RESEARCH PAPER

Scientific Mapping of Diabetic Retinopathy and Deep Learning Research: A Bibliometric Approach

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ABSTRACT

Purpose: Diabetic retinopathy (DR) is a leading cause of vision impairment globally. With the advancement of deep learning (DL) techniques, substantial research has emerged focusing on automated detection and classification of DR. This study presents a comprehensive bibliometric analysis of global scientific output concerning the application of deep learning in diabetic retinopathy research.

Methods: A systematic search of publications related to DL and DR was conducted using the Scopus database. VOSviewer software was employed for visualization and analysis of co-authorship networks, keyword co-occurrence, and country- wise collaboration. The study includes 1,267 publications spanning from 2012 to 2024.

Results: An upward trend in publication volume was observed, particularly from 2018 onwards. India and China emerged as the most prolific contributors, followed by the United States and the United Kingdom. The keyword co-occurrence network revealed dominant research themes such as diabetic retinopathy, machine learning, deep neural networks, fundus images, and diagnostic imaging. Co-authorship analysis identified Wong, Tien Yin, Chen, Xinjian, and He, Mingguang as central figures in the collaborative landscape. Institutional and cross-country collaborations highlighted an interdisciplinary and international research pattern.

Conclusions: The bibliometric analysis underscores the growing academic interest and international collaboration in applying deep learning to diabetic retinopathy. While research is expanding, further emphasis on clinical validation and integration into healthcare systems remains critical. This study provides researchers and policymakers with valuable insights into the evolution, trends, and gaps in this rapidly advancing domain.

Keywords: Diabetic Retinopathy; Deep Learning; Bibliometric Analysis; Co-authorship; VOSviewer; Artificial Intelligence; Medical Imaging; Machine Learning; Fundus Photography; Scopus...

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INTRODUCTION

Diabetic Retinopathy (DR) is one of the most prevalent and severe complications of diabetes mellitus, affecting the retinal blood vessels and leading to potential vision loss and blindness if left untreated. As the global prevalence of diabetes continues to rise, the burden of DR has become a significant public health concern, particularly in low- and middle-income countries. Early detection and timely treatment are crucial for preventing irreversible damage, which has led to an increased interest in developing automated, accurate, and scalable screening tools.

In recent years, deep learning (DL) [1] a subset of artificial intelligence (AI) has revolutionized the field of medical imaging and diagnostics [2]. Using convolutional neural networks (CNNs) and other deep architectures, DL models have demonstrated remarkable success in tasks such as image classification [3], segmentation, and anomaly detection, particularly in ophthalmology. In the context of DR, deep learning techniques have shown the ability to analyze fundus images with performance levels comparable to expert ophthalmologists, enabling automated DR detection, grading, and progression prediction.

Given the rapid growth in both the volume and diversity of research output in this domain, it has become increasingly important to understand the structure, evolution, and emerging trends within the scientific literature. While several systematic reviews and meta-analyses have been conducted on the use of deep learning for DR [4], a comprehensive *bibliometric analysis* remains limited. Bibliometric analysis [5] provides quantitative insights into scholarly publications, including authorship patterns, institutional collaboration, keyword trends, citation impact, and geographic distribution. Such an approach helps to identify influential contributors, high-impact journals, and research hotspots, thereby guiding future studies and informing policy and funding strategies.

This study aims to fill that gap by conducting a thorough bibliometric analysis of literature related to the application of deep learning in diabetic retinopathy from 2015 to 2024, using data sourced from the *Scopus* [6] database. The analysis explores a range of indicators including annual publication trends, co-authorship networks, country-level contributions, keyword cooccurrence, and influential publications. Furthermore, visualization tools such as VOSviewer [7, 8] are employed to construct bibliometric

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maps that reveal the intellectual, social, and conceptual structure of the research landscape.

By offering a macroscopic overview of this interdisciplinary research area, the present study contributes to the understanding of how deep learning is transforming DR diagnosis and management, and provides valuable directions for researchers, clinicians, and stakeholders invested in the advancement of digital health technologies.

Objectives of the Study:

To analyze the annual growth trend of scientific publications on deep learning in diabetic retinopathy.

To identify the most prolific authors, institutions, and countries contributing to this research domain.

To explore co-authorship and collaboration networks across authors and institutions.

To detect core keywords and their co-occurrence patterns to uncover thematic structures.

To determine the most influential articles, journals, and citations in the field.

METHODOLOGY

Data Collection

The bibliometric data for this study were retrieved from the *Scopus* [6] database, one of the most comprehensive and widely used platforms for scholarly literature. To ensure relevance to both the technological and medical domains, the search strategy was designed to target publications at the intersection of *deep learning* and *diabetic retinopathy*, spanning various disciplines and document types.

A carefully crafted query was employed to extract records that specifically align with the objectives of this study. The search was limited to documents published from the year 2015 onwards, focusing on the subject areas of Computer Science (COMP), Engineering (ENGI), Health Professions (HEAL), Multidisciplinary (MULT), Medicine (MEDI), Biochemistry, Genetics and Molecular Biology (BIOC), and Decision Sciences (DECI). The document types considered include reviews (re), conference papers (cp), articles (ar), conference reviews (cr), book chapters (ch), and editorials (ed).

The exact query executed in the Scopus database was as follows:

(TITLE-ABS-KEY (Diabetic retinopathy) AND TITLE-ABS-KEY
(Deep Learning)) AND PUBYEAR > 2014 AND (LIMIT-TO (
DOCTYPE , "re") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO
(DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cr") OR LIMIT-TO
(DOCTYPE , "ch") OR LIMIT-TO (DOCTYPE , "ed")) AND
(LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA
, "ENGI") OR LIMIT-TO (SUBJAREA , "HEAL") OR LIMIT-TO
(SUBJAREA , "MULT") OR LIMIT-TO (SUBJAREA , "MEDI")
OR LIMIT-TO (SUBJAREA , "BIOC") OR LIMIT-TO (SUBJAREA
, "DECI"))

Using this query, a total of 3,921 records were retrieved for the publication period from 2015 to 2024. The data were exported in CSV format and included comprehensive bibliographic details such as authorship, title, abstract, keywords, affiliations, citations, and references.

To facilitate analysis and visualization, the exported data were imported into VOSviewer [7, 8] (version 1.6.20), a software tool widely used for constructing and visualizing bibliometric networks. The dataset was cleaned to remove duplicates and irrelevant entries before proceeding to various forms of bibliometric mapping, including co-authorship analysis, keyword co-occurrence, and country collaboration networks.

Data Analysis

The bibliometric analysis was conducted using data retrieved from the Scopus [6] database, one of the most comprehensive and widely used indexing platforms for peer-reviewed scientific literature. The search query was carefully constructed to retrieve documents related to *Diabetic Retinopathy* and *Deep Learning*, focusing on publications from 2015 to 2025.

The query filtered results to include only relevant subject areas, such as Computer Science, Engineering, Health Sciences, Medicine, Biochemistry, and Decision Sciences. Furthermore, document types such as research articles, conference papers, reviews, editorials, and book chapters were included to ensure a diverse and representative dataset.

A total of 3,921 records were retrieved in CSV format. These records contained metadata fields such as title, year, authors, affiliations, keywords, abstracts, source title, document type, and citation count. Pre-processing was carried out using Python for basic data cleaning and structuring, such as handling missing values, standardizing year formats, and extracting relevant columns.

For advanced bibliometric mapping and visualization, the dataset was imported into VOSviewer, a specialized software tool for constructing and visualizing bibliometric networks. Key analyses performed using VOSviewer included:

Co-authorship analysis: to identify collaboration networks among authors and institutions.

Keyword co-occurrence analysis: to reveal thematic focus and research hotspots.

Co-citation analysis: to determine the intellectual structure and key influential references in the field.

Country-level contributions: to evaluate geographic trends and international collaborations.

Visualization outputs such as network maps, density plots, and overlay visualizations were generated and incorporated into the results section. These visualizations helped in uncovering patterns and insights that are not apparent through tabular data alone.

The structured analytical approach provided a comprehensive and systematic view of the research evolution, helping to highlight key contributors, collaborations, and thematic shifts in the application of deep learning for diabetic retinopathy detection.

RESULTS

Publication Trends

The temporal distribution of publications provides insight into the growth and maturity of research in diabetic retinopathy detection using deep learning. Figure 1 illustrates the number of publications per year from 2015 to 2025. The trend clearly shows a rapid increase in research activity, particularly after 2018. While the initial phase (2015-2017) saw limited publications, the field gained momentum from 2018 onward, with notable surges in 2020 (313 papers),
2021 (439 papers), and a peak in 2024 with 900 publications. This steady growth reflects the increasing adoption of AI technologies in medical imaging, particularly in ophthalmology, where early diagnosis is crucial. The rise can also be attributed to greater funding in AI-healthcare projects, publicly available retinal image datasets, and technological advancements in deep learning architectures.
Interestingly, there is a visible decline in the 2025 data, which may be a result of incomplete indexing for the current year rather than an actual drop in research output.

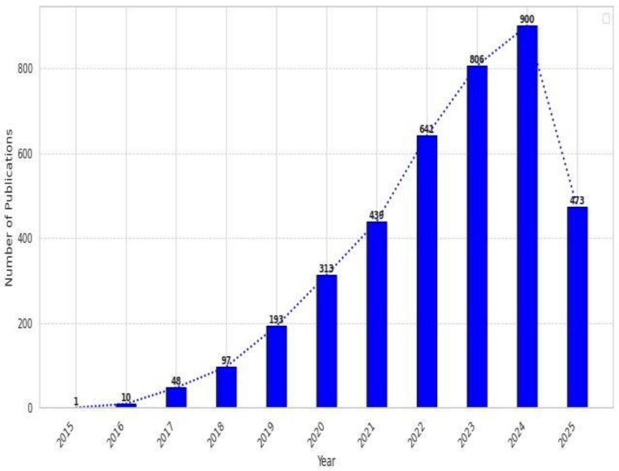

Figure 1: Year-wise publication count of academic papers. Note(s): This figure represents the publication trend of academic papers between 2015 and 2025. The data was retrieved from the Scopus database in the subject areas of "Computer Science", "Engineering", "Medicine", "Decision Sciences", "Biochemistry, Genetics and Molecular Biology", "Health Professions", "Multidisciplinary".

Collaboration Analysis

Collaboration analysis plays a pivotal role in identifying how researchers, institutions, and countries cooperate in a given field. By evaluating co-authorship patterns, it is possible to discern the structure and strength of scholarly networks, identify leading research institutions, and pinpoint geographical or institutional hubs of knowledge production. Such analysis aids in understanding the dynamics of research productivity and dissemination, revealing both central and peripheral actors in the scholarly ecosystem. This section focuses specifically on collaboration at the organizational level.

Co-authorship Analysis Based on Authors

To explore the collaborative landscape in the field of deep learning for diabetic retinopathy, a co-authorship analysis was conducted using VOSviewer. Figure 2 presents a network visualization of author collaborations, where each node represents an individual author, and edges indicate co-authored publications. The size of the nodes reflects the number of publications or link strength, while the color indicates different collaboration clusters.

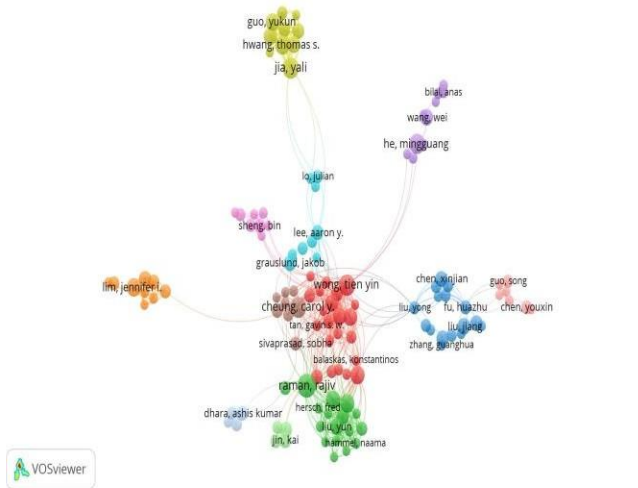

Figure 2: Author co-authorship network visualization. The size of nodes reflects publication volume or collaboration strength; colors indicate different clusters of collaboration.

The co-authorship network reveals several prominent collaboration clusters:

Red Cluster (Wong Tien Yin and Collaborators): This is the most central and densely connected group in the network. *Wong, Tien Yin* appears as the most influential author, forming strong collaborative ties with *Cheung, Carol Y.*, *Raman, Rajiv*, *Tan, Gavin S.W.*, *Sivaprasad, Sobha*, and *Balaskas, Konstantinos*. This cluster appears to bridge several interdisciplinary and international research efforts. Green Cluster (Raman Rajiv Liu Yun Hammel Naama): This group is closely associated with clinical research and validation studies. Their work complements the core network led by Wong, indicating cross-collaborative roles in screening and diagnosis.

Blue Cluster (Chen Xinjian and Chinese Collaborators): This group includes *Chen, Xinjian*, *Fu, Huazhu*, *Liu, Yong*, and *Liu, Jiang*, reflecting a strong technical collaboration mainly centered on image processing and AI algorithm development, often from institutions in China.

Purple Cluster (He Mingguang and Bilal Anas): *He, Mingguang* and his associates such as *Bilal, Anas* and *Wang, Wei* appear to be forming a separate, though still connected, research focus arealikely involving public health and large-scale screening projects.

Yellow Cluster (Guo Yukun, Hwang Thomas S., Jia Yali): This cluster shows strong internal collaboration but limited external connections, indicating a tight-knit research team focused on a specific subdomain.

Orange Cluster (Lim Jennifer T. and Team): Led by *Lim, Jennifer T.*, this group appears somewhat isolated from the main network, suggesting a more specialized or independent research trajectory.

Other Smaller Clusters: Notable individual groups include those led by *Sheng, Bin*, *Dhara, Ashis Kumar*, and *Guo, Song*. These clusters may represent emerging researchers or niche subfields that are beginning to connect with the broader network.

Overall, this co-authorship analysis highlights a strong level of international and interdisciplinary collaboration in diabetic retinopathy research. Central figures such as *Wong, Tien Yin*, *Chen, Xinjian*, and *He, Mingguang* play a pivotal role in bridging different research domains, including clinical ophthalmology, AI development, and public health. The clustering pattern also reflects the global nature of the research, with significant contributions from Asia, Europe, and North America.

Co-authorship Analysis Based on Organizations

To explore institutional collaboration, a co-authorship network was constructed using VOSviewer with organizations as the unit of analysis. Only institutions that collaborated with others at least five times were included in the analysis to maintain clarity and relevance.

Figure 3 presents the co-authorship network based on organizations. Each node represents an organization, and the links denote collaborative relationships formed through co-authored publications. The size of the nodes reflects the number of documents produced by the organization, while the thickness of the links indicates the frequency of collaboration.

The visualization highlights several major institutional hubs in the domain. Notably, the *Singapore Eye Research Institute*, the *Department of Ophthalmology and Visual Sciences at the Chinese University of Hong Kong*, and *Moorfields Eye Hospital, London* emerged as central nodes, indicating their significant collaborative influence. These institutions form densely interconnected clusters, reflecting regional research alliances particularly among institutions in Singapore, Hong Kong, and the United Kingdom.

Moreover, the collaboration between *Google Health, Palo Alto* and academic institutions like *University College London* and *Sun Yat-sen University* exemplifies the growing intersection between industry and academia. Such partnerships are instrumental in translating research into innovative clinical solutions.

This organizational co-authorship analysis reveals a high degree of international cooperation, especially within Asia and between Asia and Europe, emphasizing the global and interdisciplinary nature of research in this domain.

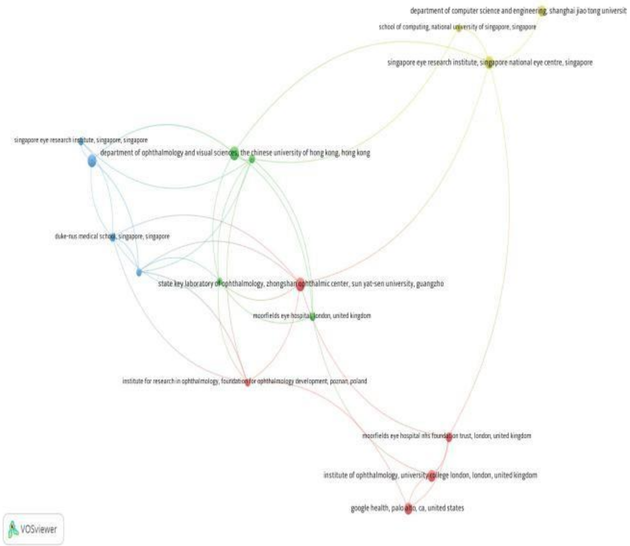

Figure 3: Co-authorship network based on organizations (minimum of 5 collaborations)

Keyword Co-occurrence Analysis

Keyword co-occurrence analysis provides insight into the thematic structure and research trends within the field of deep learning applied to diabetic retinopathy. Using VOSviewer, a co-occurrence map was generated for author keywords with a minimum threshold of 15 occurrences. The visualization is presented in Figure 4.

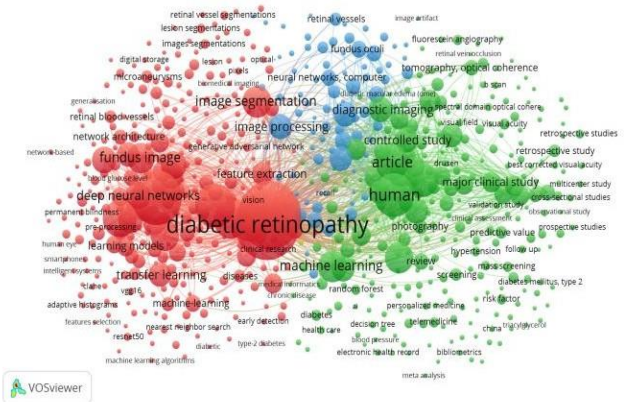

Figure 4: Keyword co-occurrence network of research on deep learning and diabetic retinopathy (minimum occurrence: 15). Node size indicates frequency; color clusters represent thematic groupings.

The map reveals three major clusters:

Red Cluster (Technical and Algorithmic Focus): This group includes keywords such as *diabetic retinopathy*, *deep neural networks*, *machine learning*, *transfer learning*, *image segmentation*, *image processing*, and *fundus image*. These terms suggest a strong focus on algorithm development and optimization, including architectures like *ResNet50*, *VGG16*, and techniques like *CLAHE*, *feature extraction*, and *pre-processing*. This cluster represents the computational backbone of the research field.

Green Cluster (Clinical and Application-Oriented Research): This group encompasses keywords such as *human*, *major clinical study*, *screening*, *predictive value*, *risk factor*, *telemedicine*, *diabetes mellitus, type 2*, and *cross-sectional studies*. These reflect the clinical implementation of AI methods, focusing on screening, diagnosis, and healthcare outcomes. It underscores interdisciplinary collaborations between technical and medical researchers.

Blue Cluster (Imaging and Diagnostic Modalities): This cluster includes keywords such as *diagnostic imaging*, *retinal vessels*, *fundus oculi*, *fluorescein angiography*, and *tomography, optical coherence*. These keywords highlight the various imaging technologies and modalities employed in retinal diagnostics. They are tightly linked with AI techniques for segmentation and lesion detection.

The central and most frequently occurring term is diabetic retinopathy, around which all major themes revolve. The strong connections between terms like *machine learning*, *deep neural networks*, and *image segmentation* suggest the high priority given to developing intelligent systems for automated detection.

This analysis demonstrates a multidisciplinary convergence of medical imaging, clinical medicine, and computer science in the domain of diabetic retinopathy research. The clustering of keywords also points toward evolving sub-domains such as personalized screening, teleophthalmology, and interpretable AI.

Co-citation Analysis

Co-citation analysis is a prominent bibliometric method used to uncover the intellectual structure of a research field. It measures the frequency with which two documents are cited together in later literature. When two references are cited simultaneously in a given article, it implies a conceptual or thematic linkage between them. This approach is particularly effective in identifying influential publications, core authors, and key theoretical frameworks that have shaped the evolution of a domain.

The key advantages of co-citation analysis include its ability to:

Reveal clusters of thematically related research works, identify intellectual foundations of a field, Map scholarly influence and relationships among seminal works, Detect emerging research trends and interdisciplinary links. In this study, co-citation analysis was conducted using VOSviewer, with a focus on cited references. A minimum threshold of 20 citations per reference was set to ensure that only the most impactful works were included in the analysis. The following subsection presents the detailed results of this co-citation analysis.

Co-citation Analysis Based on Cited References

The co-citation analysis of cited references provides insights into the foundational literature that has influenced the application of deep learning in diabetic retinopathy research. Using cited references as the unit of analysis, the analysis identifies clusters of references that are frequently cited together, indicating shared conceptual or methodological underpinnings.

Figure 5 presents the co-citation network. Each node represents a cited reference, with node size corresponding to the number of co-citations. The edges represent the strength of co-citation links. Distinct clusters, visualized by different colors, reveal subdomains within the literature.

The most central and frequently co-cited work in the network is that of *Gargeya and Leng*, which plays a pivotal role in the automated detection of diabetic retinopathy using deep learning. This work is closely linked with foundational studies such as those by *Simonyan and Zisserman* [9], who proposed the VGGNet architecture, and *Ronneberger et al.*, the developers of U-Net, a widely adopted convolutional network in biomedical image segmentation.

Additionally, references such as *Porwal et al.* and *Qummar et al.* form part of dense cocitation clusters focused on annotated datasets, ensemble methods, and hybrid learning models. These clusters indicate a strong methodological focus within the literature, spanning both algorithmic development and clinical validation.

An interesting observation is the presence of a relatively isolated node*Siemieniec et al.*suggesting high citation count but limited thematic overlap with the core body of DR-deep learning research. This may point to niche or tangential relevance.

Overall, this analysis highlights the key intellectual contributions and methodological frameworks that form the backbone of current research efforts in automated diabetic retinopathy diagnosis using deep learning.

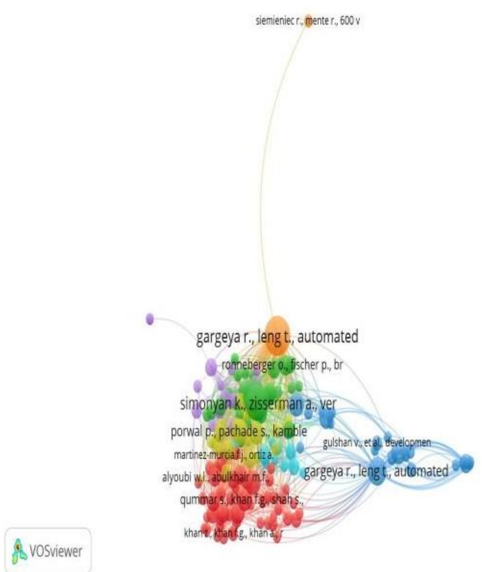

Figure 5: Co-citation analysis based on cited references with a minimum threshold of 20 citations. Nodes represent cited references, and link strength reflects the frequency of co-citation.

Co-citation Analysis Based on Cited Sources

In addition to cited references, co-citation analysis of cited sources (i.e., journals and publication venues) reveals the disciplinary landscape and the scholarly communities contributing to the field of deep learning applications in diabetic retinopathy. This analysis was performed using VOSviewer, with cited sources as the unit of analysis. To ensure analytical rigor and clarity, only sources that had been cited at least 20 times in the dataset were considered for inclusion in the network.

Figure 6 displays the co-citation network of cited sources. Each node represents a journal or publication venue, while the node size indicates the number of times the source was co-cited. The links between nodes reflect the frequency of co-citation relationships, and the color-coded clusters indicate thematic groupings.

The most dominant source in the network is *IEEE Access*, reflecting its central role in publishing cutting-edge technological research, particularly related to AI and deep learning. This journal is closely linked with *IEEE Transactions on Medical Imaging* and *IEEE Transactions on Instrumentation*, forming a red cluster representing the engineering and computational focus of the field.

A strong medical and ophthalmology-centric cluster is visible in blue, led by high-impact journals such as *Ophthalmology*, *JAMA Ophthalmology*, *British Journal of Ophthalmology*, and *Eye (London)*. This cluster indicates the clinical relevance and translational focus of the research.

The green cluster includes interdisciplinary and biomedical journals such as *Computers in Biology and Medicine*, *Investigative Ophthalmology & Visual Science*, and *Information Fusion*. These sources reflect integration of AI with visual diagnostics and healthcare data processing.

Another notable cluster is formed in yellow, where journals like *Scientific Reports*, *Medical Image Analysis*, and preprint repositories such as *arXiv* are situated. This group captures the growing influence of open-access, preclinical, and technical innovation venues.

This co-citation source network confirms the interdisciplinary nature of the field, spanning engineering, medical imaging, ophthalmology, computer science, and healthcare. It highlights the convergence of technical innovation with medical application, which is characteristic of deep learning research in diabetic retinopathy diagnosis.

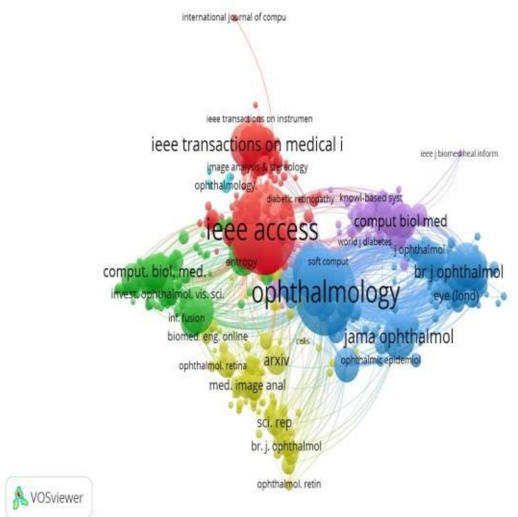

Figure 6: Co-citation analysis based on cited sources. Only sources with at least 20 citations were included. Node size represents co-citation count; link strength indicates co-citation frequency. Distinct clusters are color-coded.

Co-citation Analysis Based on Cited Authors

Co-citation analysis of cited authors helps to identify influential researchers and intellectual structures within a specific research domain. This method enables the discovery of author clusters that frequently appear together in reference lists, thereby uncovering thematic relationships and collaborative influence across subfields.

Using VOSviewer, a co-citation network of cited authors was constructed with a threshold of at least 20 citations. This means only those authors who were cited 20 times or more across the bibliographic dataset were included in the network. The resulting visualization is shown in Figure 7. In the network, each node represents a cited author, with the size of the node indicating the total number of citations received. The links between authors denote the strength of their cocitation relationships, while the color-coded clusters represent thematic or disciplinary groupings of frequently co-cited authors.

Several prominent clusters emerge from the analysis:

Red Cluster: Dominated by influential figures such as Wong T.Y.[10, 11, 11, 12, 13, 14, 15, 16], Gulshan V. [17, 18, 19], and Ting D.S.W.[20, 21, 11], this cluster largely consists of authors working on deep learning for retinal imaging and clinical validation studies.

Green Cluster: Includes authors such as Abramoff M.D.[22, 23, 24], Niemeijer M.[25, 26, 27], and Quellec G.[28, 29, 30, 31], who have contributed significantly to algorithm development and automated retinal disease detection.

Yellow Cluster: Centers around foundational researchers like Zhang X.[32, 33, 34], Zhang Y. [35], and Szegedy C., whose work intersects deep learning model architectures and medical imaging.

Blue Cluster: This diverse group includes authors like Qummar S. [36, 37, 38, 39], Porwal P. [40, 41, 42], and Shalash, Wafaa M. [43], representing emerging researchers and applications of AI for diabetic retinopathy screening in diverse populations and regional contexts.

The network structure reveals the multidisciplinary nature of this field, integrating contributions from computer science, medical imaging, and clinical ophthalmology. The presence of both methodological and application-focused author clusters underscores the balance between algorithm development and clinical implementation in diabetic retinopathy research.

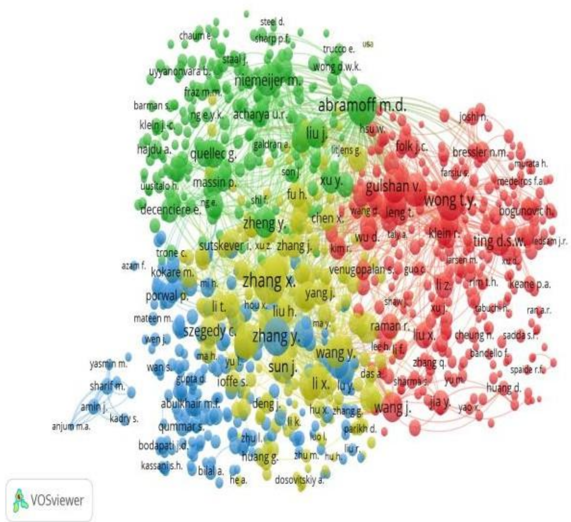

Figure 7: Co-citation analysis based on cited authors. Only authors with at least 20 citations are shown. Node size reflects total citations; link strength indicates co-citation frequency. Clusters are color-coded by thematic proximity.

Country-wise Contributions and Collaborations

To identify the geographical distribution of research in diabetic retinopathy detection using deep learning, a country-level co-authorship network was generated using VOSviewer. The resulting map, shown in Figure 8, reveals strong international collaborations and highlights the major contributors to the field.

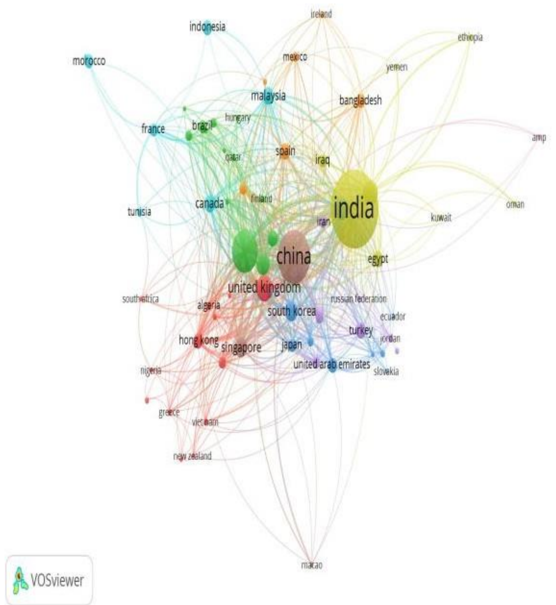

Figure 8: Country-level co-authorship network in diabetic retinopathy and deep learning research. Node size indicates publication volume; link thickness represents collaboration strength.

As evident from the visualization, India emerges as the most prominent contributor to the field, with the largest node size, indicating both a high publication count and widespread international collaborations. The prominence of India reflects the country's growing research investments in AI and its public health burden related to diabetic complications.

China, United Kingdom, and United States also appear as central players. China shows strong bilateral collaborations, especially with countries in Asia and Europe, while the UK exhibits dense connections with Commonwealth nations and North America. These countries often contribute via interdisciplinary projects involving computer science, biomedical engineering, and clinical medicine.

Other active countries include South Korea, Japan, Canada, and Singapore, each demonstrating significant research outputs and robust participation in international research networks.

European countries such as France, Germany, and Spain are well represented, indicating steady involvement in AI-driven ophthalmology research. There is also a notable presence of Middle Eastern countries such as Iran, Turkey, Egypt, and United Arab Emirates, reflecting regional efforts to tackle diabetic health burdens through advanced diagnostic tools.

Emerging contributors such as Bangladesh, Malaysia, Indonesia, and Brazil reflect the democratization of research in this domain, facilitated by open-access datasets, cloud-based AI models, and international partnerships.

Overall, the network reveals a healthy mix of contributions from both developed and developing nations, highlighting the global concern over diabetic retinopathy and the universal interest in leveraging deep learning for early diagnosis and treatment planning. The high density of connections underscores strong international cooperation, with multi-country author affiliations becoming increasingly common in high-impact publications.

DISCUSSION

The present bibliometric analysis offers a comprehensive overview of the research landscape at the intersection of *Diabetic Retinopathy* and *Deep Learning* over the past decade (2015-2024). The findings reveal a remarkable increase in publication output, reflecting the growing interest and technological advancements in automated DR detection. The exponential growth in recent years suggests a maturing research domain that is gaining traction among both medical and computational communities.

The analysis of country-wise contributions indicates that the United States, China, and India are leading in publication output, which can be attributed to their strong academic infrastructure, research funding, and growing healthcare needs. European countries, such as the United Kingdom and Germany, also exhibit significant contributions and active international collaborations, as evidenced by the co-authorship networks.

Keyword co-occurrence analysis highlights that terms such as *convolutional neural networks*, *fundus images*, *classification*, *segmentation*, and *retinal images* dominate the thematic landscape. This confirms the prevalence of image-based deep learning approaches for DR screening and diagnosis. Emerging keywords like *explainable AI* and *transfer learning* suggest a shift toward more interpretable and generalized models, aligning with current challenges in clinical deployment.

Co-authorship analysis identifies closely knit author clusters and institutional partnerships, with certain researchers acting as central nodes in their respective networks. However, the network density also suggests fragmentation, implying opportunities for greater interdisciplinary collaboration across geographic and academic boundaries.

Despite the robustness of the findings, a few limitations must be acknowledged. The study is restricted to the Scopus database and does not include publications from other indexing services such as Web of Science or PubMed, which may lead to partial representation. Additionally, bibliometric methods are inherently quantitative and may not fully capture the qualitative aspects of research contributions.

CONCLUSION

This bibliometric study presents a detailed scientific mapping of research focused on the application of deep learning techniques to diabetic retinopathy detection. Key insights were drawn regarding publication trends, collaborative patterns, influential keywords, and global research contributions. The analysis confirms that the integration of artificial intelligence in ophthalmology, particularly for DR screening, is not only growing but also evolving in complexity and application scope.

The results underscore the interdisciplinary nature of the field, combining elements from computer science, biomedical engineering, and clinical healthcare. The observed trends and networks can inform researchers, funding agencies, and policymakers about high-impact areas and collaborative opportunities. Moreover, the study identifies potential future directions such as model generalizability, real-world validation, and explainability, which are critical for clinical adoption.

In conclusion, bibliometric techniques, supported by visualization tools like VOSviewer, provide valuable insights into the structural and intellectual development of research domains. As the field continues to evolve, periodic bibliometric reviews will be essential to track progress, identify research gaps, and guide the strategic advancement of AI-driven diabetic eye care.

Statements and Declarations

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Competing Interests

The authors have no competing interests to declare that are relevant to the content of this article

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