothelial growth factor for myopic choroidal neovascularization
		75	Avila [1984], Natural history of choroidal neovascularization in degenerative myopia	13	Freitas-da-Costa [2014], Anti-VEGF therapy in myopic choroidal neovascularization: long-term results

Table 1 (*continued*)

Table 1 (*continued*)

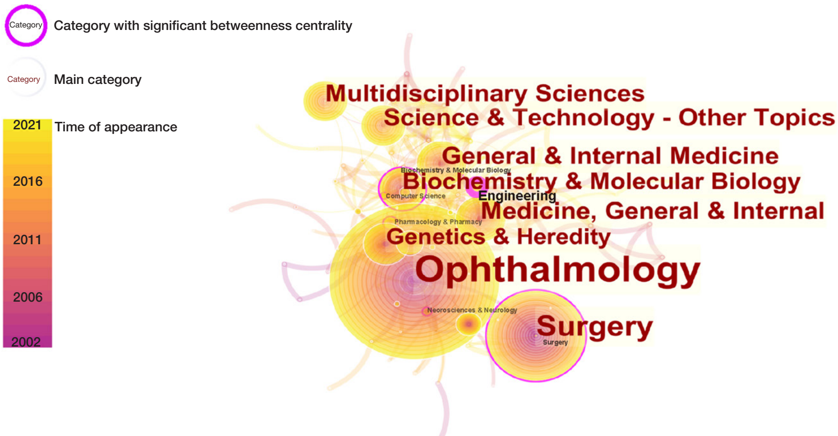
Mean year	Frontier labels	Top five cited references with the highest citation in each cluster		Top five citing articles with the highest coverage in each cluster	
		Citations (n)	Author [year], title	Coverage (%)	Author [year], title
2004	#3, high myopia genetics	90	Kempen [2004], The prevalence of refractive errors among adults in the United States, Western Europe, and Australia†	17	Hornbeak [2009], Myopia genetics: a review of current research and emerging trends
		88	Young [1998], A second locus for familial high myopia maps to chromosome 12q	17	Wojciechowski [2009], Genomewide linkage scans for ocular refraction and meta-analysis of four populations in the Myopia Family Study
		58	Young [1998], Evidence that a locus for familial high myopia maps to chromosome 18p	16	Young [2009], Molecular genetics of human myopia: an update
		58	Paluru [2003], New locus for autosomal dominant high myopia maps to the long arm of chromosome 17	16	Li [2009], An international collaborative family-based whole-genome linkage scan for high-grade myopia
		38	Hammond [2001], Genes and environment in refractive error: the twin eye study	16	Ng [2009], AC and AG dinucleotide repeats in the PAX6 P1 promoter are associated with high myopia
2010	#1, myopic maculopathy	296	Holden [2016], Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050‡	19	Ohno-Matsui [2021], IMI pathologic myopia
		267	Morgan [2012], Myopia‡	17	Ohno-Matsui [2016], Updates of pathologic myopia
		184	Hayashi [2010], Long-term pattern of progression of myopic maculopathy: a natural history study‡	15	Chan [2016], Epidemiology and diagnosis of myopic choroidal neovascularization in Asia
		170	Ohno-Matsui [2015], International photographic classification and grading system for myopic maculopathy‡	13	Farinha [2014], Progression of myopic maculopathy after treatment of choroidal neovascularization
		157	Wong [2014], Epidemiology and disease burden of pathologic myopia and myopic choroidal neovascularization: an evidence-based systematic review‡	13	Ruiz-Medrano [2019], Myopic maculopathy: current status and proposal for a new classification and grading system (ATN)

The cited references represent the references to the articles retrieved through our search strategies, with a temporal scope extending beyond the years 2002–2021. The citing articles were also retrieved through our search strategies and fall within the years 2002–2021. †, five significant bridging references (betweenness centrality >0.1); ‡, top six most cited references of all cited references. Mean year: average cluster formation year; Coverage: percentage of cited references of the citing article that belong to the corresponding cluster in the total cited references of the article. LASIK, laser in situ keratomileusis; VEGF, vascular endothelial growth factor; IMI, International Myopia Institute; ATN, atrophy, traction, and neovascularization.

Discussion

A total of 4,226 SCIE-indexed original research and review articles related to high myopia were collected, with the predominant actors being identified. The research hotspots were refractive error correction, epidemiology, ocular biometry, drug and laser treatment of myopic fundus lesions, and surgical treatment of myopic fundus lesions. High myopia genetics and myopic fundus lesion research

A



B

Subject Categories	Year	Strength	Begin	End	2002–2021
Surgery	2022	72.85	**2002**	2009	
Optics	2022	3.72	**2004**	2010	
Biochemistry & Molecular Biology	2022	7.46	**2009**	2011	
Biotechnology & Applied Microbiology	2022	3.61	**2014**	2021	
Science & Technology—Other Topics	2022	14.88	**2015**	2021	
Multidisciplinary Sciences	2022	14.69	**2015**	2021	
Medicine, Research & Experimental	2022	6.26	**2018**	2021	
Research & Experimental Medicine	2022	6.26	**2018**	2021	
Biochemical Research Methods	2022	3.08	**2019**	2021	

Figure 4 Key high myopia research subject categories. (A) Distribution map of the subject categories. Eight dominant categories (occurrence >100) and six bridge categories (betweenness centrality >0.1) are shown. Nodes with purple outer rings represent bridge subject categories. (B) Top hot subject categories and their popularity durations. A burst indicated a sharp increase in frequency, and the period of the citation burst was indicated by a red line segment. High strength represented a high degree of the burst.

were the research frontiers. Ophthalmology, engineering, and science & technology—other topics were the most dominant, the most bridging, and the hottest subject categories, respectively.

An overall upward trend in publications was detected in this study which may reflect the development of the field in terms of socioeconomic input and scientific data (7). The observed intervals between years of remarkable publication activity suggest that breakthroughs in the field occur every 2 to 5 years. China, Japan, and South Korea were among the top 10 contributing countries. This suggests that East Asia occupies a prominent position in high myopia research, which may be related to the high prevalence of myopia in this region (24). The particular areas of the studies published in the top 10 journals show that high myopia research is focused on refractive error-related surgical treatment (*Journal of Cataract and Refractive Surgery*, *Journal of Refractive Surgery*), basic science research (*Investigative Ophthalmology & Visual Science*), and fundus-related lesions (*Retina*). In terms of authors, Kyoko Ohno-Matsui, and Jost B. Jonas were among the top co-authors and first authors and were central to the researcher collaboration network, arguably the most active researchers in the field.

In order of the cluster size, five research hotspots related to high myopia have been formed in the past 20 years. To begin with, refractive error correction is a hot topic in high myopia research. There has been some controversy regarding the efficacy and safety of interventions for refractive error correction. New interventions, such as low-intensity long-wavelength red light, need further confirmation (25). In the next place, a burning epidemiological question is whether the pathological consequences of acquired high myopia are comparable to those associated with typical hereditary high myopia (26). The identification of environmental and genetic factors associated with high myopia may help to reverse the rising prevalence trajectory. Furthermore, technological advances in ocular biometry constitute another hot topic in high myopia research. Recent developments have made it possible to visualize pathological changes objectively and accurately and facilitate the diagnosis of high myopia. OCT can detect new lesions or conditions, such as domed macula and myopic tractional maculopathy, and wide-field OCT can successfully visualize the entire range of large staphylomas (27,28). In the end, pharmacological, laser, and surgical treatment methods for myopic fundus lesions constitute other hot research topics. As traditional therapies have not been effective in preventing and controlling the complications of high myopia, new therapies have emerged. Some of them, such as anti-VEGF therapy for myopic macular neovascularization and macular buckling therapy for full-thickness macular holes and associated macular detachment, have proven their effectiveness against complications (29,30).

On the frontiers in research topics, our findings suggest that high myopia research has undergone at least one shift over the last two decades, which is ongoing. Early research focused on the correction of refractive errors. This was followed by high myopia genetics and myopic fundus lesion research. The trend indicates that scientists are still striving to gain a comprehensive understanding of the issue and that a breakthrough in these areas may be imminent (31).

For one thing, evidence of the changing directions of myopic fundus lesion research came from studies with significant BCs, which signified important research structural changes. The earliest frontier cluster, refractive surgery, included a large number of refractive surgery related studies (17,18). Thereafter, Grossniklaus *et al.* (19) reported the manifestations of pathological myopia and their clinicopathological correlations, which was subsequently co-cited by many articles belonging to Clusters #1, #2, and #3. It could be argued that research related to high myopia is gradually beginning to move structurally towards myopic fundus lesion research with this article as a bridge. Clinically, pathological changes in the fundus can cause irreversible damage to visual function. To prevent this, it is crucial to predict and detect its long-term progression at an early stage. By doing so, we can minimize the damage through early intervention and possibly reverse its effects.

For another, our results showed that high myopia genetics represented another trend in high myopia research, and the formation of this topic was clued in from the most cited references in the cluster. A noteworthy finding was reported by Young *et al.* (32), who provided evidence that a locus for familial high myopia maps to chromosome 18p. The finding of a new locus for autosomal dominant high myopia mapping to the long arm of chromosome 17 was subsequently reported (33). Although these studies have provided some chromosomal localization information associated with high myopia, specific causative genes have rarely been identified.

The relationship between high myopia and genetics was complex. The occurrence of high myopia in syndromes suggested that mutations in single genes played a role in the development of high myopia. In non-syndromic high myopia, some views suggested that the increasing prevalence of high myopia was due to early-onset myopia developing into high myopia at a high progression rate, driven by environmental factors, particularly in East Asia (34). However, this did not necessarily explain the occurrence of high myopia in preschool children, where the etiology may have involved both single-gene and a combination of polygenic and environmental factors (35). Furthermore, the genes responsible for the pathological complications of high myopia had yet to be identified. Genetic studies will undoubtedly continue and may eventually lead to the prediction of high myopia development. Further deepening the research on the genes of high myopia, controlling the progression of the disease is crucial, and it also helps to improve the prognosis of systemic genetic diseases related to high myopia.

Concerning subject categories, this study identified dominant categories, bridging categories, and hot categories for high myopia research. Ophthalmology, surgery, and genetics were the dominant disciplines in high myopia research. Engineering, surgery, and biochemistry & molecular biology showed significant bridging effects, contributing to the collaboration between ophthalmology and other disciplines. At the same time, science & technology, and multidisciplinary science had high burst degrees as of 2021, indicating an increasing interest in these fields and an increase in interdisciplinary collaboration. Collaboration between ophthalmology, biotechnology, biochemistry, genetics, and other fields is expected to form the next frontier of high myopia research.

To the best of our knowledge, this study represents the first comprehensive investigation into the 20-year evolution and trends of high myopia research. Our findings contribute novel insights to the field. In order to address common challenges in scientometrics, we employed a rigorous methodology that included standardizing author names and data sources as well as utilizing an enhanced search strategy to ensure both comprehensiveness and accuracy.

This study has certain limitations that are common among scientometric studies. First of all, only the SCIE database was used. Moreover, analyses using VOSviewer and CiteSpace can include only articles published in English. There may be a delay in updating the database, causing the omission of newly indexed articles. Literature searches at a later time would yield more data. This study's search was conducted until December 19, 2021, limiting the publication volume for 2021. However, our study covered most articles published between 2002 and 2021, so including new articles would not significantly alter our conclusions. Despite these limitations, we believe that our detailed scientometric analysis offers valuable insight into the international study of high myopia.

Conclusions

In conclusion, the prevention and control, correction, and treatment of high myopia are research hotspots, with genetics and myopic fundus lesion as potential key spots of breakthrough. The interdisciplinary intersection of ophthalmology, engineering, and others contributes greatly to the advances in high myopia research. It is recommended that future research endeavors persist in examining the genetics and fundus lesions associated with high myopia, as well as exploring the potential of interdisciplinary innovation at the intersection of medicine and engineering as an emergent technological trend. By building upon the findings of this investigation, subsequent inquiries may enhance our comprehension of high myopia and contribute to the amelioration of its public health implications.

Acknowledgments

Funding: This study was supported by the National Natural Science Foundation of China (No. 81873675), the Science and Technology Program of Guangzhou, China (No. 202201011815), the Guangdong Basic and Applied Basic Research Foundation (No. 2022A1515011181), the Teaching Reform Research Program of Sun Yat-sen University (No. JX3030604024), and the Youth Project of State Key Laboratory of Ophthalmology (No. 2022QN03).

Footnote

Peer Review File: Available at https://aes.amegroups.com/article/view/10.21037/aes-23-35/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://aes.amegroups.com/article/view/10.21037/aes-23-35/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Holden BA, Fricke TR, Wilson DA, et al. Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050. Ophthalmology 2016;123:1036-42.
2. Haarman AEG, Enthoven CA, Tideman JWL, et al. The Complications of Myopia: A Review and Meta-Analysis. Invest Ophthalmol Vis Sci 2020;61:49.
3. Cao K, Zhang J, Wang J, et al. Implantable collamer lens versus small incision lenticule extraction for high myopia correction: A systematic review and meta-analysis. BMC Ophthalmol 2021;21:450.
4. Ivancheva L. Scientometrics today: A methodological overview. COLLNET Journal of Scientometrics and Information Management 2008;2:47-56.
5. Chen C. CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. J Am Soc Inf Sci 2006;57:359-77.
6. Boudry C, Denion E, Mortemousque B, et al. Trends and topics in eye disease research in PubMed from 2010 to 2014. PeerJ 2016;4:e1557.
7. Yang C, Wang X, Tang X, et al. Research trends of stem cells in ischemic stroke from 1999 to 2018: A bibliometric analysis. Clin Neurol Neurosurg 2020;192:105740.
8. Chen D, Zhang G, Wang J, et al. Mapping Trends in Moyamoya Angiopathy Research: A 10-Year Bibliometric and Visualization-Based Analyses of the Web of Science Core Collection (WoSCC). Front Neurol 2021;12:637310.

9. Wang X, Liu J, Sheng F. Analysis of Hotspots in the Field of Domestic Knowledge Discovery Based on Co-word Analysis Method. In: Zhang Z, Shen Z, Zhang J, et al. editors. LISS 2014. Berlin, Heidelberg: Springer, 2015:643-9.
10. Van Eck NJ, Waltman L. VOSviewer Manual. Version 1.6.14 ed. 2020.
11. van Eck NJ, Waltman L. Citation-based clustering of publications using CitNetExplorer and VOSviewer. Scientometrics 2017;111:1053-70.
12. Chen C. Searching for intellectual turning points: progressive knowledge domain visualization. Proc Natl Acad Sci U S A 2004;101 Suppl 1:5303-10.
13. Chen C, Hu Z, Liu S, et al. Emerging trends in regenerative medicine: a scientometric analysis in CiteSpace. Expert Opin Biol Ther 2012;12:593-608.
14. Chen C, Ibekwe-SanJuan F, Hou J. The structure and dynamics of cocitation clusters: A multiple-perspective cocitation analysis. J Am Soc Inf Sci 2010;61:1386-409.
15. Kempen JH, Mitchell P, Lee KE, et al. The prevalence of refractive errors among adults in the United States, Western Europe, and Australia. Arch Ophthalmol 2004;122:495-505.
16. Wong TY, Foster PJ, Hee J, et al. Prevalence and risk factors for refractive errors in adult Chinese in Singapore. Invest Ophthalmol Vis Sci 2000;41:2486-94.
17. Alió JL, de la Hoz F, Pérez-Santonja JJ, et al. Phakic anterior chamber lenses for the correction of myopia: a 7-year cumulative analysis of complications in 263 cases. Ophthalmology 1999;106:458-66.
18. Zaldivar R, Davidorf JM, Oscherow S. Posterior chamber phakic intraocular lens for myopia of -8 to -19 diopters. J Refract Surg 1998;14:294-305.
19. Grossniklaus HE, Green WR. Pathologic findings in pathologic myopia. Retina 1992;12:127-33.
20. Ohno-Matsui K, Kawasaki R, Jonas JB, et al. International photographic classification and grading system for myopic maculopathy. Am J Ophthalmol 2015;159:877-83.e7.
21. Wong TY, Ferreira A, Hughes R, et al. Epidemiology and disease burden of pathologic myopia and myopic choroidal neovascularization: an evidence-based systematic review. Am J Ophthalmol 2014;157:9-25.e12.
22. Morgan IG, Ohno-Matsui K, Saw SM. Myopia. Lancet 2012;379:1739-48.
23. Hayashi K, Ohno-Matsui K, Shimada N, et al. Long-term pattern of progression of myopic maculopathy: a natural history study. Ophthalmology 2010;117:1595-611, 1611.e1-4.
24. Matsumura S, Ching-Yu C, Saw SM. Global Epidemiology of Myopia. In: Ang M, Wong TY. editors. Updates on Myopia: A Clinical Perspective. Singapore: Springer Singapore; 2020:27-51.
25. Jiang Y, Zhu Z, Tan X, et al. Effect of Repeated Low-Level Red-Light Therapy for Myopia Control in Children: A Multicenter Randomized Controlled Trial. Ophthalmology 2022;129:509-19.
26. Morgan IG, He M, Rose KA. EPIDEMIC OF PATHOLOGIC MYOPIA: What Can Laboratory Studies and Epidemiology Tell Us? Retina 2017;37:989-97.
27. Shinohara K, Shimada N, Moriyama M, et al. Posterior Staphylomas in Pathologic Myopia Imaged by Widefield Optical Coherence Tomography. Invest Ophthalmol Vis Sci 2017;58:3750-8.
28. Ng DS, Cheung CY, Luk FO, et al. Advances of optical coherence tomography in myopia and pathologic myopia. Eye (Lond) 2016;30:901-16.
29. Lai TY, Luk FO, Lee GK, et al. Long-term outcome of intravitreal anti-vascular endothelial growth factor therapy with bevacizumab or ranibizumab as primary treatment for subfoveal myopic choroidal neovascularization. Eye (Lond) 2012;26:1004-11.
30. Zhao X, Li Y, Ma W, et al. Macular buckling versus vitrectomy on macular hole associated macular detachment in eyes with high myopia: a randomised trial. Br J Ophthalmol 2022;106:582-6.
31. Kuhn TS. The Structure of Scientific Revolutions. University of Chicago Press; 1962.
32. Young TL, Ronan SM, Alvear AB, et al. A second locus for familial high myopia maps to chromosome 12q. Am J Hum Genet 1998;63:1419-24.
33. Paluru P, Ronan SM, Heon E, et al. New locus for autosomal dominant high myopia maps to the long arm of chromosome 17. Invest Ophthalmol Vis Sci 2003;44:1830-6.
34. Dolgin E. The myopia boom. Nature 2015;519:276-8.
35. Flitcroft I, Ainsworth J, Chia A, et al. IMI-Management and Investigation of High Myopia in Infants and Young Children. Invest Ophthalmol Vis Sci 2023;64:3.

doi: 10.21037/aes-23-35

Cite this article as: Tan Y, Zhu W, Zou Y, Zhang B, Yu Y, Li W, Xu C, Hu L, Jin G, Liu Z. Evolution and trends of high myopia research from 2002 to 2021: a scientometric analysis. Ann Eye Sci 2023;8:17.

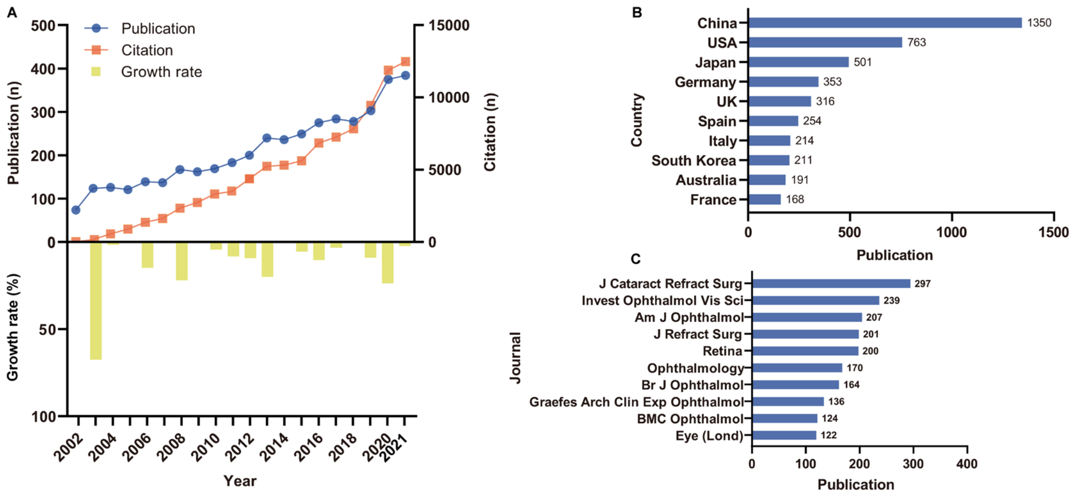


Figure S1 Profile of high myopia research publications over the period 2002–2021. (A) Top graph: global trends of annual publications and citations. Bottom graph: year-on-year publication growth rates. (B) Top 10 countries in terms of publications. (C) Top 10 journals in terms of publications.

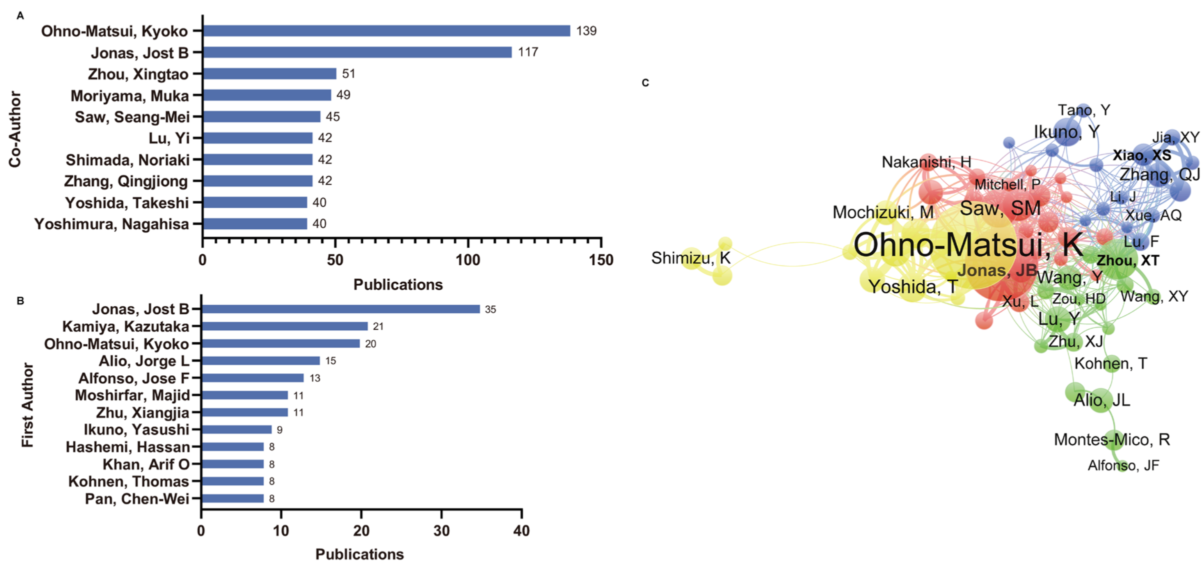


Figure S2 The most active authors in the field of high myopia. (A) Top 10 co-authors. (B) Top 12 first authors. (C) Author collaboration network map.

Table S1 Reference list for *Table 1*

1. Grossniklaus HE, Green WR. Pathologic findings in pathologic myopia. Retina 1992;12:127-33.

2. Zaldivar R, Davidorf JM, Oscherow S. Posterior chamber phakic intraocular lens for myopia of -8 to -19 diopters. J Refract Surg 1998;14:294-305.

3. Alió JL, de la Hoz F, Pérez-Santonja JJ, et al. Phakic anterior chamber lenses for the correction of myopia: a 7-year cumulative analysis of complications in 263 cases. Ophthalmology 1999;106:458-66.

4. Wong TY, Foster PJ, Hee J, et al. Prevalence and risk factors for refractive errors in adult Chinese in Singapore. Invest Ophthalmol Vis Sci 2000;41:2486-94.

5. Kempen JH, Mitchell P, Lee KE, et al. The prevalence of refractive errors among adults in the United States, Western Europe, and Australia. Arch Ophthalmol 2004;122:495-505.

6. Hayashi K, Ohno-Matsui K, Shimada N, et al. Long-term pattern of progression of myopic maculopathy: a natural history study. Ophthalmology 2010;117:1595-611, 1611.e1-4.

7. Morgan IG, Ohno-Matsui K, Saw SM. Myopia. Lancet 2012;379:1739-48.

8. Wong TY, Ferreira A, Hughes R, et al. Epidemiology and disease burden of pathologic myopia and myopic choroidal neovascularization: an evidence-based systematic review. Am J Ophthalmol 2014;157:9-25.e12.

9. Ohno-Matsui K, Kawasaki R, Jonas JB, et al. International photographic classification and grading system for myopic maculopathy. Am J Ophthalmol 2015;159:877-83.e7.

10. Holden BA, Fricke TR, Wilson DA, et al. Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050. Ophthalmology 2016;123:1036-42.

11. Avila MP, Weiter JJ, Jalkh AE, et al. Natural history of choroidal neovascularization in degenerative myopia. Ophthalmology 1984;91:1573-81.

12. Young TL, Ronan SM, Alvear AB, et al. A second locus for familial high myopia maps to chromosome 12q. Am J Hum Genet 1998;63:1419-24.

13. Young TL, Ronan SM, Drahozal LA, et al. Evidence that a locus for familial high myopia maps to chromosome 18p. Am J Hum Genet 1998;63:109-19.

14. Budo C, Hessloehl JC, Izak M, et al. Multicenter study of the Artisan phakic intraocular lens. J Cataract Refract Surg 2000;26:1163-71.

15. Hammond CJ, Snieder H, Gilbert CE, et al. Genes and environment in refractive error: the twin eye study. Invest Ophthalmol Vis Sci 2001;42:1232-6.

16. Malecaze FJ, Hulin H, Bierer P, et al. A randomized paired eye comparison of two techniques for treating moderately high myopia: LASIK and artisan phakic lens. Ophthalmology 2002;109:1622-30.

17. Maloney RK, Nguyen LH, John ME. Artisan phakic intraocular lens for myopia:short-term results of a prospective, multicenter study. Ophthalmology 2002;109:1631-41.

18. Sanders DR, Vukich JA, ICL in Treatment of Myopia (ITM) Study Group. Incidence of lens opacities and clinically significant cataracts with the implantable contact lens: comparison of two lens designs. J Refract Surg 2002;18:673-82.

19. Blinder KJ, Blumenkranz MS, Bressler NM, et al. Verteporfin therapy of subfoveal choroidal neovascularization in pathologic myopia: 2-year results of a randomized clinical trial--VIP report no. 3. Ophthalmology 2003;110:667-73.

20. Paluru P, Ronan SM, Heon E, et al. New locus for autosomal dominant high myopia maps to the long arm of chromosome 17. Invest Ophthalmol Vis Sci 2003;44:1830-6.

21. Sanders DR, Vukich JA, Doney K, et al. U.S. Food and Drug Administration clinical trial of the Implantable Contact Lens for moderate to high myopia. Ophthalmology 2003;110:255-66.

22. Yoshida T, Ohno-Matsui K, Yasuzumi K, et al. Myopic choroidal neovascularization: a 10-year follow-up. Ophthalmology 2003;110:1297-305.

23. Sanders DR, Doney K, Poco M, et al. United States Food and Drug Administration clinical trial of the Implantable Collamer Lens (ICL) for moderate to high myopia: three-year follow-up. Ophthalmology 2004;111:1683-92.

24. Lovisolo CF, Reinstein DZ. Phakic intraocular lenses. Surv Ophthalmol 2005;50:549-87.

25. Hornbeak DM, Young TL. Myopia genetics: a review of current research and emerging trends. Curr Opin Ophthalmol 2009;20:356-62.

26. Li YJ, Guggenheim JA, Bulusu A, et al. An international collaborative family-based whole-genome linkage scan for high-grade myopia. Invest Ophthalmol Vis Sci 2009;50:3116-27.

27. Ng TK, Lam CY, Lam DS, et al. AC and AG dinucleotide repeats in the PAX6 P1 promoter are associated with high myopia. Mol Vis 2009;15:2239-48.

28. Wojciechowski R, Stambolian D, Ciner E, et al. Genomewide linkage scans for ocular refraction and meta-analysis of four populations in the Myopia Family Study. Invest Ophthalmol Vis Sci 2009;50:2024-32.

29. Young TL. Molecular genetics of human myopia: an update. Optom Vis Sci 2009;86:E8-E22.

30. Alfonso JF, Fernández-Vega L, Fernandes P, et al. Collagen copolymer toric posterior chamber phakic intraocular lens for myopic astigmatism: one-year follow-up. J Cataract Refract Surg 2010;36:568-76.

31. Mitry D, Zambarakji H. Recent trends in the management of maculopathy secondary to pathological myopia. Graefes Arch Clin Exp Ophthalmol 2012;250:3-13.

32. Neelam K, Cheung CM, Ohno-Matsui K, et al. Choroidal neovascularization in pathological myopia. Prog Retin Eye Res 2012;31:495-525.

33. Ng DS, Kwok AK, Chan CW. Anti-vascular endothelial growth factor for myopic choroidal neovascularization. Clin Exp Ophthalmol 2012;40:e98-e110.

34. Silva R. Myopic maculopathy: a review. Ophthalmologica 2012;228:197-213.

35. Farinha CL, Baltar AS, Nunes SG, et al. Progression of myopic maculopathy after treatment of choroidal neovascularization. Ophthalmologica 2014;231:211-20.

36. Freitas-da-Costa P, Pinheiro-Costa J, Carvalho B, et al. Anti-VEGF therapy in myopic choroidal neovascularization: long-term results. Ophthalmologica 2014;232:57-63.

37. Chan NS, Teo K, Cheung CM. Epidemiology and Diagnosis of Myopic Choroidal Neovascularization in Asia. Eye Contact Lens 2016;42:48-55.

38. Ohno-Matsui K, Lai TY, Lai CC, et al. Updates of pathologic myopia. Prog Retin Eye Res 2016;52:156-87.

39. Ruiz-Medrano J, Montero JA, Flores-Moreno I, et al. Myopic maculopathy: Current status and proposal for a new classification and grading system (ATN). Prog Retin Eye Res 2019;69:80-115.

40. Ohno-Matsui K, Wu PC, Yamashiro K, et al. IMI Pathologic Myopia. Invest Ophthalmol Vis Sci 2021;62:5.

 https://dx.doi.org/10.21037/aes-23-35