Bibliometric Analysis

Global Research Trends in Dry Eye Diagnosis Tools: A Bibliometric Analysis

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ABSTRACT

This study provides a bibliometric analysis of recent publications focused on Dry eye disease (DED) diagnostic tools. A comprehensive literature search was conducted in the Scopus database retrieved 2,625 records (2014–2024). After manual screening, 135 articles were selected. VOS viewer was used to perform co-authorship, country collaboration, and keyword co-occurrence analyses. Among 829 authors, 19 met the threshold of at least three publications. The United States, China, and Germany were leading contributors, with strong international collaboration networks. Keyword analysis from 1,576 keywords, 184 appearing ≥5 times, revealed thematic clusters around traditional diagnostic tests like the Schirmer test, modern imaging techniques like meibography, interferometry, and biochemical assessments like tear osmolarity. Overlay visualization showed a temporal shift toward more advanced and objective diagnostic methods between 2019 and 2024.The findings of the study provide valuable insights into global research trends and can guide future studies and clinical advancements in DED diagnosis.

Keywords: Dry Eye Disease, Diagnostic Tools, Bibliometrics, VOS viewer, Tear Film, Osmolarity, Meibography.

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INTRODUCTION

Dry eye disease (DED) is a condition of the ocular surface in which multiple factors are responsible for the loss of homeostasis of the tear film and, in many cases, are accompanied by symptoms of discomfort, visual disturbance, and tear film instability.[1] DED affects millions of people around the world and is considered a significant public health problem, especially among the elderly, frequent screen users, patients with autoimmune diseases, or contact lens wearers.[2-5] The rising prevalence of dry eye has driven the development and advancement of diagnostic instruments to achieve greater accuracy and objectivity of clinical judgment. Despite progress in the field, the diagnosis of dry eye disease is still clinically challenging.[6,7] The symptoms do not necessarily correlate with the objective findings, and the disease can occur in different subtypes, like aqueous-deficient and evaporative dry eye, which accounts for individual diagnostic strategies.[8,9] Conventional techniques such as the Schirmer test, fluorescein staining, and TBUT are also widely used but limited since they vary and are poorly repeatable.[10] In recent years, the ocular surface interferometry, tear osmolarity and meibography have emerged as new techniques which provide more precise and standardized evaluation processes.[10]

With the use of bibliometric analysis, it is possible to observe shifts in trends and patterns of scientific research. The examination of major metrics in publication data (collaborative authorship, changing keywords, citation landscapes, and regional stake) allows researchers to map the shape and direction of a particular research area. Cylindrical integration using tools such as VOS viewer enables the construction of interactive maps that unveil thematic aggregates and connections among researchers and what is lying ahead in the form of emerging trends of interest in a particular field.[11]

This study aims to examine global publications on dry eye diagnosis tools with the help of an in-depth bibliometric point of view. Based on data in a well-chosen literature database and showing findings in VOS viewer visualization, the current study aims to answer the following key questions:

1. Who are the most prolific authors, and which institutions dominate the field?
2. Which countries are most involved in research work, and what networks do they develop through their cooperation?
3. What are the dominant concepts in the existing research, and what has influenced the evolution of the topics that are raised for research in this area?

Using this analysis, researchers will be able to chart the scene of the studies on diagnosing dry eye, noting the synergies, progression, and direction of those studies in the form of the field. These findings are necessary in identifying areas that require additional probing and directing the focus of future research and guidelines for translating diagnostic progress into clinical activity.

METHODS

The present study intends to examine and visualize the development of research dedicated to diagnostic methods of DED with the help of bibliometric tools. The research design is based on a structured method of PRISMA standards, supplemented using VOS viewer software for quantitative bibliometric methodology.[12]

Database Selection and Justification: Scopus was selected in the current study because it has a broad multidisciplinary nature and it has more quality peer-reviewed literature indexing in the bio-medical and clinical sciences. Scopus offers enhanced results in high research bibliometrics by offering elaborate citation data, researcher descriptions, and institutional facts.

Search Strategy and Query Formation: To obtain the maximum number of results, the Final search query was run on 24 September 2024, at 11:30 AM. The search was performed using the following terms: (Dry Eye Disease" OR "Dry Eye Syndrome" OR "DED" OR "DES") AND (Diagnostic Test) OR (Screening tool) terms were composed of common words used by laymen and medical terms used in conjunction with the name of a diagnostic method and tools. The use of Boolean operators helped the search process to narrow down on irrelevant papers and reduced extraneous background noise.

Screening and Selection Process

The first set of 2,625 records were retrieved. After screening for publication years 2014-2024, 1,113 articles were left. Full-length research articles after excluding reviews, editorials, letters, and conference abstracts, 1,034 articles were retained. Onlythe articles published in peer-reviewed journals were considered to ensure quality (1,033 articles retained).Language filter was restricted to English-language publications (741 articles retained).A final refining step excluded duplicates, poorly indexed entries, or off- topic articles, yielding a final corpus of 135 articles (Figure 1).

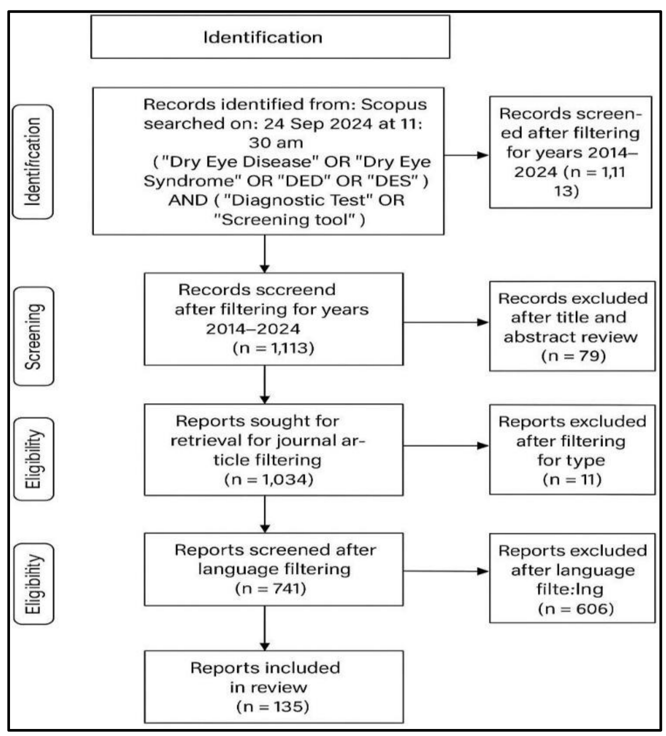

Figure 1: *PRISMA diagram of the data extraction from the Scopus database.*

Data Extraction and Preprocessing: The bibliographic metadata of the final 135 articles were exported in RIS/CSV format from Scopus. Extracted fields included: Article title, author names, affiliated institutions, country of origin, abstract, keywords (author-provided and indexed), source title (journal), year of publication and total citations. The data were cleaned to eliminate inconsistencies, unify author names (e.g., different spellings), and normalize country names.

Software Tool: VOS viewer: VOSviewer, developed by the Centre for Science and Technology Studies at Leiden University, was used to construct and visualize the bibliometric networks. This software enables:

Network visualizations (e.g., co-authorship, country collaboration) Density visualizations (keyword usage intensity).

Overlay visualizations (temporal trends).

It uses co-occurrence and link strength metrics to cluster terms or entities based on similarity and citation patterns. Clustering is performed via a modularity-based algorithm that automatically detects natural groupings in the data.

Analysis Types and Threshold Criteria

Author Analysis: Minimum 3 documents to focus on prolific contributors.

Country Analysis: Minimum 5 documents and 5 citations to filter sporadic contributors.

Keyword Co-occurrence: Keywords appearing at least 5 times were included to highlight frequent and thematic terms.

Index Terms: Included terms used by databases to standardize content tags.

Each threshold was selected to strike a balance between data comprehensiveness and interpretability of visual maps.

RESULTS

This section contains the bibliometric results in terms of authorship, geographical distribution, and themes in terms of key-word analysis. The narrative is accompanied and supported by visual maps that are created by VOS viewer.

Author Contribution and Collaboration

Among the 829 authors involved in the diagnosis of the issue of dry eyes, a total of 19 were selected to reach the criteria of publications of at least three publications, as indicated in Table 1. It implies that there is a rather small circle of active interventions, which means that, on one hand, the subject is thoroughly researched, on the other hand, only a few researchers are involved in deep research. It was found that there were a number of collaboration clusters within the co-authorship network. These clusters tended to be an institutional relationship or regionalism especially in East Asia, North America and Europe. Firm co-authorship relationships suggest effective research relationships, which are essential in promoting complex diagnostics like those of dry eye disease.

Country-wise Research Output

Research on dry eye diagnostics has been conducted in 50 different countries. Of these, only 12 countries met the dual threshold of contributing at least five documents and receiving a minimum of five citations.

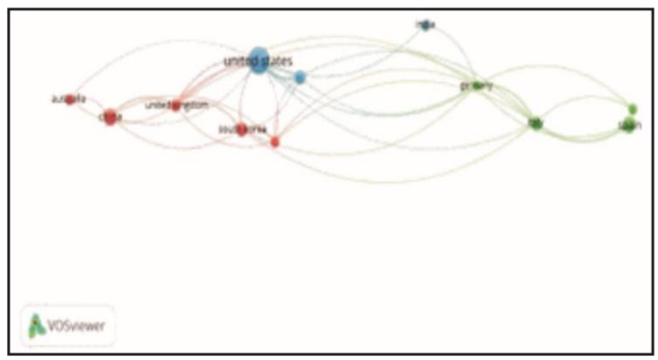

Figure 2: *Shows the visualization map of the countries contributing to the dry eye disease diagnosis study, in which the US is the highest contributor.*

According to the VOS viewer collaboration map, the most productive countries are shown in Figure 2. United States, exhibiting both high publication volume and strong international collaboration links. China, showing a rapid rise in research output over recent years. Germany, with a stable contribution and at the heart of the European networks of research. The connecting lines on the map are thick to show the intensity of the international cooperation. There are wide bilateral agreements in the United States particularly with Japan, the United Kingdom and Australia. There are also moderate to strong connections between China and Germany which is an indication of growing global synergy in this area of research.

Temporal Evolution of Research Themes

The overlay visualization provides insights into how the focus of dry eye diagnostics research has shifted over time. Colors in the map represent the average publication year of each term. Older terms (2015–2017) are shown in blue and include well-established diagnostic methods like the Schirmer test, tear breakup time, and fluorescein staining-range terms (2018–2019) in green-yellow tones include ocular surface analysis, TBUT, meibography, and subjective symptoms. Emerging terms (2020 onward) appear in yellow, such as tear osmolarity, interferometry, lipid layer thickness, optical coherence tomography (OCT), and diagnostic imaging.

This transition reflects a technological evolution in the field, moving from invasive, symptom-driven tests toward non-invasive, quantitative imaging and molecular diagnostics.

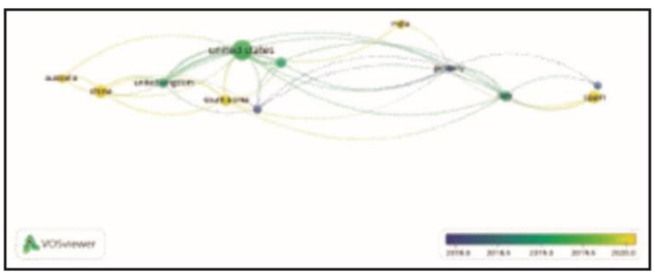

Figure 3: *The visualization map, which shows the US is the country among all where the research theme evolved widely over the period of the time.*

Keyword Co-occurrence Analysis

A total of 1,576 keywords were extracted from the dataset, with 184 appearing at least five times. Among the 324 author keywords, only 13 met this threshold.

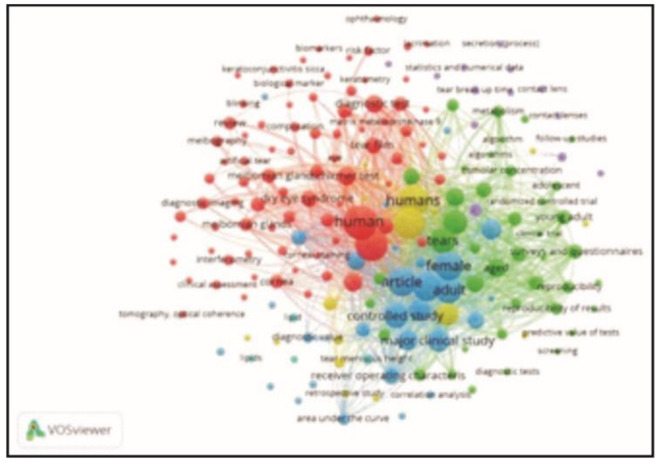

Figure 4: *Visualization of the keywords' co-occurrence, in which the highest keywords are human, tears, female and soon.*

These keywords were visualized into thematic clusters using co-occurrence mapping.

Notable clusters include:

Cluster 1 (Red): Focused on traditional diagnostics, including Schirmer test, tear break-up time, ocular surface, and staining.

Cluster 2 (Blue): Focused on imaging technologies and more recent technologies, including meibography, interferometry, OCT, and non-invasive TBUT.

Cluster 3 (Green): It included patient-related variables such as symptom questionnaires, OSDI (Ocular Surface Disease Index), and subjective symptoms.

Cluster 4 (Yellow): Urgently required biochemical and high-level diagnostics, such as, osmolarity, biomarkers, inflammation, and proteomics.

Table 1: *Shows the author list with the number of documents and citations.*

Selected	Author	Documents	Citations	Total link strength
☑	giannaccare, giuseppe	4	104	7
☑	pellegrini, marco	4	104	7
☑	bulum, tomislav	3	3	6
☑	garcia-queiruga, jacobo	3	5	6
☑	kawashima, motoko	3	74	6
☑	pena-verdeal, hugo	3	5	6
☑	petri?ek, igor	3	3	6
☑	scorcia, vincenzo	3	61	6
☑	tomi?, martina	3	3	6
☑	tsubota, kazuo	3	74	6
☑	yebra-pimentel, eva	3	5	6
☑	yokoi, norihiko	3	74	6
☑	craig, jennifer p.	3	1341	3
☑	tong, louis	3	1366	3
☑	wolffsohn, james s.	3	1441	3
☑	basu, sayan	3	24	1
☑	galor, anat	8	193	1
☑	jhanji, vishal	4	69	1
☑	srinivasan, sruthi	3	41	0

Table 2: *This table shows that the highest occurrence of the keywords among them the human and dry eye keyword occurs 139 and 125 times, respectively.*

Selected	Keyword	Occurrences	Total link strength
☑	human	139	3141
☑	dry eye	125	2845
☑	humans	111	2711
☑	dry eye syndromes	110	2689
☑	male	101	2552
☑	article	102	2539
☑	female	99	2494
☑	adult	95	2426
☑	tears	72	1830
☑	controlled study	73	1826
☑	lacrimal fluid	69	1741
☑	middle aged	63	1697
☑	diagnostic test accuracy study	62	1618
☑	major clinical study	59	1567
☑	sensitivity and specificity	54	1397
☑	questionnaire	49	1258
☑	aged	42	1210
☑	priority journal	40	1121
☑	ocular surface disease index	42	1100
☑	schirmer test	39	1063

The number of newly introduced terms suggests the shift in the direction of precise diagnostics and patient-focused assessment models.

Index Term Analysis

From a total of 1,387 index terms, 171 occurred at least five times. These index terms corroborated the keyword findings, reaffirming the dominance of imaging modalities, tear film metrics, and biochemical markers in the recent literature.

DISCUSSION

The bibliometric results of the current research project provide an in-depth understanding of research tendencies in the world in the field of diagnosing dry eye with the help of tools. Through the analysis of the trends in publications, networks of authors, geographic contributions, and the development of the key words, one can make several important observations that represent not only the historical trend of this significant research area but also determine the modern course of this direction.

Out of the 829 authors present in the study, only 19 were those with at least three publications. This would imply a subject that has received enormous inquisitiveness, but few standards apply to the subject. This observation might mean that the experts of the different fields, such as ophthalmology, optometry, biomedical engineering, or, say, immunology, treat the research on the dry eye very sporadically.[13] The fact that key authors are few, implies that the field can employ more specialized partnerships or even research networks. Regular collaborations can contribute to the alignment of the principles of diagnosis and harmonization of the procedures along with the introduction of new medical tools into practice.

The published study volumes are the highest in the United States, China, and Germany. The leadership of innovation in the ophthalmic diagnostics that is years-long, powerful financing, and flourishing research environment all contribute to the driving role of the United States in the area. Proper international collaboration reflects the imperfect shaping hand when defining the path of research all over the world. The augmented research activities in China can be considered an indicator of governmental and institutional interest in the ophthalmologic sphere.[14] The high rate of publication is evident, and it is important to continue the analysis to evaluate the impact of citations and new outcomes. Another reason is that Germany and other European nations are the large fishes in the research field, though with low outputs in terms of publications, all due to the focus on high technical standards and standardized diagnostic.[15]

Co-authorship maps and country co-presence maps indicate that there are strong regional clusters, especially in East Asia and Europe indicating that relationships based on proximity, similarities in the official languages, and policies tend to determine the structure of research networks. The interaction between researchers of different geographical locations and specialization can permit creativity and differing views in the research of diagnoses.

The revisiting of keywords indicated gradual trends in the changing priorities of the area. Traditionally, most research has depended on the customary diagnostics, with the Schirmer test, tear break-up measurements, and staining tests as the dominant methods. Though these traditional techniques may be crucial, they are in fact compromised by such problems as variability, patient inconvenience, and inadequate connection with reported symptoms.[16] The inclusion of ideas such as tears osmolarity, meibography, and ocular surface interferometry in the recent studies is an indication of objective, quantitative, and non-invasive methods of testing in eye care diagnostics.[10,17] Such methodologies give more consistency and are now commonly used in medical settings. It was concluded by the TFOS DEWS II report that it was necessary to measure tear osmolarity, to diagnose the dry eye.[18]

Just like the biomarkers, proteomics, and inflammation, there is also growing interest in collaborating towards understanding the molecular cause of dry eye disease. Such innovations offer the prospect of customizing treatments to individual biology and utilizing biomarkers for earlier and more precise diagnosis, which could influence how we handle such a condition.

A significant factor is the growing interest in including patient feedback and self-reported symptoms. The results of both the objective and the subjective experience of a patient is included in the Ocular Surface Disease Index (OSDI).[18] This kind of combination is required since patients can have symptoms which cannot be discerned through examinations at a clinic. Simultaneously, the potential of the technologies like symptom trackers on a smartphone and the image interpretation with the help of AI has immense potential to enhance accessibility and quality of a diagnosis, especially in individuals who are living in remote/underserved areas.[19-21]

Despite new development, some of the diagnostic techniques are abandoned in their normal clinical use, due to the cost-effectiveness, technicality, or absence of consistent guidelines.[22]The high-income countries produce most published research and it leads to a necessity to enhance research and clinical implementations in countries with low and middle income.

This analysis can be used to form a number of strategic actions. Encourage trans-institutional and trans-border research, especially between high-income and low-income regions, standardize diagnostic criteria and clinical protocols to aid in comparative research, invest in imaging, molecular diagnostic and patient-centric technologies and design inexpensive and easy to use diagnostic systems to increase access in primary care and developing countries.

With a perfect match of technological innovation with clinical practicability, the diagnostic side of the dry eye issue is capable of advancing to the stage of early diagnosis, more precise sub-classification, and patient outcomes.

Dry eye disease due to the heterogeneous nature and pathophysiology will continue to be a diagnostic challenge. A retrospective perspective of the information obtained in this literature analysis demonstrates that there had been considerable changes in the scientific literature and clinical literature on the diagnosis of dry eye over the past ten years. Special attention should be paid to the level of output of publications and international cooperation of the United States, China and Germany. The cooperation analysis demonstrates that collaboration at the international level is the most significant to enhance not only the research but also the actual application of new diagnostic tools.

Co-occurrence mapping in research interest revealed the change of symptom-based assessment to the present state of advanced imaging, markers, and patient-specific diagnostics. The integration of such terms as tear osmolarity, interferometry, and biomarkers in the present study shows the greater interest in improving the quality of the diagnostics, ability to identify the issues in the appropriate moment, and ability to apply the molecular results to the everyday practice.

CONCLUSION

The current study demonstrates that the creation of the diagnostics of dry eye is a process that needs a long period of time, creative thinking, and cooperation with other people, not to mention following the standards. They constitute significant suggestions for the researchers, clinicians, and healthcare authorities seeking the polishing of diagnostic criteria and improvement of clinical decisions in the ophthalmologic practice. To gain the most possible effect of new diagnostics on the global scale, future research must be accessible and less expensive and may have an interdisciplinary character. Lastly, narrower, and more detailed ways of diagnosing dry-eye disease can make significant contributions to the therapeutic outcome and significantly increase the quality of life of patients across different countries.

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