• Bibliometric Research •

Artificial intelligence in ophthalmology: a bibliometric analysis of current status, hot topics, and trends (2016–2025)

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Abstract

● **AIM:** To systematically analyze the current state of research, evolving trends, and future directions regarding the application of artificial intelligence (AI) in ophthalmology from 2016 to 2025, thereby providing a reference for researchers in this field.

● **METHODS:** The Web of Science Core Collection database was searched, and journal publications related to AI in ophthalmology published between January 1, 2016, and December 31, 2025, were included. CiteSpace 6.3.1 was used to perform visual analyses of publication volume, distribution by country or region, research institutions and researchers, journal sources, keyword emergence, and high-impact publications.

● **RESULTS:** A total of 5798 research publications were included. The global annual publication volume showed a continuous upward trend, entering a period of stable growth after 2021. China ranked first globally with 1964 papers, followed by USA and India. University of London (204 papers), University College London (190 papers), and Sun Yat-sen University (190 papers) were the top three institutions by publication volume. Schmidt-Erfurth U (94 papers), Bogunovic H (86 papers), Yang WH (50 papers), and Wong TY (50 papers) were the leading researchers in terms of publication output. Research hotspots were highly concentrated on the automated screening and diagnosis of diabetic retinopathy (DR), with segmentation, retinal images, and feature extraction being the keywords with the highest growth rates. Analysis of high-impact papers further confirmed that DR screening is currently the most influential application scenario.

● **CONCLUSION:** Over the past decade, global research on AI in ophthalmology has developed rapidly, with China making particularly notable contributions in terms of publication volume. Research focus has shifted from traditional image processing methods to automated diagnosis using deep learning, with DR screening being the most mature application area.

● **KEYWORDS:** artificial intelligence; ophthalmology; deep learning; diabetic retinopathy; hotspot; trends
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INTRODUCTION

With the rapid development of artificial intelligence (AI), it has made an indispensable contribution to the field of medicine. From medical image analysis to electronic health record mining, and from diagnostic assistance to personalized treatment decisions, AI technology has permeated numerous subfields of clinical medicine[1-2]. Among these, ophthalmology—due to its strong reliance on imaging examinations—has become one of the most active and mature

fields for AI applications[3-4]. AI algorithms, particularly deep learning, have demonstrated performance comparable to or even superior to that of clinical experts or professionals in tasks such as screening for diabetic retinopathy (DR), diagnosing age-related macular degeneration, and assessing optic nerve damage in glaucoma[5-6]. In recent years, with the rapid development of technologies such as computer vision, transfer learning, and large language models, the application of AI in ophthalmology has expanded from simple diagnostic assistance to comprehensive multi-disease screening, systemic disease risk prediction, and human-machine collaborative diagnosis and treatment[7-9].

With the rapid growth of AI research in ophthalmology, the field has accumulated a wealth of research findings and technical approaches. However, this rapid growth has also made it difficult for researchers to quickly grasp the field's overall development trends, key research forces, hot topics, and future directions amid a vast and scattered body of publications. Bibliometric methods, through quantitative analysis of metrics such as publication volume, international collaboration, keyword co-occurrence, and high-impact papers, can objectively and systematically reveal the developmental patterns and research frontiers of a discipline or field. Currently, there is a lack of systematic bibliometric analysis for the rapidly evolving interdisciplinary field of ophthalmic AI.

This study used the Web of Science Core Collection (WoSCC) database as its data source to retrieve papers related to AI in ophthalmology published between January 1, 2016, and December 31, 2025, and employed bibliometric methods for analysis.

MATERIALS AND METHODS

Publication Sources and Search Strategies Search the WoSCC database; citation indexes include Science Citation Index Expanded (SCIE) and Social Science Citation Index (SSCI). The detailed search query is: topic search (TS)=("artificial intelligence" or "AI" or "machine learning" or "deep learning" or "transfer learning" or "neural network" or "robot*" or "supervised learning" or "unsupervised learning" or "computer vision system" or "computational intelligence" or "evolutionary computation" or "ensemble learning" or "reinforcement learning" or "large language model" or "LLM") AND ("eye" or "ocular" or "ophthalmology" or "ophthalm*" or "retin*" or "uveitis" or "keratitis" or "age-related macular degeneration" or "glaucoma" or "orbitopathy"). The search period is from January 1, 2016, to December 31, 2025; the search language is limited to English; and the publication type is limited to "article".

Inclusion criteria: 1) Relevant to the topics of ophthalmology and AI; 2) published in English; 3) publication type: article; 4) published between January 1, 2016, and December 31, 2025. Paper exclusion criteria: 1) Publications unrelated to the subject or content of this study; 2) duplicate publications; 3) publications classified as retracted articles, letters, conference papers, *etc*.

Data Filtering Two researchers (Shen Y and Wang XY) independently screened and extracted data from the articles, using a cross-checking method; any disagreements were resolved by a third party. A total of 20 735 publications were retrieved; after excluding irrelevant publications based on titles, abstracts, and full texts, 5798 research publications were included in the analysis.

Data Analysis and Visualization Use Excel 2021 to analyze publication trends, and use CiteSpace 6.3.1 to visualize the countries, institutions, journals, research categories, keywords, and references related to the application of AI in the field of ophthalmology. After importing the extracted data into CiteSpace 6.3.1, set the time span to 2016–2025, the time slice to 1, and the *K*-value in the "g-index" to 10; leave all other settings at their CiteSpace 6.3.1 defaults.

RESULTS

Annual Publication Volume in China and Abroad This study included a total of 5798 research papers, of which 1964 were published in China during this 10-year period, accounting for approximately 33.9%. From 2016 to 2025, the number of domestic and international publications on AI in ophthalmology showed an overall upward trend: between 2016 and 2021, the number of publications in this field was relatively low but exhibited a gradual increase, indicating that AI research in ophthalmology was still in its infancy during this period. In contrast, from 2021 to 2025, the total number of publications on ophthalmic AI research was substantial and showed a slow growth trend, indicating that research in this field had entered a stable phase during this period (Figure 1).

Number of Publications by Country or Region Figure 2 illustrates the collaborative co-occurrence patterns among countries or regions. The size of each node is proportional to the number of publications; that is, the larger the node, the greater the number of publications from that country in the field. In Figure 2, China is shown to have the highest number of publications. The lines connecting the nodes represent collaborative relationships between countries or regions.

Publication Output by Different Institutions and Researchers Table 1 shows the top 10 institutions ranked by publication output from highest to lowest. Among the top 10 institutions, three are from China; the top three institutions by publication output are, in order, University of London (204 papers), University College London (190 papers), and Sun Yat-sen University (190 papers).

Table 2 lists the top 10 researchers ranked by publication output. Among the top 10 researchers, five are from China, indicating that Chinese researchers have made an indispensable contribution to the development of this field. Among them, Yang WH and Wong TY published a combined total of 50 relevant papers during this period, leading the nation.

Journal Sources and Research Fields Cited journals reflect the cutting edge of AI research in ophthalmology. Table 3 lists the top 10 journals ranked by citation frequency from highest to lowest, including the journal title, number of publications published, research category, and the journal's latest impact factor. At the broadest level, research categories include medicine, computer science, engineering, and interdisciplinary sciences, reflecting the cross-disciplinary nature of the field; within the medical field, the main categories include ophthalmology, biomedicine, internal medicine, and optics.

Keyword Analysis In CiteSpace 6.3.1, with Years Per Slice set to 1, Top N% set to 10%, and Minimum Duration set to 1, the Figure 3 shows the top 25 most frequently cited keywords along with their emergence times and intensity. Here, "Strength" represents the intensity of the surge, and the red lines indicate emerging keywords within that time period. As shown in the Figure 3, the keywords with the highest burst intensity are segmentation, retinal images, and extraction, while retinal images, extraction, algorithms, automatic detection, matched filters, and classifiers are the keywords with the longest active periods.

High-Impact Papers High-impact papers indicate that a study has had a significant impact; their high citation counts reflect research findings that are widely recognized within the field. Table 4 lists the top 10 most-cited papers in this field, covering areas such as prediction and prevention, diagnosis, and classification of AI applications in ophthalmology[10-19].

DISCUSSION

Analysis of Publication Trends The results of the publication trend analysis show that China accounts for 33.9% of research in ophthalmic AI, indicating that China is a major contributor to this field. The number of publications gradually increased between 2016 and 2021, which may be related to the exploratory development of AI technologies such as deep learning in the field of ophthalmic imaging. However, the overall growth in ophthalmic AI research publications slowed between 2021 and 2025 compared to the previous period, suggesting that ophthalmic AI research is currently in a stable phase. This may be attributed to the increasing maturity of AI technologies and their gradual application in real-world settings[20-21].

Analysis of Publication Output by Country The results show that China and USA lead the world in publication output. This may be attributed to their large patient populations and the relatively mature application of AI technology in this field. Among the top 10 countries, Asian nations account for

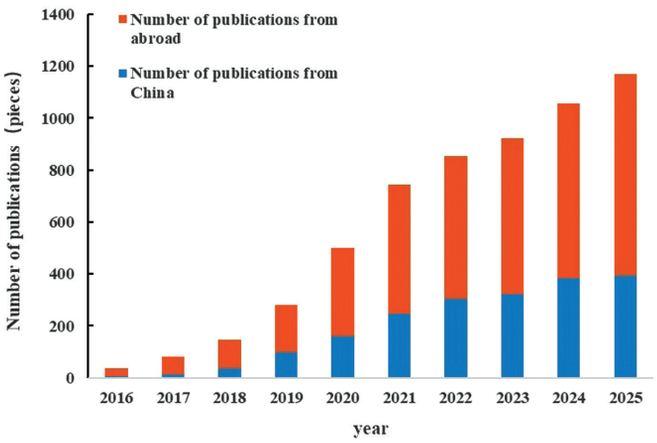


Figure 1 Trend in annual publications on ophthalmic AI research, 2016–2025 AI: Artificial intelligence.

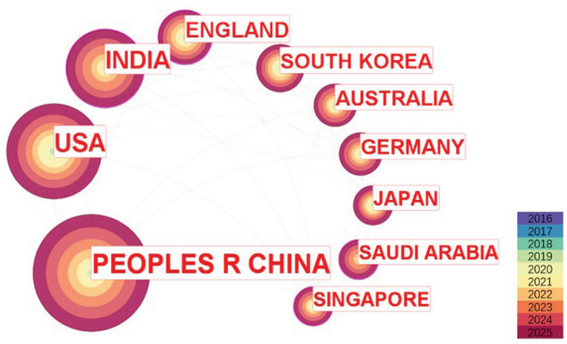


Figure 2 Co-occurrence map of international collaborations in ophthalmic AI research, 2016–2025 AI: Artificial intelligence.

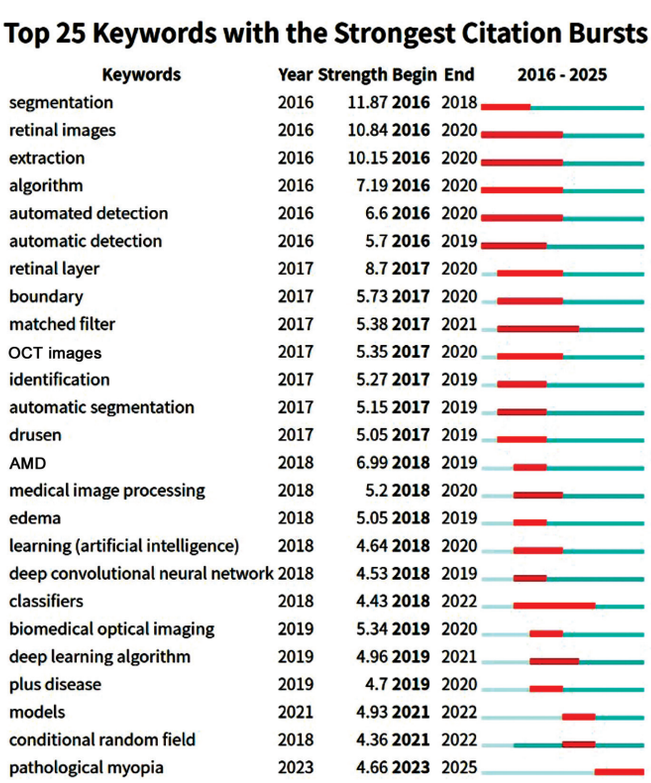


Figure 3 The 25 most frequently used keywords in ophthalmic AI research, 2016–2025 AI: Artificial intelligence.

Table 1 Top 10 research institutions by number of publications in the field of ophthalmic AI, 2016–2025

Order	Institution	Number of publications	Country/region
1	University of London	204	United Kingdom
2	University College London	190	United Kingdom
3	Sun Yat-sen University	190	China
4	University of California System	189	USA
5	National University of Singapore	168	Singapore
6	Chinese Academy of Sciences	162	China
7	Singapore National Eye Center	159	Singapore
8	Moorfields Eye Hospital NHS Foundation Trust	156	United Kingdom
9	Capital Medical University	151	China
10	Medical University of Vienna	144	Austria

University College London is a constituent college of the University of London. AI: Artificial intelligence.

Table 2 Top 10 researchers by number of publications in the field of ophthalmic AI, 2016–2025

Order	Researcher	Number of publications	Country/region
1	Schmidt-Erfurth, Ursula	94	Austria
2	Bogunovic, Hrvoje	86	Austria
3	Yang, Weihua	50	China
3	Wong, Tien Yin	50	China
5	Keane, Pearse	44	United Kingdom
6	He, Mingguang	42	China
6	Lin, Haotian	42	China
8	Cheng, Ching-Yu	39	Singapore
9	Reiter, Gregor S.	38	Austria
10	Ye, Juan	35	China

Author names are standardized to the format "Last name, First initial(s)". For authors with multiple affiliations, only the primary affiliation is recorded based on the publication metadata from WoSCC. WoSCC: Web of Science Core Collection; AI: Artificial intelligence.

Table 3 Top 10 journals by number of publications in the field of ophthalmic AI, 2016–2025

Order	Journal title	Number of publications	Category of the research journal	Latest impact factor
1	*Scientific Reports*	360	Multidisciplinary	3.9
2	*Translational Vision Science & Technology*	306	Ophthalmology	2.6
3	*American Journal of Ophthalmology*	241	Ophthalmology	4.2
4	*IEEE Access*	224	Computer science	3.6
5	*Biomedical Signal Processing and Control*	187	Biomedical engineering	4.9
6	*Diagnostics*	134	Medicine	3.3
7	*Biomedical Optics Express*	128	Optics	3.2
8	*Multimedia Tools and Applications*	115	Engineering	3.0
9	*Frontiers in Medicine*	111	Medicine	3.0
10	*PLoS One*	106	Multidisciplinary	2.6

AI: Artificial intelligence.

half of the list, indicating that Asian countries are performing exceptionally well in this field. This may be related to the high prevalence of eye diseases such as DR and refractive errors, as well as the high demand for screening[22]. China, USA, and the United Kingdom have high H-indexes, suggesting that these countries not only rank among the top in terms of publication volume but also possess strong academic influence in this field.

Analysis of Publication Output by Research Institutions and Researchers This study found that among the top 10 research institutions, those in the United Kingdom led the pack, followed by institutions in China and USA, indicating a high level of interest in ophthalmic AI research. Among Chinese institutions, Sun Yat-sen University had the highest publication output, which may be attributed to the fact that the Sun Yat-sen University Eye Center, affiliated with the university, was one of the first ophthalmic institutions in China to embrace AI[23]. The results regarding the number of publications indicate that Schmidt-Erfurth U, Bogunovic H, Yang WH, and Wong TY

Table 4 Top 10 high-impact papers in the field of ophthalmic AI, 2016–2025

Order	High-impact paper titles	DOI	Times cited	Key findings	Limitations of the study
1	Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs[10]	10.1001/jama.2016.17216	4617	Deep learning algorithms have demonstrated high sensitivity and specificity in detecting DR and diabetic macular edema requiring referral based on fundus photographs	The algorithm's reference standards are based on the consensus of most ophthalmologists, which may compromise its performance on retinal images, as these images contain subtle pathological features that most raters are unable to identify
2	Clinically applicable deep learning for diagnosis and referral in retinal disease[11]	10.1038/s41591-018-0107-6	1691	This framework has demonstrated expert-level performance in the diagnosis and triage of retinal diseases using OCT scans, highlighting its potential for clinical applications and the training of healthcare professionals	The segmentation map of this framework assigns a label to each pixel, which limits its direct application in clinical settings that require multidimensional organization of feature information (such as radiomics)
3	Development and validation of a deep learning system for diabetic retinopathy and related eye diseases using retinal images from multiethnic populations with diabetes[12]	10.1001/jama.2017.18152	1568	The study shows that a deep learning system designed to detect DR and related eye conditions requiring referral performs comparably to professionally trained raters across different populations and settings	As a "black box", deep learning systems are unable to clearly identify specific lesions associated with DR (such as microaneurysms), resulting in a lack of transparency that may hinder their clinical application
4	Prediction of cardiovascular risk factors from retinal fundus photographs *via* deep learning[13]	10.1038/s41551-018-0195-0	1128	Deep learning models can predict various cardiovascular risk factors based on fundus images, with accuracy comparable to that of traditional risk assessment tools	The main limitations of this study are that it used only retinal images with a 45° field of view, did not validate the results using images with other field-of-view sizes, and the overall dataset size was relatively small for deep learning
5	Pivotal trial of an autonomous AI-based diagnostic system for detection of diabetic retinopathy in primary care offices[14]	10.1038/s41746-018-0040-6	980	The study demonstrates that in primary care settings, the autonomous AI system IDx DR can effectively detect cases of mild-to-moderate DR (mtmDR) with a sensitivity of 87.2% and a specificity of 90.7%, representing a significant advancement in diabetic eye care	1) This AI system is not designed to detect non-diabetic retinal abnormalities and may therefore miss clinically significant incidental findings 2) In primary care settings, its sensitivity (87.2%) is lower than that observed in laboratory studies
6	Automated identification of diabetic retinopathy using deep learning[15]	10.1016/j.ophtha.2017.02.008	850	This deep learning algorithm shows great promise for the automatic detection of DR, achieving high sensitivity and specificity across multiple datasets. This is expected to improve screening efficiency and reduce vision loss worldwide	1) The sample size is relatively small, and the study focused only on a specific disease 2) Furthermore, additional testing is needed to optimize the model's sensitivity
7	Improved automated detection of diabetic retinopathy on a publicly available dataset through integration of deep learning[16]	10.1167/iovs.16-19964	737	The IDx DR X2.1 device utilizes deep learning algorithms to demonstrate significantly improved performance in the detection of DR, achieving higher levels of both sensitivity and specificity compared to traditional methods	The high sensitivity threshold chosen for this algorithm is for comparison purposes only and does not reflect the actual balance between sensitivity and specificity
8	Segmenting retinal blood vessels with deep neural networks[17]	10.1109/TMI.2016.2546227	700	This study demonstrates that deep neural networks are an effective method for segmenting retinal vessels in fundus imaging, with accuracy and area under the ROC curve that are significantly superior to those of previous algorithms	Compared to the model's overall segmentation accuracy, its performance on fine retinal vessels is relatively weaker
9	Joint optic disc and cup segmentation based on multi-label deep network and polar transformation[18]	10.1109/TMI.2018.2791488	699	The proposed M Net architecture achieves state-of-the-art performance in segmenting the optic disc and cup in fundus images, and significantly improves the effectiveness of glaucoma screening through the use of polar coordinate transformations and multi-label deep learning methods	M-Net's performance declines on fundus images with low contrast or blurriness, and it is unable to accurately segment the optic cup border in these challenging conditions
10	DUNet: a deformable network for retinal vessel segmentation[19]	10.1016/j.knosys.2019.04.025	623	As a deformable convolutional neural network, DUNet has demonstrated superior performance to existing methods in retinal vessel segmentation, highlighting its effectiveness in clinical applications for the early diagnosis of diseases	A key limitation of the DUNet in this study is that it incurs increased computational time during both training and testing, which is attributed to the addition of extra convolutional layers designed to learn deformable offsets for adaptive receptive fields

DR: Diabetic retinopathy; OCT: Optical coherence tomography; ROC: Receiver operating characteristic; AI: Artificial intelligence.

are the top four scholars in this field. Although the research of these four scholars in the field of ophthalmic AI is similar, their specific areas of focus differ. Schmidt-Erfurth U primarily applies AI to optical coherence tomography (OCT) image analysis, particularly for the prediction of age-related macular degeneration and the assessment of treatment response[24-25]; her core team member, Bogunovic H focuses on OCT image processing and machine learning[26-28]; Yang WH, the Chinese scholar with the highest publication output, differs from the first two scholars. Yang's team has a more diverse research portfolio, covering multiple directions such as AI in ophthalmic imaging, myopia prevention and control, and AI for dry eye syndrome, and has led the development of several clinical research guidelines for ophthalmic AI[29-30]; Chinese scholar Wong TY's primary contribution lies in expanding the application of ophthalmic AI imaging from eye disease screening to the prediction of systemic diseases[31-33]. Among the top 10 researchers by publication volume, half are from China, indicating the active engagement of Chinese scholars in this field.

Analysis of Publication Sources The volume of journal publications indicates that research in this field spans medicine, computer science, engineering, and interdisciplinary sciences, highlighting the field's distinctly interdisciplinary nature. As a branch of computer science, AI has seen significant development in ophthalmology. The application of AI technologies—such as deep learning and classifiers—to analyze ophthalmic images for the screening, diagnosis, and prevention of eye diseases exemplifies this multidisciplinary approach[34-35]. However, achieving a high level of integration between AI and ophthalmology remains a major challenge in this field. To address this, a system for cultivating interdisciplinary professionals and an evaluation mechanism should be established in the future to contribute to breakthroughs in this field.

Keyword Analysis This study conducted a word emergence analysis of keywords in the field of ophthalmic AI from 2016 to 2025, presenting the 25 most frequently cited keywords and their temporal intensity. The analysis revealed that keywords in this field exhibit distinct characteristics and trends in terms of timing and intensity of emergence.

From a temporal perspective and in terms of the disease spectrum, between 2016 and 2020, keywords such as "retinal images" and "retinal layers" indicate that early AI research in ophthalmology primarily focused on DR. This may be attributed to the following reasons: 1) DR is one of the most common microvascular complications among patients with diabetes; however, many countries and regions face shortages of ophthalmologists and equipment, resulting in an inability to meet the demand for DR screening[36]; 2) Compared to other eye diseases, DR exhibits a higher degree of image standardization, making it easier for algorithms to process[37]; 3) DR screening is highly cost-effective and can reduce healthcare costs[38]. Subsequently, keywords such as age-related macular degeneration and macular edema saw a significant increase. From 2023 to the present, pathological myopia (PM) has become the most active keyword, suggesting that the range of diseases under study is gradually expanding.

It is particularly noteworthy that PM is currently the most frequently occurring keyword, indicating that PM has attracted substantial research interest in the ophthalmic AI community and warrants further investigation. As the terminal stage of high myopia, PM is characterized by progressive axial lengthening and degeneration of the posterior pole tissues. It can lead to irreversible retinal pathologies such as posterior scleral staphyloma and choroidal neovascularization, and has become the leading cause of irreversible blindness among young- and middle-aged adults worldwide[39]. Studies indicate that by 2050, the global prevalence of high myopia will reach 9.8%, and the number of people with PM-related visual impairment will exceed 50 million, representing a significant disease burden. This provides a solid context for AI research on PM[40]. AI technology has demonstrated exceptional performance in PM screening, diagnosis, staging, classification, and progression prediction; for example, deep learning models based on color fundus photography generally achieve an area under the curve (AUC) of 95%–99% for PM diagnosis[41]. However, compared to DR, AI research on PM suffers from insufficient external validation and a lack of multimodal fusion, and remains in its early stages[42]. It is evident that there is still significant room for advancement in AI research on PM.

In terms of search volume, keywords such as "segmentation", "retinal images", "extraction", "algorithms", and "automatic detection" showed high search volumes. This may be related to early research, suggesting that early AI research in ophthalmology focused primarily on methodological and technological changes and breakthroughs, rather than solely on the diseases themselves. After 2019, the emergence of keywords such as "deep learning" and "convolutional neural networks" reflected a shift in AI technology: a transition from traditional machine learning to deep learning. Furthermore, the keyword emergence map as a whole reveals that ophthalmic AI is an interdisciplinary field that utilizes deep learning algorithms to analyze ophthalmic imaging data, thereby enabling disease screening, diagnosis, and prevention[3].

Analysis of High-Impact Papers The results of the top 10 most-cited papers show that 6 of the top 10 focus on DR, suggesting that early AI research in ophthalmology concentrated on this condition. Furthermore, 5 of the 10

papers validated the clinical performance of AI models or systems, emphasizing their sensitivity and specificity. This indicates that most researchers prioritize the application level and are committed to improving clinical performance and enhancing generalizability. Furthermore, citation counts reveal that papers examining AI clinical performance are cited far more frequently than those focusing solely on AI methodological innovations, suggesting that applied research addressing clinical problems has garnered broader academic attention. However, high-impact papers also have certain limitations, primarily: 1) Poor generalizability: Factors such as small sample sizes or limited image diversity can impair generalizability; 2) Lack of interpretability: AI algorithms such as deep learning suffer from "black-box" issues and lack interpretability, which is one of the major challenges in ophthalmic AI research; 3) Reference standard bias: The reference standards for algorithms are based on ophthalmologists' judgments rather than histopathological gold standards, which lacks objectivity and leads to a certain degree of bias in the results. Moreover, generalizability is further compromised by ethnic bias in training datasets, as most fundus image databases are derived from Caucasian populations, while Asian and African populations exhibit different pigmentation and choroidal thicknesses. On the other hand, some AI systems (*e.g.*, IDx-DR) have obtained regulatory approvals [Food and Drug Administration (FDA)/ European Conformity (CE)/ National Medical Products Administration (NMPA)], demonstrating that high-impact research is gradually translating into clinical deployment.

Limitations of the Study This study has several limitations. First, our reliance on the WoSCC as the sole data source may introduce selection and language bias, as WoSCC predominantly indexes English-language journals from North America and Europe. Consequently, non-English studies—particularly from Asia—may be underrepresented, which could affect the generalizability of our findings. Second, restricting the search to articles and reviews excluded other document types such as conference proceedings and case reports, potentially omitting timely preliminary findings. Third, the parameter settings in CiteSpace (*e.g.*, time-slice length, co-occurrence thresholds) are known to influence clustering outcomes. While we followed established practices, alternative parameter choices might yield slightly different results; our findings should therefore be interpreted as indicative rather than definitive.

Based on the WoSCC database, this study conducted a systematic bibliometric analysis of 5798 papers published between 2016 and 2025 on the application of artificial intelligence in ophthalmology. The results revealed that global AI research in ophthalmology is showing a sustained growth trend, with China, USA, and India ranking as the top three countries in terms of publication volume. Institutions such as University College London and Sun Yat-sen University are the leading research forces in this field, while researchers including Schmidt-Erfurth U, Bogunovic H, Yang WH, and Wong TY lead in publication output. Research focus is highly concentrated on the automated screening and diagnosis of DR, with image segmentation, deep learning, and retinal image analysis remaining consistently active technical keywords; an analysis of high-impact papers further confirms that DR screening is currently the application scenario with the highest consensus and greatest influence, yet algorithmic interpretability and real-world generalization remain the primary challenges facing the field. This study provides quantitative evidence for understanding the development trends of ophthalmic AI. In the future, as new technologies such as multimodal data fusion and large language models mature, ophthalmic AI is expected to evolve from the screening of single eye diseases to the prediction and screening of systemic diseases; simultaneously, the cultivation of interdisciplinary talent and breakthroughs in explainable algorithms will be key drivers of progress in this field. Notably, our bibliometric findings also capture an emerging "out-of-eye" trend, in which retinal imaging is increasingly studied for predicting systemic conditions such as cardiovascular disease and chronic kidney disease. This shift, supported by the growing volume of relevant publications and interdisciplinary collaborations, suggests that ophthalmic AI is evolving from a single-disease screening tool toward a broader systemic biomarker platform.

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