Research Article

Dry Eye Analysis: A Citation Network Study

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Received 29 March 2019; Revised 4 June 2019; Accepted 19 June 2019; Published 14 August 2019

Guest Editor: David Madrid-Costa

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Introduction. Dry eye is one of the most frequent eye problems with prevalence and incidence from 5% to 50%. Citation network analysis allows us to simplify information in a visual way and provides a better understanding of the research done in a specific field. The objective of this paper is to quantify and analyse the relationships among the scientific literature in this field using citation network analysis.

Materials and Methods. The program used to analyse the citations was CitNetExplorer®. Previously, papers published in the research field during a predefined period were found using the keywords defined in Web of ScienceTM (WOS).

Results. Using the keyword “dry eye,” during the period 2007 to 2018, the most cited paper is by Lemp, MA (2007), with a citation index score of 913 in our citation network containing 6,500 most relevant papers. Analysing clustering, we found 5 relevant groups that match the main areas of research in this field: definition and classification, treatment, retina, refractive surgery, and quality of vision. Core Publication is composed of 64% of the papers in the network, which is a high percentage. It indicates a clear focus on the research carried out in this field. Conclusions. This citation network analysis shows definition and classification of dry eye to be the most researched area in this field, followed by treatment.

1. Introduction

Dry eye is one of the most frequent eye problems reported by adults in eye care practitioner consultations. The prevalence and incidence vary from 5% to 50%, depending on the diagnosis criteria or on the type of dry eye. Women and older people are the most affected. Dry eye prevalence is rising, due to the gradual increase of the population age and to a higher incidence of some risk factors [1].

Dry eye was defined as a disease just 30 years ago. Since then, there have been many advances in the knowledge and definition of this pathology. In 1995, it was defined as a “disorder of the tear film due to tear deficiency or excessive evaporation, which causes damage to the interpalpebral ocular surface and is associated with symptoms of ocular discomfort”. In 2017, a new definition was published in the DEWS II report [2].

Nowadays, according to the abovementioned report, dry eye is defined as “a multifactorial disease of the ocular surface characterized by a loss of homeostasis of the tear film and accompanied by ocular symptoms, in which tear film instability and hyperosmolarity, ocular surface inflammation and damage, and neurosensory abnormalities play etiological roles” [3]. This new definition admits the multifactorial origin of dry eye and points out the etiological factors implied in this disease.

Regarding dry eye classification, traditionally, dry eye was classified into aqueous tear-deficient and evaporative. Now, we know that both exist as a continuum and, as dry eye progresses, it is used to find characteristics of both subtypes [2]. The aqueous tear-deficient dry eye implies a failure of lacrimal tear secretion, while the evaporative dry eye is related to eyelids and ocular surface.

The great number of patients suffering from dry eye and the impact of this disease on patients both financially and in terms of quality of life justify the analysis of all the research studies published about this public health problem. Citation network analysis allows us to simplify information in a visual way and provides a better understanding of the research done in a specific field. It also lets...
us quantify the most cited papers and create groups based on
cornections between papers and citation frequencies [4]. Citation
network analysis has been a very useful tool since
the citation index concept appeared.

These citation networks appear as different fields related
through connections. Authors, journals, and papers are an
essential part of these networks [5].

Because research on dry eye pathology is so extensive,
use of this citation analysis methodology will allow us to
identify the most relevant authors, publications, and jour-
nals, as far as their citation is concerned, the most important
years in terms of their publications, and the different clusters
of study within dry eye pathology.

The aim is to identify not only the most relevant research
but also the different areas of study and thus focus future
research on dry eye.

The objective of this paper is to quantify and analyse the
relationships among the scientific literature in this field
using citation network analysis.

2. Materials and Methods

CitNetExplorer® was used to analyse the citation networks
of individual publications. This software is a tool for visual-
izing the most important publications in a field and
showing the citation relations between these publications
[6].

First, the researchers define the keywords and look for the
publications according to these words in Web of ScienceTM
(WOS). The file from WOS shows papers in the research field
published during the predefined period.

The final file is the selection of 6,500 publications of the
WOS list sorted by relevance, because the citation network
program does not allow more publications to be introduced.

Then, once the file is imported to CitNetExplorer®, the
software produces the first graph about the most cited
publications, with a maximum of 40 papers for a clearer
understanding.

Quantitative analysis shows values of publications, ci-
tation links (total number of citations in the network), and
time period. This analysis shows the most cited papers in
order from the highest to the lowest, according to their
citation index score.

The clustering function allows us to identify groups
according to the level of association among papers. In this
way, subnetworks are obtained depending on the citations
among them [7].

Finally, central publications are analysed through the
Core Publication function, revealing the main papers of the
field. For this analysis, only those that have 4 citations or
more are selected.

3. Results

The keywords used for the search were “dry eye”. The period
chosen was from 2007 to 2018. The year 2007 was chosen as
the starting point because of the change that the Dry Eye
Workshop (DEWS) report represented in the definition and
treatment of dry eye. 9,359 papers were found using the
previous criteria.

We made a citation network with 6,500 most relevant
papers, obtaining 44,942 citations across the network.

Table 1 shows the 20 most cited papers in this network.
The paper by Lemp et al., published in 2007, is the most
cited, with a citation index score of 913.

Figure 1 shows the graph of this network.

With the clustering function, we obtained 13 groups or
clusters, 5 of them having a relevant number of papers, while
the other 8 did not reach 1%.

Figures 2–6 show the citation network of each group,
and Figure 7 shows that there are no citations among dif-
ferent groups.

In group 1, we had 4,014 papers, almost 61% of the
network. Lemp’s paper, published in 2007 in Ocular Surface
Journal [2], was the most cited in this group.

In group 2, we found 360 publications. Yoon’s paper,
published in 2007 in American Journal of Ophthalmology
[26], was the most cited.

In group 3, we found 198 publications. Lim’s paper,
published in 2012 in The Lancet [27], was the most cited.

In group 4, we found 179 publications. Ambrosio’s
paper, published in 2008 in Journal of Refractive Surgery
[28], was the most cited.

Finally, in group 5, we found 143 publications. Kaido’s
paper, published in 2007 in Cornea [29], was the most cited.

When we analysed relationships among clusters, we
could not find any connections.

When we analysed the Core Publication, we found a total
of 4,161 papers that cited, or were cited by, at least 4 papers.
This 4,161 represented 64% of the papers, and the citation
network across this group is 42,791. Figure 8 shows the
graph of this network.

4. Discussion

This analysis has proved how publications about dry eye
have been increasing in recent years, 2007 being a key
year.

There is no doubt about the relevance of the publication
of the DEWS report since Lemp et al. in 2007 [2].

The network analysed papers published from 2007 to
2018, but the most cited papers are in the period from 2007
to 2012. This suggests that 2012 could be another key year in
dry eye research because of the number and content of
papers, analysing the different publications.

Regarding clustering, we found 5 relevant groups that
match the main areas of research in this field: definition and
classification, treatment, retina, refractive surgery, and
quality of vision.

This clustering also shows a difference among the
journals that published each of the clusters. It clearly in-
dicates the editorial lines of each scientific journal, no matter
how cross the subject was, as in the case of dry eye.

The biggest cluster is the one related to definition and
classification of dry eye, with more than 60% of the papers of
this network. DEWS report heads this cluster due to the
broad consensus on the new definition and classification of
Table 1: 20 most cited papers from 2007 to 2018 in the dry eye citation network.

| Authors                | Paper title                                                                                                                                                                                                                                                                                                                                 | Journal                                                                 | Year   | Citation index |
|------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------                                                                         |                                                                        |        |                |
| Lemp et al. [2]        | The definition and classification of dry eye disease: report of the Definition and Classification Subcommittee of the International Dry Eye Workshop (2007)                                                                                                                                  | The Ocular Surface. 2007 Apr; 5(2): 75–92.                             | 2007   | 913            |
| Smith et al. [1]       | The epidemiology of dry eye disease: report of the Epidemiology Subcommittee of the International Dry Eye Workshop (2007)                                                                                                                                                                           | The Ocular Surface. 2007 Apr; 5(2): 93–107.                            | 2007   | 380            |
| Miljanović et al. [8]  | Impact of dry eye syndrome on vision-related quality of life Methodologies to diagnose and monitor dry eye disease: report of the Diagnostic Methodology Subcommittee of the International Dry Eye Workshop (2007)                                                                                           | American Journal of Ophthalmology. Mar 143(3): 409–15.                  | 2007   | 271            |
| Bron [9]               |                                                                                                                                                                                                                                                                                                                                          | The Ocular Surface. 2007 Apr; 5(2): 108–52.                            | 2007   | 253            |
| Sullivan et al. [10]   | An objective approach to dry eye disease severity                                                                                                                                                                                                                                                                                           | Investigative Ophthalmology & Visual Science. 2010 Dec; 51(12): 6125–30. | 2010   | 213            |
| Lemp et al. [11]       | Tear osmolarity in the diagnosis and management of dry eye disease Prevalence of dry eye disease among US men: estimates from the Physicians’ Health Studies.                                                                                                                                                             | American Journal of Ophthalmology. May 151(5): 792–798.e1.              | 2011   | 211            |
| Schaumberg et al. [12] |                                                                                                                                                                                                                                                                                                                                          | Archives of Ophthalmology. 2009 Jun; 127(6): 763–8.                     | 2009   | 207            |
| Lam et al. [13]        | Tear cytokine profiles in dysfunctional tear syndrome. Management and therapy of dry eye disease: report of the Management and Therapy Subcommittee of the International Dry Eye Workshop (2007)                                                                                                               | American Journal of Ophthalmology. 2009 Feb; 147(2): 198–205.          | 2009   | 192            |
| Pflugfelder et al. [14]| The international workshop on meibomian gland dysfunction: report of the Subcommittee on Anatomy, Physiology, and Pathophysiology of the Meibomian Gland.                                                                                                                                                                                                 | The Ocular Surface. 2007 Apr; 5(2): 163–78.                            | 2007   | 182            |
| Knop et al. [15]       |                                                                                                                                                                                                                                                                                                                                          | Investigative Ophthalmology & Visual Science. 2011 Mar 30; 52(4): 1938–78. | 2011   | 171            |
| Stevenson et al. [16]  | Dry eye disease: an immune-mediated ocular surface disorder.                                                                                                                                                                                                                                                                              | Archives of Ophthalmology. 2012 Jan; 130(1): 90–100.                    | 2012   | 156            |
| Massingale et al. [17] | Analysis of inflammatory cytokines in the tears of dry eye patients.                                                                                                                                                                                                                                                                       | Cornea. 2009 Oct; 28(9): 1023–7.                                      | 2009   | 147            |
| De Paiva et al. [18]   | IL-17 disrupts corneal barrier following desiccating stress.                                                                                                                                                                                                                                                                              | Mucosal Immunology. 2009 May; 2(3): 243–53.                            | 2009   | 146            |
| Nelson et al. [19]     | The international workshop on meibomian gland dysfunction: report of the Definition and Classification Subcommittee The international workshop on meibomian gland dysfunction: report of the Diagnosis Subcommittee.                                                                                                                               | Investigative Ophthalmology & Visual Science. 2011 Mar 30; 52(4): 1930–7. | 2011   | 141            |
| Tomlinson et al. [20]  | A link between tear instability and hyperosmolarity in dry eye. Noncontact infrared meibography to document age-related changes of the meibomian glands in a normal population. Dry eye-induced conjunctival epithelial squamous metaplasia is modulated by interferon-gamma. | Investigative Ophthalmology & Visual Science. 2011 Mar 30; 52(4): 2006–49. | 2011   | 133            |
| Liu et al. [21]        |                                                                                                                                                                                                                                                                                                                                          | Investigative Ophthalmology & Visual Science. 2009 Aug; 50(8): 3671–9.   | 2009   | 129            |
| Arita et al. [22]      |                                                                                                                                                                                                                                                                                                                                          | Ophthalmology. 2008 May; 115(5): 911–5.                                 | 2008   | 128            |
| De Paiva et al. [23]   |                                                                                                                                                                                                                                                                                                                                          | Investigative Ophthalmology & Visual Science. 2007 Jun; 48(6): 2553–60. | 2007   | 122            |
| Enríquez de Salamanca et al. [24] | Tear cytokine and chemokine analysis and clinical correlations in evaporative-type dry eye disease.                                                                                                                                                                                                                     | Molecular Vision. 2010 May 19; 16: 862–73.                            | 2010   | 122            |
| Chotikavanich et al. [25] | Production and activity of matrix metalloproteinase-9 on the ocular surface increase in dysfunctional tear syndrome.                                                                                                                                                                                                                   | Investigative Ophthalmology & Visual Science. 2009 Jul; 50(7): 3203–9. | 2009   | 120            |
dry eye established in this report. This was used until DEWS II was published in July 2017, which included a redefinition of dry eye.

The second cluster we found is related to the treatment. It shows that dry eye is a chronic pathology and how treatment is one of the main challenges for vision.
Figure 3: Citation network of cluster 2.

Figure 4: Citation network of cluster 3.
professionals. The cluster is led by the prospective case-control study of Yoon et al., published in 2007 in American Journal of Ophthalmology, where autologous serum was compared with umbilical cord serum eye drops in 48 patients with severe dry eye syndrome. Finding retina as a third cluster could seem surprising because retina has no bearing on the relationship between ocular surface and dry eye. However, it could be explained by the relationship between age and dry eye and between age and pathology of the retina. In other words, studies with
older people could shed light on different pathologies such as dry eye and retina problems. It would be worth carrying out further research in the future.

The fourth cluster is about refractive surgery. This is due to the fact that one of the most common complications of LASIK is dry eye. The most cited article in this cluster is a review from Ambrosio et al., published in 2008 in Journal of Refractive Surgery. They reviewed the scientific literature and summarized the experience of the authors to propose methods for decreasing dry eye after surgery.

Finally, the fifth cluster relates to quality of vision. This is one of the concerns for patients suffering from dry eye.

The absence of relationships among the clusters’ most cited articles is striking. We assumed we would find some
5. Conclusions

Dry eye is a very important field for researchers, with a very high number of publications and many connections among articles.

This citation network analysis shows that definition and classification of dry eye is still very important, most of the articles being related to this cluster. It is followed in relevance by treatment.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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