

Publication Trends in Corneal Neovascularization: A Bibliometric and Visualized Analysis

Korneal Neovaskülerizasyon Yayın Eğilimleri: Bibliometrik ve Görselleştirilmiş Analiz

Nejat ÜNLÜKAL¹  Serhat EKER²  Hakan SERİN³  Ender ERDOĞAN¹ 

Öz

Amaç: Mekanik yaralanma, kimyasal yanıklar, inflamasyon ve/veya limbal kök hücre eksikliği kornea neovaskülerizasyonuna (KNV) neden olabilir. Bu çalışmada KNV'deki bilgi kapsamını, odaklanılan konuları ve ortaya çıkan araştırmalardaki eğilimleri göstermeyi amaçladık.

Araçlar ve Yöntem: Ocak 1980 ile Mart 2024 arasında Web of Science Core Collection'da yayımlanan tüm KNV araştırma makaleleri, editöre mektuplar, vaka raporları, incelemeler ve bildiriler değerlendirildi. Elde edilen literatür çalışmaları, R sürüm 4.2.3'teki "bibliometrix" paketi ile toplandı ve analiz edildi. Referansların eş atfı analizi ve anahtar kelimelerin eş oluşum analizi kullanılarak temel ve önemli noktalar belirlendi ve böylece bu alan hakkında genel bir bakış elde edildi.

Bulgular: Toplamda 1439 adet KNV hakkında makale toplandı, bunların çoğu Amerika Birleşik Devletleri ve Çin'de yayınlandı. En fazla makale yayımlayan kuruluş Harvard Üniversitesi olduğu görüldü. Cursiefen C ve Bock F KNV hakkında bildirileri olan en etkili yazarlardı. *Investigative Ophthalmology & Visual Science* en yüksek H-indeksine ve yayın sayısına sahip dergi olarak saptandı. En fazla yayını olan ikinci dergi *Cornea* oldu. Toplam KNV yayın sayısı 1980 yılından 2013 yılına ortalama atfı sayısı 26.72 idi. *Investigative Ophthalmology & Visual Science*, dergiler arasındaki toplam atfı sayısına göre listenin başında yer aldı (n=10505).

Sonuç: Mevcut çalışma, KNV araştırmalarının giderek akademisyenlerin ve araştırmacıların ilgisini çektiğini göstermektedir.

Anahtar Kelimeler: anjiyogenez; bibliyometri; kornea; korneal transplantasyon; küresel eğilimler

ABSTRACT

Purpose: Mechanical injury, alkali and acid injury of the cornea, inflammation and/or dysfunction of the corneal epithelial stem/progenitor cells can cause corneal neovascularization (CNV). We aimed to demonstrate the knowledge elements, focused topics, and recent interests in emerging research in CNV.

Materials and Methods: The CNV research documents, reviews, case reports and proceedings papers issued between January 1980 and March 2024 on the Web of Science Core Collection were gathered. The retrieved literature was collected and analyzed by the "bibliometrix" package in R version 4.2.3. Basic and important points were determined by using bibliographic coupling, co-citation and co-word analysis, thus obtaining a general overview of this field.

Results: A total of 1439 articles on CNV were achieved, most of which were featured in the United States and China. The institution that reported the most publications was the Harvard University. Cursiefen C and Bock F were the most dominant authors about CNV. The *Investigative Ophthalmology & Visual Science* had the highest H-index and most publications. The second journal with the most publications was *Cornea*. The overall number of CNV publications raised from the year 1980 to 2013. The mean citation count per CNV document was 26.72. *Investigative Ophthalmology & Visual Science* was the leading journal at the list based on the total number of citations (n=10505).

Conclusions: The current study shows that the research interest of CNV is progressively growing the attention of scholars and researchers.

Keywords: angiogenesis; bibliometrics; cornea; corneal transplantation; global trends

Received: 12.12.2024; Accepted: 23.04.2025

¹Department of Histology and Embryology, Faculty of Medicine, Selçuk University, Konya, Türkiye.

²Department of Ophthalmology, Isparta Yalvac State Hospital, Isparta, Türkiye.

³Department of Biostatistics, Faculty of Veterinary, Selçuk University, Konya, Türkiye.

Corresponding Author: Serhat Eker, Department of Ophthalmology, Isparta Yalvac State Hospital, Isparta, Türkiye. e-mail: drserhateker@gmail.com

How to cite: Unlukal N, Eker S, Serin H, Erdoğan E. Publication trends in corneal neovascularization: a bibliometric and visualized analysis. *Ahi Evran Med J.* 2025;9(2):251-258. DOI: 10.46332/aemj.1600606



INTRODUCTION

The healthy cornea, located on the anterior surface of the eye, is optically clear and contains no vascular structure. In normal physiology, the transparent cornea provides a refractive surface for vision and mechanical barrier against infections and structural damage. It consists of well-recognized⁵ anatomical layers (from anterior to posterior), (1) the corneal epithelium, (2) Bowman's layer, (3) the corneal stroma, (4) Descemet's membrane, and (5) the corneal endothelium.¹ Any defects occurring in these layers due to infections, dystrophies, autoimmune diseases, trauma, inflammation or congenital disorders might damage corneal transparency and clarity causing visual impairment.^{2,3} Mechanical injury, chemical exposure (varnish removers, dyes, acids, and alkali), inflammation and/or dysfunction of the corneal epithelial stem cells may induce corneal neovascularization (CNV) during the healing process.⁴ Nearly 1.4 million people are diagnosed with CNV each year, of whom 12% are thought to experience vision loss.⁵

CNV may compromise corneal clarity, leading to corneal edema, chronic inflammation, stromal deposits of protein and lipid, haze and scarring. The corneal transplantation is required for the treatment of a cornea that has lost its optical transparency in many cases.⁶ However, the prognosis and outcomes of corneal transplantation vary depending on the existing disease. Additionally, it has been previously reported that there is a powerful correlation between vascularization of the recipient cornea and a lower chance of corneal transplant success.⁷ Several studies have been designed for the management of CNV in the literature.⁸⁻¹⁰

Bibliometric study is a quantitative method used to evaluate academic literature, where citation status and content reviews are commonly investigated.¹¹ Academic publication patterns and the geographical and institutional distribution of articles in a particular field can be assessed by bibliometrics. Although there are numerous bibliometric studies in literature related to ophthalmology practice, the bibliometric study of CNV has not been reported. The present study explores the research elements, collaborations

and the current trends within the field of CNV. We aim to investigate the publication trends of CNV to date and present researchers with a general framework of the field in terms of citations, origins of the papers and journals. As far as we know, this study is the first bibliometric report on CNV.

MATERIALS and METHODS

Data Source and Research Process

The data source for this bibliometric analysis study was achieved from the Web of Science Core Collection (WoSCC). The literature search was completed on March 23, 2024, using the advanced search strategy. 3533 articles were found as a result of the search conducted between January 1, 1980, and March 23, 2024, using the term "corneal neovascularization". When the WoS category "Ophthalmology", document types "article", "review" or "early access" and language "English" were selected as inclusion criteria for the study, 1646 articles were reached. When the obtained articles were examined in terms of content, 207 studies were determined not to be related to CNV and were excluded. As a result, the dataset consists of 1439 articles. Basic information such as title, journal name, authors, country, institution, total number of citations, references, abstract and keywords and are included in the dataset for each article. The working procedure (workflow diagram) for the method of obtaining the data set is demonstrated in Figure 1.

For the analysis of bibliometric indicators, the "bibliometrix" package in R version 4.2.3 (R Foundation for Statistical Computing, Vienna, Austria) was used.¹² Data were exported from WoSCC in "bib text" format with the "Full record and cited references" option. The publications in the dataset were evaluated in terms of indicators such as the relevant year, country, institution, author and number of citations. Since no human or animal research was conducted, ethics committee approval is not required.

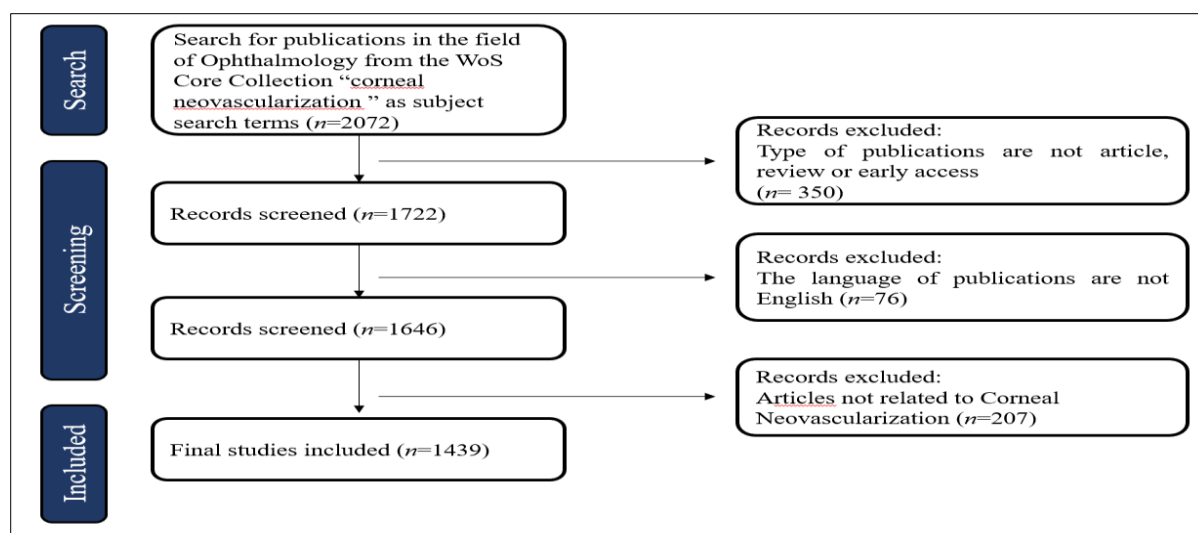


Figure 1. The process of obtaining the bibliometric dataset.

For the analysis of bibliometric indicators, the “bibliometrix” package in R version 4.2.3 (R Foundation for Statistical Computing, Vienna, Austria) was used.¹² Data were exported from WoSCC in “bib text” format with the “Full record and cited references” option. The publications in the dataset were evaluated in terms of indicators such as the relevant year, country, institution, author and number of citations. Since no human or animal research was conducted, ethics committee approval is not required.

Bibliometric Methodology

Bibliometrics has recently emerged as a popular method applied in various branches of science. Bibliometric analysis is an academic method used to examine large volumes of data in any large field. While this method shows the evolutionary development of a particular field, it also enables the identification of new research areas.¹³ Bibliometric analysis demonstrates these functions by applying quantitative methods (such as citation analysis) to bibliometric data (such as citation units). Bibliometric analysis enables large volumes of data to be analyzed objectively and evaluated subjectively. In addition, bibliometric analysis offers the opportunity to visually evaluate the relationship between bibliometric elements by mapping them.^{13,14}

RESULTS

A sum of 1439 articles were included in the current study. Table 1 shows the description of the articles with classifications. Original articles related to CNV were the most published document type. The overall growth rate during

this period was 5.81%. The number of citations per article was 26.72 and the total amount of references was 30747. The bibliometric data included 2902 keywords plus and 2421 author keywords. According to the author collaboration statistics, the total number of authors was 4960 and the single-authored studies were 31. The number of co-authors per report was 5.27 and the international co-authorship rate was 19.39%.

Table 1. Main descriptions.

Description	Results
Main Information About Data	
Timespan	1980:2024
Sources (Journals, Books, etc)	87
Documents	1439
Annual growth rate %	5.81
Document average age	13
Average citations per document	26.72
References	30747
Document Contents	
Keywords Plus (ID)	2902
Author's Keywords (DE)	2421
Authors	
Authors	4960
Authors of single-authored documents	31
Authors Collaboration	
Single-authored documents	31
Co-Authors per document	5.27
International co-authorships %	19.39
Document Types	
Article	1278
Article; Book Chapter	7
Article; early access	4
Article; proceedings paper	54
Review	96

The number of articles published by year is demonstrated in Figure 2. CNV articles were found to be doubled in the

year 2022 (n=53) when compared to the year 2001 (n=27). The cumulative number of CNV articles almost doubled in 2024 (n=1439) when compared to 2012 (n=734). From the year 1980 to 2013, the number of studies on CNV had increased gradually. After 2013, there had been a decrease in

the total. As a result, an increasing trend was observed in the total number of articles. It was determined that most articles were published in 2013, 84 publications.

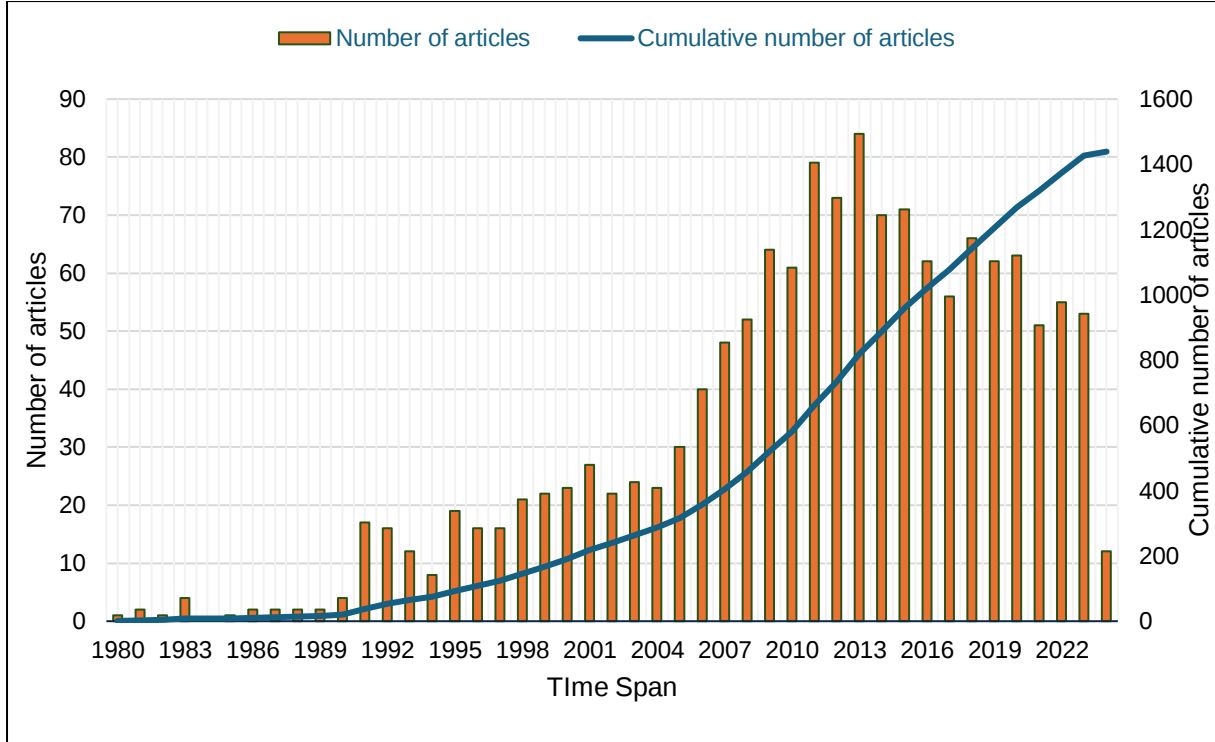


Figure 2. Annual publication outputs for CNV from 1980 to 2024.

The top 10 countries which reported most of the articles are given in Table 2 and the network between them is shown in Figure 3. The United States ranked first among countries according to the number of articles. Germany was on the top of the list according to the citation impact. The analysis of Multiple Country Publication (MCP) data showed that only one country, Germany, surpassed an

MCP rate of 30%. The two countries with the most single country publication data were the United States and China. Interestingly, nearly all publications from Turkey and Israel were conducted domestically.

Table 2. Ranking of the top 10 countries with the most publications in CNV research, during 1980-2024.

Country	TC	NP	CI	SCP	MCP	MCP Ratio
USA	13117	389	33.72	296	93	0.239
CHINA	3646	266	13.71	231	35	0.132
JAPAN	3415	115	29.70	92	23	0.2
GERMANY	3518	82	42.90	55	27	0.329
KOREA	1346	75	17.95	63	12	0.16
TURKEY	934	62	15.06	61	1	0.016
ISRAEL	860	36	23.89	35	1	0.028
UNITED KINGDOM	1097	34	32.26	25	9	0.265
ITALY	733	31	23.65	25	6	0.194
IRAN	744	29	25.66	26	3	0.103

TC = total citations, NP = number of publications, CI = citation impact, SCP = single country publication, MCP = multiple countries publication.

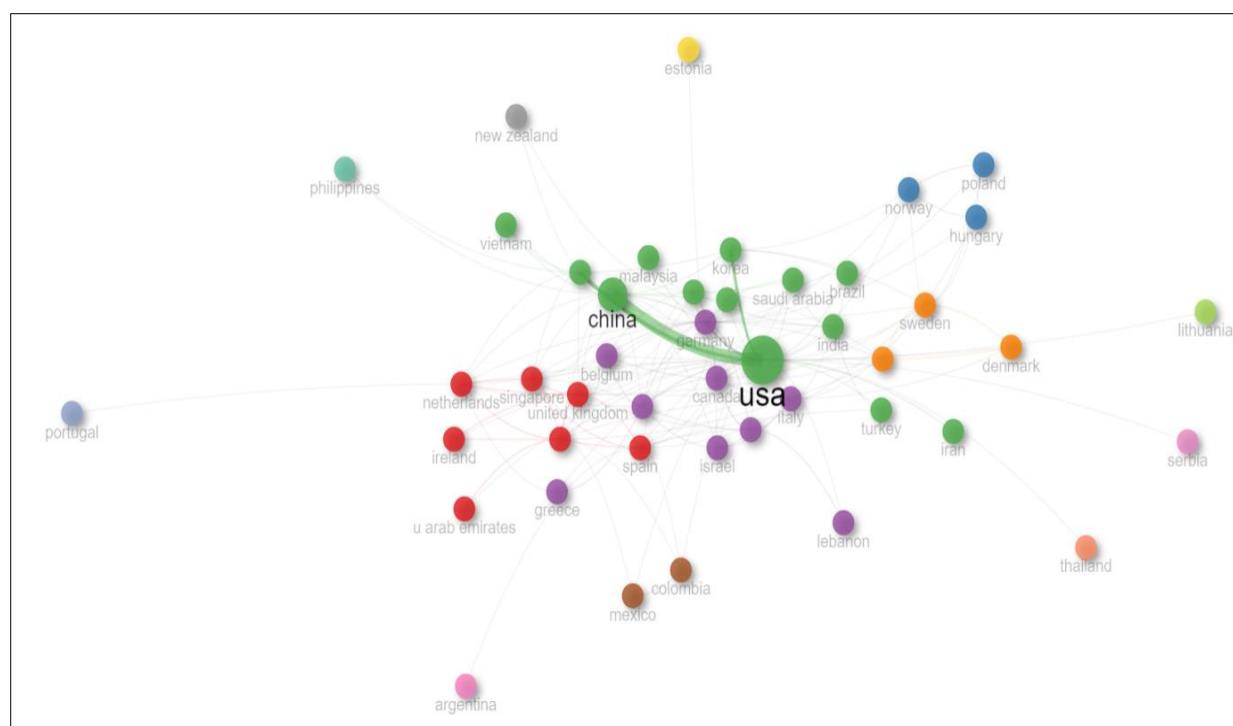


Figure 3. Network map of countries reporting CNV research. Each node represents a country; the links show the association between countries; the color and distance between items represent the similarity between countries that met the threshold of a minimum of 5 reports related to CNV were included.

The top 3 institutions with the most publications in the field examined were the Harvard University in Massachusetts (The United States of America), the University of Cologne (Germany), and the Catholic University of Korea (South Korea) (Table 3). Cursiefen C and Bock F were the most generative authors about CNV (Table 4). The top 10 journals which reported most of CNV articles are shown in Table 5. We used the H-index to evaluate the journal's impact. The *Investigative Ophthalmology & Visual Science* was found to be the journal with the highest H-index, which also published the most articles (n=248). The second journal with the most publications was *Cornea* with 236 publications.

The mean number of citations per article was found to be 26.72. Cursiefen C was the most cited author of CNV.

Table 3: Ranking of the top 10 institutions with the most publications in CNV research during 1980-2024.

Affiliation	Articles
Harvard University	127
University Cologne	91
Catholic University Korea	83
Sun Yat Sen University	76
University Illinois	75
University Erlangen Nurnberg	53
Shandong Eye Institution	48
Soochow University	45
University Pittsburgh	40
Xiamen University	40

Among the journals, *Investigative Ophthalmology & Visual Science* were ranked first in terms of total citation count (n=10505). However, *Ophthalmology* was at the top of the list according to the citation impact.

According to the relationships between the top 20 most influential sources (SO)", "authors (AU)", and "keywords (DE)" illustrated in Figure 4, the journal *Investigative Ophthalmology & Visual Science* was identified as the most influential sources in this field. On the other hand, Cursiefen C, Bock F and Dana R were identified as the most influential authors. Additionally, "cornea", "angiogenesis", and "corneal neovascularization" were the most abundantly used keywords.

In the database, 1439 articles were found in the CNV field containing the subject of 'corneal neovascularization'. When the keywords of these articles were examined, it was seen that the terms 'corneal neovascularization', 'cornea', 'neovascularization', 'angiogenesis' and 'bevacizumab' were frequently used (Figure 5). In addition, recent studies have primarily focused on the management of CNV.

Table 4. Ranking of the top 10 authors with the most publications in CNV research during 1980-2024.

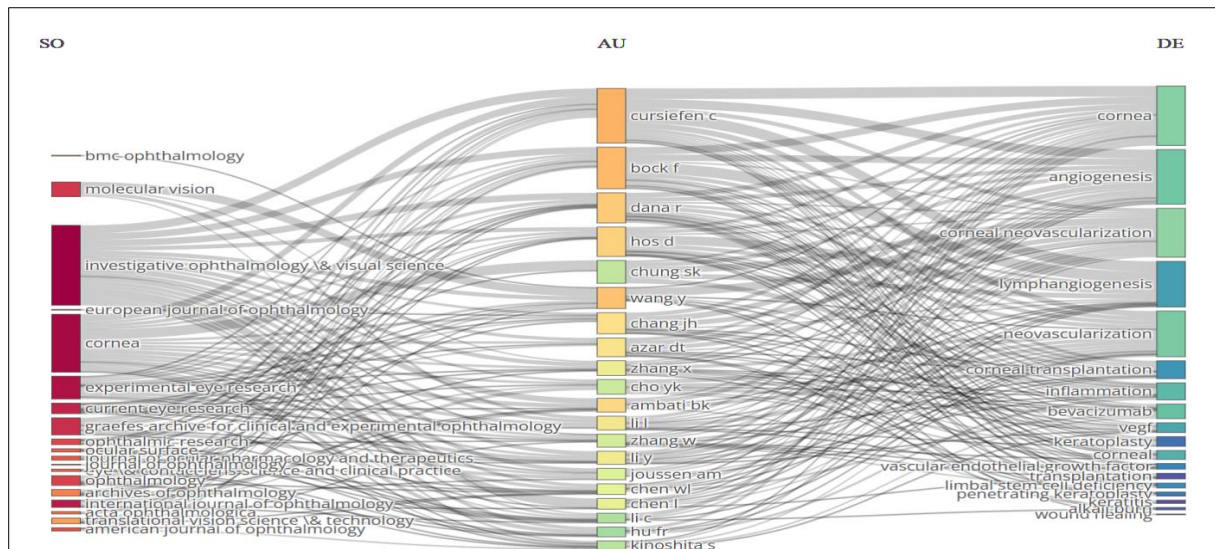
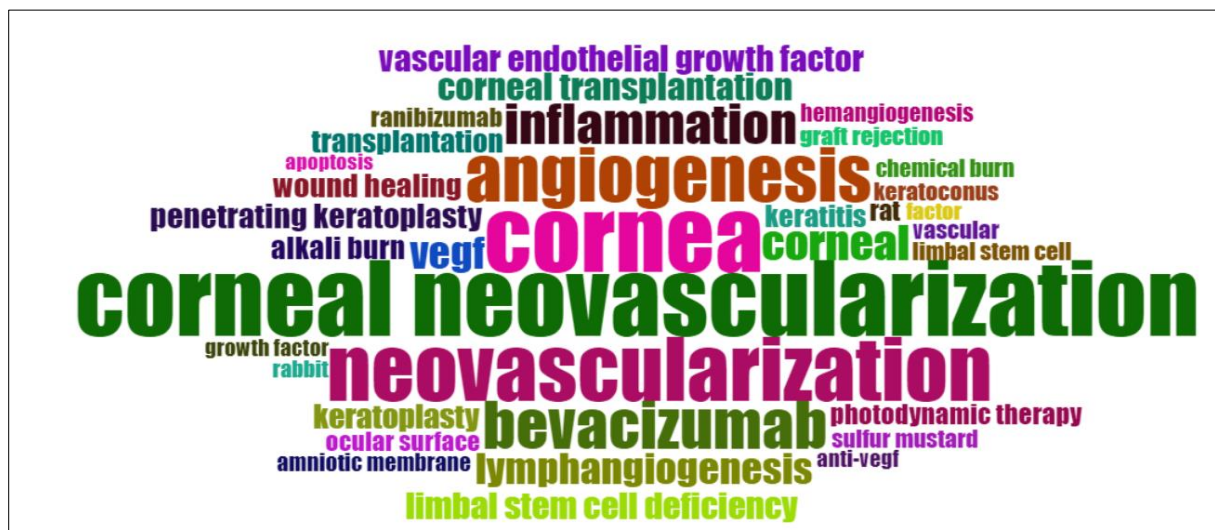
Author	h index	g index	m index	TC	NP	CI
Cursiefen C	26	43	0.963	2659	43	61.84
Bock F	18	31	1	1612	31	52.00
Dana R	18	22	1.125	1066	22	48.45
Wang Y	16	21	0.842	477	27	17.67
Chang JH	14	18	0.583	1346	18	74.78
Azar DT	13	16	0.542	1274	16	79.63
Joussen AM	13	14	0.481	699	14	49.93
Chung SK	12	13	0.8	253	13	19.46
Ambati BK	11	18	0.478	616	18	34.22
Chen L	11	14	0.524	542	14	38.71

TC = total citations, NP = number of publications, CI = citation impact.

Table 5. Ranking of the top 10 journals with the most publications in CNV research during 1980-2024.

Source	h index	g index	m index	TC	NP	CI	PY Start
Investigative Ophthalmology & Visual Science	54	83	1.227	10505	248	42.36	1981
Cornea	40	58	1.053	5586	236	23.67	1987
Ophthalmology	31	45	0.795	2636	45	58.58	1986
Experimental Eye Research	30	49	0.882	2786	114	24.44	1991
Graefes Archive for Clinical and Experimental Ophthalmology	24	40	0.706	1751	55	31.84	1991
Molecular Vision	24	32	1	1156	48	24.8	2001
Current Eye Research	23	33	0.742	1241	61	20.34	1994
American Journal of Ophthalmology	22	33	0.512	1162	36	32.28	1982
Archives Of Ophthalmology	18	19	0.4	1080	19	56.84	1980
Ophthalmic Research	15	21	0.441	535	37	14.46	1991

TC = total citations, NP = number of publications, CI = citation impact, PY = publication of year.

**Figure 4.** Three-area graph for the top 20 most influential sources (SO), authors (AU), and keywords (DE) on CNV.**Figure 5.** Map of keywords in CNV research.

DISCUSSION

The results obtained by bibliometric and retrospective data set analysis revealed an updated perspective on CNV. The annual number of articles is an important factor of development trends in the field and shows the change in the level of knowledge on the subject. Judging by the number of articles per year, the total publication is increasing but fluctuating slightly. When the number of articles in recent years is evaluated, it is observed that they reached their peak in 2013. However, it is still trending above a threshold currently in the works. With the increase in corneal transplantation surgeries and improved techniques in the last 20 years, there has been a significant increment in the number of reports.

Approximately 216.6 million people worldwide are visually impaired, and 4.5 million people experience visual impairment as a result of loss of corneal transparency.¹⁵ Corneal diseases are known to be the fifth leading cause of blindness, following cataracts, refractive errors, glaucoma, and age-related macular degeneration. Since it is frequently seen in young adults, it can reduce the quality of life of young people. The corneal transplantation is usually required for the treatment of an impaired corneal transparency. Even if corneal transplantation surgery is performed successfully, sometimes graft rejection can occur. Corneal rejection is a specific immunologic response of the recipient to donor corneal tissue.¹⁶ The most common clinical findings of graft rejection include corneal edema, keratic precipitates in the corneal graft, and CNV.¹⁷ Transplant rejection is not that easy to manage. CNV is a predominant indicator of graft survival and creates difficulty in re-establishing ocular immunity after surgery. It is possible to see many publications on management of CNV in the literature.^{2,3,7,9,18} Fasciani et al.¹⁹ reported successful results using anti-vascular endothelial growth factor (anti-VEGF) agents as advanced therapy in individuals with high immune risk and CNV. It can be inferred that many studies have been conducted on the connection between corneal transplantation and CNV. In the current study, our focus is on CNV. Because it is a condition encountered in the management of corneal diseases as the fifth leading cause of vision loss.

CNV may occur due to different etiologies such as improper contact lens use, corneal infections, inflammation, chemical injury, and limbal stem cell deficiency.^{10,20} The mainstay of treatment is corticosteroids and other anti-inflammatory drugs before surgical options.²¹ In experimental animal models, CNV treatment has been investigated using various pharmacological agents.^{22,23} Some anti-VEGF drugs, such as bevacizumab, are approved for use in different cancers due to their antiangiogenic effects and are used off-label in the treatment of CNV.^{24,25} In recent years, studies related to anti-VEGF agents have begun to gain ground in the management of CNV by application to the cornea.^{26,27} In the present bibliometric analysis, it is seen that the 5th most used keyword in the articles is 'Bevacizumab'. Topical or systemic pharmacotherapy can be used in the management of CNV.⁸ It can be inferred that there are many studies on CNV management. Since there is still no definitive treatment for CNV, it is likely that studies on this subject will continue in the coming years.

In the country analysis (Table 2), it is seen that the most publications in the CNV field are in the United States, reflecting the dominant position and international impact. China stands out as the second country with the most articles. Turkey, as the 6th country, ranked in the top 10 in the number of publications on CNV. Besides, several European countries, such as England and Italy have relatively low publications. We observed that the institutions with the most articles originated from universities in particular countries. This suggests that the development of clinical research depends both on academic support from universities and on close association between ophthalmology departments and major institutions. *Investigative Ophthalmology & Visual Science* was found to be a leading journal on CNV. We also observed that citations per CNV articles may be considered sufficient (n=26.72).

The present article has some limitations. First, it was not possible to read and assess the full text of all the published reports to obtain knowledge in detail. Besides, the types of indicators used in statistical analysis are limited to the choices performed by the database programs. We did not classify publications as 'animal studies' or any.

In conclusion, the total number of CNV articles has been increasing cumulatively in recent years. CNV is one of the

clinical findings of graft rejection or limbal stem cell deficiency. The increasing number of articles related to corneal transplantation surgeries and management of graft survival improve our current knowledge about the safety and effectiveness of these applications.

Conflict of Interest

The authors declare that there is not any conflict of interest regarding the publication of this manuscript.

Ethics Committee Permission

Ethics committee approval is not required as no human or animal research is conducted.

Authors' Contributions

Concept/Design: NÜ, SE. Data Collection and/or Processing: SE, HS. Data analysis and interpretation: HS, SE, NÜ. Literature Search: EE, NÜ, HS. Drafting manuscript: SE, HS, NÜ. Critical revision of manuscript: NÜ, SE. Supervisor: EE, NÜ.

REFERENCES

1. DelMonte DW, Kim T. Anatomy and physiology of the cornea. *J Cataract Refract Surg*. 2011;37(3):588-598.
2. Nicholas MP, Mysore N. Corneal neovascularization. *Exp Eye Res*. 2021;202:108363.
3. Chang JH, Gabison EE, Kato T, Azar DT. Corneal neovascularization. *Curr Opin Ophthalmol*. 2001;12(4):242-249.
4. Lim P, Fuchsluger TA, Jurkunas UV. Limbal stem cell deficiency and corneal neovascularization. *Semin Ophthalmol*. 2009;24(3):139-148.
5. Lee P, Wang CC, Adamis AP. Ocular neovascularization: an epidemiologic review. *Surv Ophthalmol*. 1998;43(3):245-269.
6. Feizi S, Azari AA, Safapour S. Therapeutic approaches for corneal neovascularization. *Eye Vis (Lond)*. 2017;4(1):28.
7. Inomata T, Mashaghi A, Di Zazzo A, Lee SM, Chiang H, Dana R. Kinetics of angiogenic responses in corneal transplantation. *Cornea*. 2017;36(4):491-496.
8. Sharif Z, Sharif W. Corneal neovascularization: updates on pathophysiology, investigations & management. *Rom J Ophthalmol*. 2019;63(1):15-22.
9. Gupta D, Illingworth C. Treatments for corneal neovascularization: A review. *Cornea*. 2011;30(8):927-938.
10. Roshandel D, Eslani M, Baradaran-Rafii A, et al. Current and emerging therapies for corneal neovascularization. *Ocul Surf*. 2018;16(4):398-414.
11. Cooper ID. Bibliometrics basics. *J Med Libr Assoc*. 2015;103(4):217-218.
12. Aria M, Cuccurullo C. bibliometrix: An R-tool for comprehensive science mapping analysis. *J. Informetr*. 2017;11(4):959-975.
13. Donthu N, Kumar S, Mukherjee D, Pandey N, Lim WM. How to conduct a bibliometric analysis: An overview and guidelines. *J. Bus. Res*. 2021;133:285-96.
14. Ozturk O, Kocaman R, Kanbach DK. How to design bibliometric research: an overview and a framework proposal. *Rev. Manag. Sci*. 2024;18(11):3333-3361.
15. Flaxman SR, Bourne RRA, Resnikoff S, et al. Global causes of blindness and distance vision impairment 1990-2020: a systematic review and meta-analysis. *Lancet Glob Health*. 2017;5(12):1221-1234.
16. Williams KA, Roder D, Esterman A, Muehlberg SM, Coster DJ. Factors predictive of corneal graft survival. Report from the Australian Corneal Graft Registry. *Ophthalmology*. 1992;99(3):403-414.
17. Qazi Y, Hamrah P. Corneal Allograft Rejection: Immunopathogenesis to therapeutics. *J Clin Cell Immunol*. 2013;2013(9):6.
18. Chang J-H, Garg NK, Lunde E, Han K-Y, Jain S, Azar DT. Corneal neovascularization: An anti-vegf therapy review. *Surv Ophthalmol*. 2012;57(5):415-429.
19. Fasciani R, Mosca L, Giannico MI, Ambrogio SA, Balestrazzi E. Subconjunctival and/or intrastromal bevacizumab injections as preconditioning therapy to promote corneal graft survival. *Int Ophthalmol*. 2015;35(2):221-227.
20. Clements JL, Dana R. Inflammatory Corneal Neovascularization: Etiopathogenesis. *Semin Ophthalmol*. 2011;26(4-5):235-245.
21. McNatt LG, Weimer L, Yanni J, Clark AF. Angiostatic activity of steroids in the chick embryo cam and rabbit cornea models of neovascularization. *J Ocul Pharmacol Ther*. 1999;15(5):413-423.
22. Goktas S, Sakarya R, Erdogan E, et al. Antiangiogenic effect of itraconazole on corneal neovascularization: a pilot experimental investigation. *Ophthalmic Res*. 2014;52(4):170-174.
23. Goktas S, Erdogan E, Sakarya R, et al. Inhibition of corneal neovascularization by topical and subconjunctival tigecycline. *J Ophthalmol*. 2014;2014(1):452685.
24. Wedam SB, Low JA, Yang SX, et al. Antiangiogenic and antitumor effects of bevacizumab in patients with inflammatory and locally advanced breast cancer. *J Clin Oncol*. 2006;24(5):769-777.
25. Keating AM, Jacobs DS. Anti-VEGF treatment of corneal neovascularization. *Ocul Surf*. 2011;9(4):227-237.
26. Koenig Y, Bock F, Horn F, Kruse F, Straub K, Cursiefen C. Short- and long-term safety profile and efficacy of topical bevacizumab (Avastin) eye drops against corneal neovascularization. *Graefes Arch Clin Exp*. 2009;247(10):1375-1382.
27. Dastjerdi MH, Sadrai Z, Saban DR, Zhang Q, Dana R. Corneal penetration of topical and subconjunctival bevacizumab. *Invest Ophthalmol Vis Sci*. 2011;52(12):8718-8723.