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Original Research

International publication trends in dry eye disease research: A bibliometric analysis

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ABSTRACT

Purpose: To perform a bibliometric analysis in the field of dry eye disease (DED) research to characterize the current international status of DED research and to identify the most effective actors (journals, countries, authors) involved in this field.
Methods: Scientometric methods were used to evaluate global scientific production and development trends in DED research, using the Web of Science Core Collection.
Results: The growth of the literature related to DED averaged 12.18% over the last 10 years. A total of 5522 original and review articles, published in 821 different journals, were identified. The USA was the most productive country with 34.53% of the overall articles studied and 46.10% of the overall citations. *The Ocular Surface* published a very high percentage of articles related to DED relative to the total number of articles published (31.87%). The most productive institutions and the most frequently cited articles were from the USA and Japan. A network visualization map for country collaboration revealed that most European countries developed most of their collaborations with countries belonging to their own continent, which was not the case for the USA or Japan. A total of 41,956 KeyWords Plus were found with an average of 7.6 (SD = 3.15) KeyWords Plus per article.
Conclusions: This study provides a broad view of the current status and trends in DED research and may help clinicians, researchers and policy makers better understand this research field and predict its dynamic directions.

1. Introduction

The term "dry eye disease" (DED), often synonymous with "dry eye syndrome," "keratoconjunctivitis sicca," and "dysfunctional lacrimal functional unit," is a multifactorial disease of the tears and ocular surface that results in symptoms of discomfort, visual disturbance, and tear film instability with potential damage to the ocular surface [1]. Generally, DED patients may experience ocular discomfort, including but not limited to pain, burning sensation, foreign body sensation, grittiness, and tearing. Others may complain of dryness, ocular fatigue, and sometimes redness. DED is a common condition across populations because the prevalence of DED has been described up to 34% [2,3].

A bibliometric method is the application of quantitative and qualitative analysis to the publication of journals and articles and their accompanying citation counts over time [4,5]. It can characterize the current status of research fields by measuring scientific output of an institution or country and has played a great role in the past in governing policymaking [6] and better understanding scientific fields [7]. It also enables researchers to determine the range of research topics and identify new topics, and assists them in planning their research direction and predicting research trends [8]. A number of bibliometric studies have investigated the publishing trends in ophthalmology concerning the research output of

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1542-0124/

Abbreviations

DED	Dry eye disease
JCR	Journal Citation Reports
WoS	Web of Science

specific countries or areas [9,10], subspecialties [11–13], or the production of a selection of ophthalmology journals [14]. To the best of our knowledge, there are no bibliometric analyses that have explored research related to DED. This study used bibliometric tools to analyze DED articles retrieved on the Web of Science (Thomson Reuters Company) database and provides a retrospective and current view of the mainstream research on DED throughout the world.

2. Material and methods

The search for papers to be included in this study was carried out on 15 February 2017, using the database Science Citation Index Expanded (SCI-EXPANDED) via the Web of Science Core Collection (WoS) provided by Thomson Reuters (Philadelphia, PA, USA). The database was searched using the term "dry eye" in terms of "Topic" (title, abstract, author's keywords, and WoS-assigned keywords called KeyWords Plus) in order to retrieve all articles where the expression "dry eye" appeared, but also the expressions "dry eye disease" or "dry eye syndrome" and all possible variants (e.g., dry eye diseases). Only articles and reviews were included as document types (non-article-type documents such as meeting abstracts, editorial materials, proceedings papers, letters, book chapters, news items, corrections, and notes were excluded). Journal articles and reviews were used for the analysis because they accounted for the majority of document types that also included complete research ideas and results [15].

Data were downloaded from WoS in "Full record and cited references" and "Comma Separated Values" (CSV) formats. HISTCITE 12.3.17 (Thomson Reuters, Philadelphia, PA, USA) and Microsoft Excel 2013 (Microsoft, Redmond, WA, USA) software tools were used to analyze the data. Author's keywords and KeyWords Plus were analyzed in Microsoft Excel from raw data downloaded from WoS (CSV format). VOSviewer (Leiden University, Leiden, Netherlands) was used to generate the knowledge maps of countries related to DED research. Citation counts reflect all the papers obtained on 15 February 2017 when the WoS database search process for this study was conducted. The 2015 Journal Citation Reports (JCR) (Thomson Reuters, Philadelphia, PA, USA) was used to determine the Impact Factor (IF) and rank the journal in the "Ophthalmology" category of the JCR.

The average yearly growth rate of the literature related to DED was calculated as the mean percentage of the annual growth rate using the equation: (Annual Growth Rate = Current Year Total Number of Articles − Previous Year Total Number of Articles)/Previous Year Total Number of Articles [16]. The average yearly growth rate was also calculated for the whole WoS database. Using Excel software, the total number of articles related to DED per year was fitted to a linear equation as well as an exponential curve for our search strategy.

Countries, institutions, authors, journals, languages of publication, subject categories and most-cited articles were also examined. Institutions were determined using the "Organizations − Enhanced" field. Articles originating from England, Scotland, Northern Ireland, and Wales were reclassified as being from the United Kingdom (UK). To locate the most popular research topics and their trends, the author's keywords and KeyWords Plus were also investigated. KeyWords Plus supplies additional search terms generated by an automatic computer algorithm, extracted from titles of articles cited by authors in their bibliographies and footnotes, and substantially increases title-word and author-keyword indexing [17]. KeyWords Plus may be present for articles that have no author keywords or may include important terms not listed among the title, abstract or author keywords. The frequency of KeyWords Plus was calculated.

3. Results

3.1. Overall publication trends

The search in the WoS database resulted in a total of 5522 articles cited 104,234 times (mean 18.88 citations per article). The first article dealing with dry eye disease (DED) appeared in 1952, and the number of articles produced overall grew to 606 in 2016. Using the cumulative number of publications, we calculated the linear adjustment and the exponential adjustment and found $y = 73.539x - 145613$ with $r^2 = 0.5905$, and $y = 6^{-137} * e^{0,16x}$ with $r^2 = 0.9842$, respectively (Fig. 1). We also calculated that the average growth rate of the literature related to DED was 12.18% and 15.75% over the last 10 years and 20 years, respectively. We calculated that the average growth rate for the whole WoS database was 3.97% and 3.78% for the same periods. The difference in growth rates between the growth rate of eye diseases and all scientific production in the WoS database is equal to 8.21 (12.18−3.97.) and 11.97 (15.75−3.78) over the last 10 and 20 years, respectively.

3.2. Countries and institutions

Seventy-seven countries were identified and analysis was performed on 5522 (97.14%) articles; 158 (2.86%) articles were recorded without author information. The USA accounted for the largest number of articles published (Table 1). Interestingly, six countries (USA, Japan, People's Republic of China, France, Canada and Brazil) had a higher percentage of citations as compared to the percentage of articles they published, showing that the articles of these countries are more frequently cited. To further develop the country study, a network visualization map for country collaboration is shown in Fig. 2: This map shows that most European countries developed most of their collaborations with countries belonging to their own continent. In contrast, the USA collaborates more specifically with the People's Republic of China and/or Japan. Some of the most productive countries such as South Korea and Brazil, have developed fewer collaborations with other countries.

We also analyzed the main institutions implicated in the DED publication. Table 2 shows the output of the top 15 institutions for the 5522 articles studied. It was likewise significant that the USA also had the largest number of articles and citations, indicating that institutions in the USA played a crucial role in DED research. Twelve institutions have a higher percentage of citations as compared to the percentage of articles they published: for example, Harvard University contributed 5.43% of the articles related to DED but received 9.19% of the overall citations (nearly twice the expected value), showing that articles from this institution have a great scientific impact.

3.3. Authors and most-cited articles

The total number of authors retrieved in the 5522 articles related to DED was 27,566, an average of 4.99 authors per article. The number of different individual authors was 13,885. The great

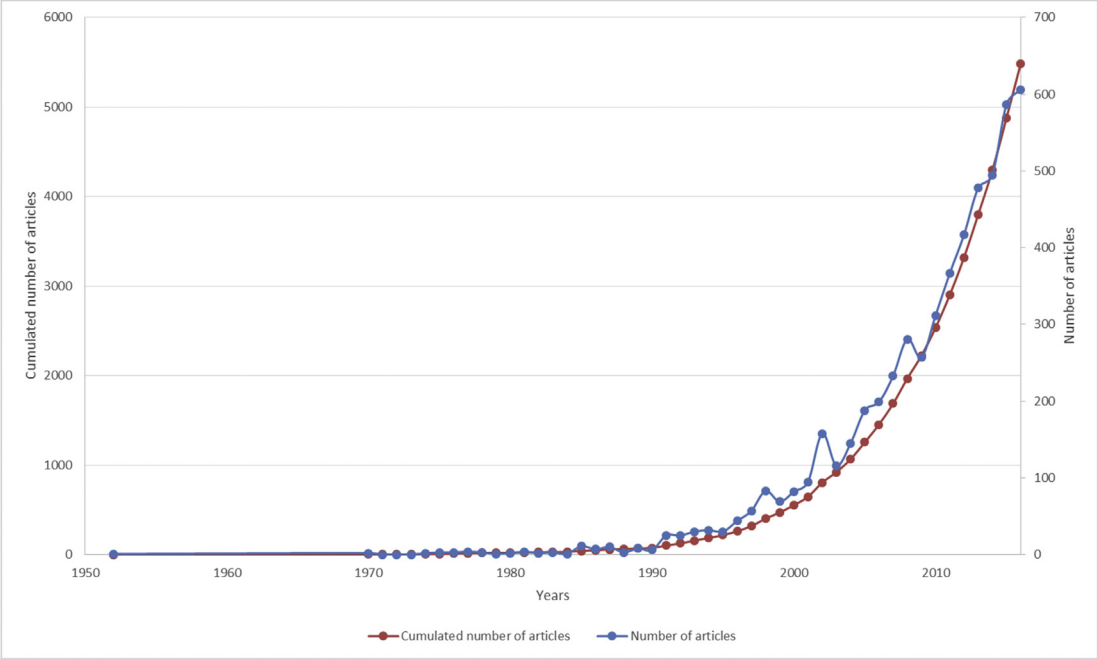

Fig. 1. Growth of the literature related to DED (annual number and total number of articles).

majority of authors ($n = 9934$; 71.55%) wrote only one article, 1846 (13.29%) wrote two, whereas 2105 (15.16%) wrote three or more. Table 3 presents the 15 most productive authors in DED research. This small group of 15 authors (0.11% of all authors) contributed a total of 1273 articles (23.05% of the overall articles) who were cited 46,126 times (44.25% of the overall citations).

Among these 5522 articles, the three most frequently cited articles were: "The importance of the omega-6/omega-3 fatty acid ratio in cardiovascular disease and other chronic diseases" by Simopoulos AP published in 2008 in *Experimental Biology and Medicine* (794 citations, 88.22 citations per year), "The definition and classification of dry eye disease: Report of the Definition and Classification Subcommittee of the International Dry Eye WorkShop (2007)" ["No authors listed" by decision of the Dry Eye WorkShop participants] published in 2007 in *The Ocular Surface* (669 citations, 66.9 citations per year) and "Reliability and validity of the ocular surface disease index" by Schiffman RM, Christianson MD, Jacobsen G, Hirsch JD, Reis BL, published in 2000 in *Archives of Ophthalmology* (668 citations, 39.29 citations per year). See Supplementary data for the following 17 most-cited articles.

Table 1
Top 15 most productive countries for DED research.

Country	No. of articles (%)	No. of citations (%)
USA	1907 (34.53)	48053 (46.10)
Japan	593 (10.74)	14736 (14.14)
United Kingdom	421 (7.62)	5368 (5.15)
People's R China	410 (7.42)	10221 (9.80)
Germany	373 (6.75)	6028 (5.78)
Italy	281 (5.09)	4540 (4.35)
Spain	274 (4.96)	5174 (4.96)
Turkey	248 (4.49)	2447 (2.35)
Australia	232 (4.20)	4199 (4.03)
South Korea	231 (4.18)	2043 (1.96)
France	196 (3.55)	3775 (3.62)
Canada	161 (2.92)	3100 (2.97)
Brazil	147 (2.66)	4774 (4.58)
India	142 (2.57)	1305 (1.25)
Singapore	106 (1.92)	1279 (1.23)

3.4. Publication patterns

A total of 5522 articles related to DED were published in a wide range of 821 journals. Out of these 821 journals, 467 (54.74%) published only one article. Only 60 (7.31%) journals published more than ten articles. Table 4 lists the 20 journals with the greatest number of papers published on DED. These top 20 journals published 2947 articles, corresponding to 53.37% of the total articles on DED. These 2947 articles received 68,039 citations that correspond to 65.28% of the overall citations. For a more precise view of the publication trends over the last 9 years, we decided to divide the last 9 years into three periods (2008–2010, 2011–2013, 2014–2016): Some journals published a growing number of articles related to DED over these last 9 years while others published fewer articles (i.e., *JAMA Ophthalmology*).

The study of the top 20 most-cited articles showed that five were published in journals not belonging to the JCR "Ophthalmology" category (*Experimental Biology and Medicine*, *Biomedicine & Pharmacotherapy*, *The New England Journal of Medicine*, *Biomedicine & Pharmacotherapy* and the *International Journal of Pharmaceutics*). *The Ocular Surface* published a very high percentage of articles related to DED relative to the total number of articles published (31.87%), as compared to other journals. *JAMA Ophthalmology* and *Ophthalmology* have the highest number of citations per article considering DED research.

Thirteen languages of publication were identified in the 5522 articles retrieved. The three predominant languages were English (n = 5250; 95.07%), German (n = 140; 2.54%) and French (n = 78; 1.41%). All other languages (Portuguese Polish, Slovene, Spanish, Italian, Serbian, Turkish, Hungarian, Korean and Russian) amounted to less than 1%.

3.5. Subject categories and distribution of KeyWords Plus

Based on the JCR categories, the DED publication output data was distributed into subject categories. Quite logically the most frequent category was by far "Ophthalmology" ($n = 3892$; 70.48%)

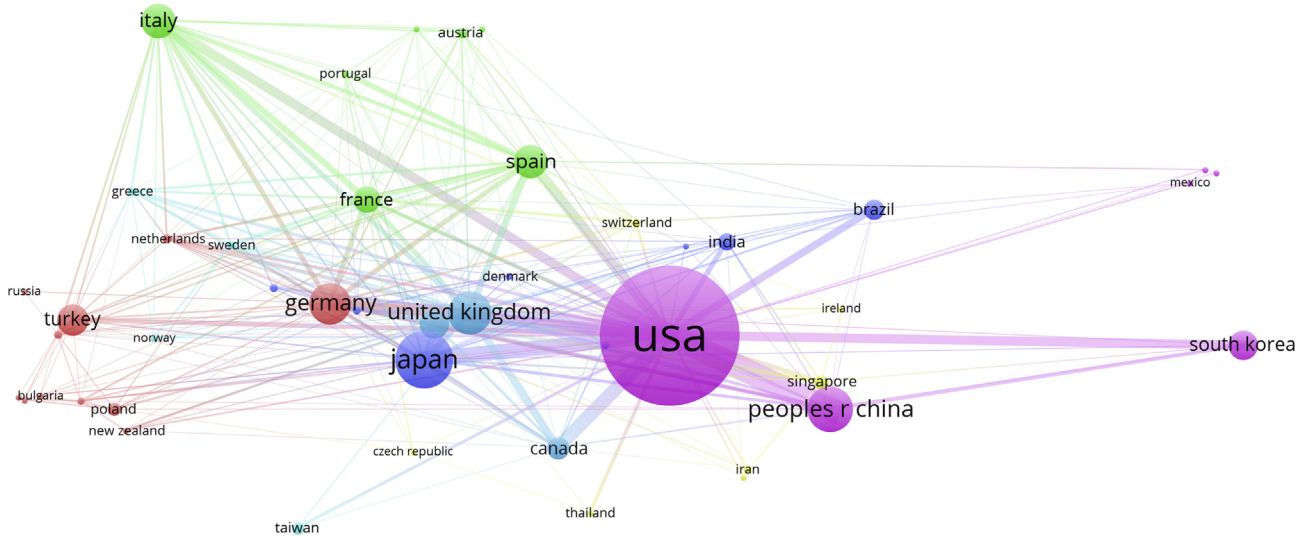

Fig. 2. Network visualization map for country collaboration. A minimum of five documents per country was set as the threshold and 50 countries were included in the map. The thickness of the link between any two countries is indicative of the extent of co-authorship (i.e., collaboration), and the colors of the circles indicate groups of countries with a high degree of collaboration.

Table 2
Top 15 most productive institutions for DED research.

Institution (country)	No. of articles (%)	No. of citations (%)
Harvard University (USA)	300 (5.43)	9577 (9.19)
Keio University (Japan)	246 (4.45)	7273 (6.98)
Baylor College of Medicine (USA)	148 (2.68)	5604 (5.38)
Tokyo Dental College (Japan)	142 (2.57)	6930 (6.65)
University of California System (USA)	140 (2.53)	2216 (2.13)
VA Boston Healthcare System (USA)	131 (2.37)	3910 (3.75)
Massachusetts Eye Ear Infirmary (USA)	115 (2.08)	3238 (3.11)
Allergan Pharmaceuticals Inc. (USA)	100 (1.81)	5698 (5.47)
University of Waterloo (Canada)	97 (1.76)	2129 (2.04)
Ohio State University (USA)	94 (1.70)	3889 (3.73)
University of Miami (USA)	93 (1.68)	3773 (3.62)
University of New South Wales Sydney (Australia)	87 (1.57)	1096 (1.05)
P. & M. Curie University XV-XX National Eye Center - APHP (France)	83 (1.50)	1480 (1.42)
Johns Hopkins University (USA)	78 (1.41)	2268 (2.18)
Kyoto Prefectural University of Medicine (Japan)	74 (1.34)	1968 (1.89)

followed by “Pharmacology & Pharmacy” (n = 312; 5.65%) and “Surgery” (n = 258; 4.67%) (see Supplementary data for the following seven categories).

The number of different author's keywords and KeyWords Plus (KeyWords Plus supplies additional search terms extracted from titles of articles cited by authors in their bibliographies and footnotes) totaled 6827 and 7690, respectively. A total of 17,784 author's keywords were found in 3505 articles (2017 articles did not have author's keywords) and the average number of keywords was 5.1 (SD = 1.82 per article). KeyWords Plus amounted to 41,956 and were found in 5522 articles; the average number of KeyWords Plus was 7.6 (SD = 3.15) per article. Because 2017 (36.52%) articles did not have author's keywords and to avoid bias in the analysis, we decided to proceed with the frequency analysis using only the KeyWords Plus, which were found in 100% of the articles studied. Table 5 lists the top 20 KeyWords Plus retrieved.

4. Discussion

This study sought to provide a detailed evaluation of the published literature on DED using the Science Citation Index Expanded (SCI-EXPANDED) database via the Web of Science Core Collection (WoS). To the best of our knowledge, such a bibliometric analysis related to DED has never been performed previously, and a network visualization map for country collaboration has never been applied to the field of ophthalmology. The WoS database used in this study, contrary to PubMed, which is also used for bibliometric analysis as we have done in the past [11,12], can quantify citations of articles and provide access to qualitative evaluation. Nevertheless, contrary to the WoS database, PubMed has the advantage of proposing a controlled vocabulary thesaurus: “Medical Subject Headings” (MeSH) (http://www.nlm.nih.gov/pubs/factsheets/mesh.html), which helps during the search process and helps map research fields in bibliometric analysis by analyzing the MeSH terms [11,18,19]. However, there are limitations in the present study: the counting of citations over time gives older articles advantages over newer articles, which can introduce bias in the interpretation of this parameter. Articles in languages other than English may not be included in the database and analyzed: the WoS database has been criticized for its heavy bias in favor of English-language journals [4,20]. Even though we tried to adjust our query in order to extract all articles dealing with DED in a significant way, some relevant articles may have been missed and some irrelevant articles may have been included (due to the large number of articles retrieved a

Table 3
Top 15 most productive authors in DED research. The institution is the last found in the most recent articles for each author.

Author	Institution	Number of articles (%)	Number of citations (%)	Mean citations per article	Number of years of activity	Mean number of articles per year of activity
Tsubota K	Keio University, Tokyo, Japan	266 (4.82)	8563 (8.22)	32.19	15	17.73
Pflugfelder SC	Baylor College of Medicine, Houston, TX, USA	152 (2.75)	8235 (7.90)	54.18	18	8.44
Dogru M	Keio University, Tokyo. Tokyo Dental College, Chiba, Japan	114 (2.06)	3342 (3.21)	29.32	16	7.13
Baudouin C	XV-XX National Eye Center, Paris, France. Versailles St Quentin en Yvelines University, AP HP, Versailles, France	90 (1.63)	3433 (3.29)	38.14	21	4.29
De Paiva CS	Baylor College of Medicine, Houston, TX, USA	73 (1.32)	2421 (2.32)	33.16	15	4.87
Stern ME	Allergan Pharmaceut Inc., Irvine, CA, USA	69 (1.25)	3736 (3.58)	54.14	19	3.63
Li DQ	Baylor College of Medicine, Houston, TX, USA	61 (1.10)	2609 (2.50)	42.77	15	4.07
Yokoi N	Kyoto Prefectural University of Medicine, Kyoto, Japan	61 (1.10)	1937 (1.86)	31.75	21	2.90
Kinoshita S	Kyoto Prefectural University of Medicine, Kyoto, Japan	58 (1.05)	1909 (1.83)	32.91	20	2.90
Dana R	Harvard Med School, Boston, MA, USA.	56 (1.01)	1758 (1.69)	31.39	12	4.67
Nichols JJ	University of Alabama, Birmingham, AL, USA	56 (1.01)	1765 (1.69)	31.52	16	3.50
Nichols KK	University of Alabama, Birmingham, AL, USA	55 (0.99)	2470 (2.37)	44.91	17	3.24
Goto E	Keio University, Tokyo. Tokyo Dental College, Chiba, Japan	54 (0.98)	2270 (2.18)	42.04	14	3.86
Matsumoto Y	Keio University, Tokyo, Japan	54 (0.98)	1678 (1.61)	31.07	13	4.15
Shimazaki J	Keio University, Tokyo. Tokyo Dental College, Chiba, Japan	54 (0.98)	2755 (2.64)	51.02	21	2.57

manual analysis to control the relevance of articles was impossible).

With an average growth of 15.75% over the last 20 years, the growth of DED publications is higher than for the whole WoS database (3.78%) and is exponential. This indicates great interest in DED on the part of the scientific community, “an attractive topic in science” according to Michon et al. [21] with its high publication

Table 4
Top 20 most productive journals on DED research.

Journal	1952–2016 ($n = 5522$)					2008–2010 ($n = 850$)	2011–2013 ($n = 1262$)	2014–2016 ($n = 1688$)
	Impact Factor[a] (JCR rank[b])	No. of articles (%)	No. of citations (%)	Citations per article	% Of articles related to DED[c]	No. of articles (%)	No. of articles (%)	No. of articles (%)
Cornea	1.833 (26)	500 (9.05)	10758 (10.32)	21.52	8.20	79 (9.29)	105 (8.32)	136 (8.06)
Investigative Ophthalmology & Visual Science	3.427 (6)	477 (8.64)	13554 (13)	28.42	0.50	71 (8.35)	153 (12.12)	144 (8.53)
Optometry and Vision Science	1.442 (37)	222 (4.02)	3874 (3.72)	17.45	4.42	45 (5.29)	51 (4.04)	76 (4.50)
American Journal of Ophthalmology	3.831 (5)	159 (2.88)	6297 (6.04)	39.60	0.91	20 (2.35)	26 (2.06)	41 (2.43)
Current Eye Research	2.025 (22)	151 (2.73)	2443 (2.34)	16.18	2.96	20 (2.35)	40 (3.17)	54 (3.2)
Ophthalmology	6.75 (2)	147 (2.66)	6798 (6.52)	46.24	0.90	20 (2.35)	32 (2.54)	23 (1.36)
British Journal of Ophthalmology	3.036 (10)	140 (2.54)	4050 (3.89)	28.93	1.02	19 (2.23)	19 (1.51)	39 (2.31)
Experimental Eye Research	2.998 (13)	135 (2.44)	3397 (3.26)	25.16	1.64	20 (2.35)	26 (2.06)	41 (2.43)
The Ocular Surface	4.477 (3)	131 (2.37)	3328 (3.19)	25.40	31.87	25 (2.94)	26 (2.06)	47 (2.78)
Eye & Contact Lens-Science and Clinical Practice	1.252 (40)	110 (1.99)	770 (0.74)	7.00	15.41	31 (3.65)	25 (1.98)	48 (2.84)
Plos One[d]	3.057	95 (1.72)	695 (0.67)	7.32	0.06	2 (0.23)	35 (2.77)	56 (3.32)
Contact Lens & Anterior Eye	1.752 (29)	91 (1.65)	607 (0.58)	6.67	15.56	12 (1.41)	25 (1.98)	53 (3.14)
Journal of Ocular Pharmacology and Therapeutics	1.754 (28)	89 (1.61)	993 (0.95)	11.16	5.17	10 (1.18)	30 (2.38)	24 (1.42)
Graefes Archive for Clinical and Experimental Ophthalmology	1.991 (23)	88 (1.59)	1619 (1.55)	18.40	1.39	9 (1.06)	22 (1.74)	12 (0.71)
JAMA Ophthalmology[e]	4.34 (4)	76 (1.38)	4313 (4.14)	56.75	0.48	17 (2)	16 (1.27)	9 (0.53)
Molecular Vision	2.11 (20)	70 (1.27)	1041 (1)	14.87	2.15	20 (2.35)	32 (2.54)	16 (0.95)
Eye	2.213 (19)	68 (1.23)	1496 (1.44)	22.00	0.86	15 (1.76)	10 (0.79)	13 (0.77)
Journal Francais d'Ophtalmologie	0.391 (56)	68 (1.23)	471 (0.45)	6.93	1.17	8 (0.94)	9 (0.71)	13 (0.77)
Journal of Cataract and Refractive Surgery	3.02 (12)	65 (1.18)	1270 (1.22)	19.54	0.60	10 (1.18)	9 (0.71)	15 (0.89)
Klinische Monatsblatter Fur Augenheilkunde	0.689 (52)	65 (1.18)	265 (0.25)	4.08	0.51	4 (0.47)	13 (1.03)	11 (0.65)

JCR. Journal Citation Report.
Journal of Ocular Pharmacology and Therapeutics also belongs to the “Pharmacology & Pharmacy” category (rank 169/255) of the JCR. Molecular Vision also belongs to the “Biochemistry & Molecular Biology” category (rank 196/289) of the JCR. Journal of Cataract and Refractive Surgery also belongs to the “Surgery” category of the JCR (rank 35/200).

[a] Impact factor for 2015.
[b] Ranking of journals in the JCR “Ophthalmology” category (2015). This category includes 56 journals.
[c] Percentage of articles related to DED relative to the total number of articles published.
[d] JCR category: “Multidisciplinary Sciences” (Rank 11/63).
[e] Formerly Archives of Ophthalmology.

Table 5
Top 20 KeyWords Plus for DED research. KeyWords Plus provides additional search terms generated by an automatic computer algorithm, extracted from titles of articles cited by authors in their bibliographies and footnotes.

KeyWords Plus	Number of articles with this keyword (%)
Dry Eye	1457 (26.39)
Ocular Surface	906 (16.41)
Disease	770 (13.94)
Keratoconjunctivitis Sicca	572 (10.36)
Prevalence	488 (8.84)
Sjögren's Syndrome	478 (8.66)
Symptoms	379 (6.86)
Expression	366 (6.63)
Dry Eye Disease	363 (6.57)
Tear Film	328 (5.94)
Meibomian Gland Dysfunction	261 (4.72)
Risk Factors	225 (4.07)
Efficacy	214 (3.88)
Diagnosis	213 (3.86)
In-Situ Keratomileusis	212 (3.84)
Cells	203 (3.68)
Dry Eye Syndrome	190 (3.44)
Management	188 (3.40)
Population	184 (3.33)
Film	181 (3.28)

rate [22]. This interest may be due to the high prevalence of DED [2,3] and the development of strategies for diagnosis and treatment [23]. The USA is by far the most productive country and is responsible for the greatest of number of citations. Interestingly, Japan was the second most productive country, a rank this country has never reached in other bibliometric analyses in the field of ophthalmology [11,12,24].

Interestingly, a very small proportion of the authors were responsible for nearly a quarter of the articles related to DED and for nearly a half of the total article citations related to DED. The same phenomenon was found for publication patterns that showed a high concentration of articles and citations in a few journals, which is consistent with former studies [16,25,26]. *The Ocular Surface* is the journal that by far publishes the highest percentage of articles related to DED (31.87%) and should be considered as the most specialized journal in DED. Among the 20 most productive journals, it is interesting to note that the mega-journal *Plos One* is the only journal belonging to the "Multidisciplinary Sciences" JCR category; all the other journals logically belong to the "ophthalmology" JCR category, confirming the important role *Plos One* plays in the dissemination of information in life sciences, despite accepting submissions from all areas of science [27].

The analysis of keywords provides details of the articles' subject and offers additional information on research trends [28], and they have proved to be important in monitoring the development of science [29]. As in former studies [29,30], we initially decided to analyze author's keywords and KeyWords Plus. In agreement with previous observations [28], our search yielded many more KeyWords Plus than author's keywords, and contrary to KeyWords Plus, we found that author's keywords were present only in 64.47% of articles, very close to the value reported by Névéol A, et al. [31]. The absence of author's keywords in some articles can be explained by the fact that some journals (e.g., *British Journal of Ophthalmology*) do not require authors to provide keywords during the submission process, whereas some do (e.g., *The Ocular Surface*). It has also been proven that the "lack of standardization among author's keywords can greatly hamper the analysis, since the use of synonymous terms, spelling variations, abbreviations, and more or less specific terms made the exact interpretation of the author's intended meaning difficult" [32]. Moreover, "KeyWords Plus are as effective as Author Keywords in terms of bibliometric analyses investigating the knowledge structure of scientific fields, but it is less comprehensive in representing an article's content" because KeyWords Plus are more broadly descriptive [28]. Consequently, we decided to perform a frequency analysis only for KeyWords Plus. This analysis of the top 20 KeyWords Plus maps the DED research field. Most of the synonyms of "dry eye" are found in this list ("dry eye disease," "dry eye syndrome" and "keratoconjunctivitis sicca"), showing that using "dry eye" in terms of "Topic" during the search process in the WoS database efficiently retrieved articles related to DED. One must note that the search for DED in the PubMed database would have been different because it would have used the MeSH term "Dry eye syndrome"; "Dry eye disease" is not the term used in the MeSH vocabulary and its use in no way leads to the discovery of synonyms allowing an efficient bibliographic search [33].

5. Conclusions

The results of this study may be helpful for all those involved in worldwide DED research. Indeed, this study can help clinicians and researchers better understand DED research worldwide and be useful, for example, in choosing appropriate journals for publication and collaborations. Fellows choosing an institution for advanced work may also be interested in such an analysis. Journals can determine where they stand in relation to other journals in publishing articles related to DED. Governments and policy makers can also ascertain the most effective countries and institutions in the world in this field, and this analysis may assist them to apprehend and predict the dynamic directions of DED research and to target resources so that further developments can be encouraged, supported and monitored.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jtos.2017.10.002.

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