Bibliometric analysis of the meibomian gland literature

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The Ocular Surface
Bibliometric analysis of the meibomian gland literature
--Manuscript Draft--

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Keywords: bibliometric analysis, citations, impact, meibomian gland, meibum, publication metrics

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Opposed Reviewers:

Response to Reviewers: THEOCULARSURFACE-D-21-00011-R3
March 10, 2021
The authors of the Research Correspondence submission entitled "Bibliometric analysis of the meibomian gland literature" are thankful to the editor/reviewer for their helpful suggestions to improve manuscript. Below are detailed comments that are included in the revision of the submission that we hope address the critiques raised. We have also condensed two paragraphs on authors, countries, affiliations, and journals and revised Figure 1 to summarize leaders in these areas (per the off-line suggestion of the Editor in Chief). Thank you again for these helpful comments.

Editor and Reviewer comments:
Thank you for resubmitting the manuscript. However, we need more insightful contents than just a list of facts. For example, we'd like ask you to provide the details of highly cited papers instead of highly cited institutions. We've requested it so far, but we need a perspective for the future research of MGD.

RESPONSE: Thank you for this excellent idea. We have collapsed text in the manuscript regarding authors, institutions, countries, and journals and summarized top leaders along these lines in Figure 1. This allows for additional space to discuss in depth further details of highly cited and uncited papers (or trends along these lines as they relate to current and future MGD research). This has been revised in the manuscript as follows:

"While citation analyses can be helpful in identifying trends in research, they do have limitations. For instance, older research is more likely to have higher citation counts than more recent research simply due to time, which itself allows for the accumulation of citations. Along these lines, it is clear from the very most current research in MGD that particularly over the very most recent years that therapeutic and diagnostic approaches are key areas of research in MGD. For instance, there is no doubt that innovations in imaging approaches (e.g., optical coherence tomography, meibography, confocal microscopy) are of vital importance to the field of MGD research, particularly
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January 11, 2021

Dear Dr. Djalilian,

My coauthors and I wish to submit a new manuscript entitled “Bibliometric analysis of the meibomian gland literature” for consideration as a short Research Correspondence by *The Ocular Surface*. We confirm that this work is original and has not been published nor is it currently under consideration for publication elsewhere.

This paper reports on the important observations of the growing body of literature on meibomian glands in the context of ocular surface disease and reports on the most impactful articles, authors, journals, countries and affiliations.

We believe this work will be of interest and highly valuable to the ocular surface community who study dry eye and the meibomian glands. The appendix is intended to be supplementary material, available online to the readership.

Thank you for your consideration of this manuscript.

Sincerely,

Corresponding Author

Jason J. Nichols, OD MPH PhD | Associate Vice President for Industry Research & Professor
Office of the Vice President for Research
Office of Industry Engagement
UAB | The University of Alabama at Birmingham
AB 714A | 1720 2nd Avenue South | Birmingham, AL 35294-0107
THEOCULARSURFACE-D-21-00011-R3

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RESEARCH CORRESPONDENCE

Bibliometric analysis of the meibomian gland literature

Jason J. Nichols, OD, MPH, PhD
Lyndon W. Jones, DSc, FCOptom
Philip B. Morgan, PhD
Nathan Efron, AC, DSc, PhD

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b. Centre for Ocular Research & Education (CORE), School of Optometry and Vision Science, University of Waterloo, Waterloo, Ontario, Canada and Centre for Eye and Vision Research (CEVR), 17W Hong Kong Science Park, Hong Kong
c. Eurolens Research, Division of Pharmacy and Optometry, The University of Manchester, Manchester, United Kingdom
d. School of Optometry and Vision Science, Queensland University of Technology, Kelvin Grove, Queensland, Australia

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Word Count (text only): 1,209

References: 11

Figures: 1

Supplementary Tables: 6

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Financial support
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The MGs produce a distinct lipid secretion (‘meibum’) made up of a variety of lipid classes, mostly composed of nonpolar wax and cholesterol esters, although other nonpolar and polar lipids are certainly known to exist in the meibum.[2] The normal function of meibum is to make its way to the tear film lipid layer, ultimately forming a resistive barrier to evaporation of the aqueous component of the tear film. In disease, the MGs lose their ability to secrete a normal meibum composition and/or are impeded due to factors such as atrophy of the MGs, keratinization of the orifice of the gland from which the meibum is secreted onto the eyelid margin, or bacterial colonization of the eyelid, altering the secretion itself once expressed.[3, 4] These conditions today are known as blepharitis, including anterior and posterior blepharitis (which includes meibomian gland dysfunction).[5]

Given the extensive study of MGs, a bibliometric analysis is warranted to acknowledge and celebrate those contributing to this important part of ophthalmic research.

A bibliometric search was undertaken on January 5, 2021 of the titles of papers on the Scopus database. The goals of the search were to identify the most relevant meibomian gland-related documents published in peer-reviewed journals that are primarily meibomian gland driven, rather than to include secondary MG themes in this search; thus,
only ‘title’ identifiers were used to capture this field of research with the highest sensitivity and specificity. To identify MG-related articles, the following search terms was used:

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The 25 most highly cited papers were determined from the total list of 1,462 papers found. The search term above was also limited to the last 10 years to determine the top contemporary articles in the field of meibomian gland research. A subject-specific meibomian gland-related h-index (h_{MG}-index) was derived for authors, institutions, countries and journals to serve as a measure of impact in the field.[6] The top constituents of each category were ranked by h_{MG}-index and tabulated for consideration.

The h_{MG}-index of the field was determined to be 85. The 1,462 papers have been cited a total of 32,657 times, and 18.2% of these papers have never been cited. The number of papers in the field published each year between 1849 and 2020 is shown in Figure 1, with a rapid increase evident from 2008.

The 25 most highly cited papers are listed in Table 1 of the Supplementary Data. Seven of the top 25 papers are affiliated with the International Workshop on Meibomian Gland Dysfunction conducted under the auspices of the Tear Film and Ocular Surface Society (TFOS), including the paper ranked #1 by first author Erik Knop (“anatomy, physiology, and pathophysiology of the meibomian glands”).[7] Outside of this, six cover MG
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Table 2 shows the top 10 contemporary articles related to the study of the meibomian glands. It is clear that the top cited contemporary literature relates to the treatment of meibomian gland dysfunction (5 of 10 articles) and assessment of the meibomian glands and/or lipid layer (4 of 10 articles); the remaining (and top cited) article is focused on the pathophysiology of meibomian gland dysfunction.

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Tables 3, 4, 5, and 6 of the Supplementary Data lists the 10 most impactful authors, institutions, countries, and journals publishing meibomian gland-related articles, respectively. This is also summarized in Figure 1. This bibliometric analysis has summarized the most important papers and themes in the field of the study of the meibomian glands. It is clear that the TFOS International Workshop
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FINANCIAL DISCLOSURES

Jason Nichols: In 2019 and 2020, Dr. Jason J. Nichols has received honoraria from Paragon Vision Sciences and CooperVision. He has also received research funding from Alcon, Bruder, Johnson and Johnson Vision, and Mallinckrodt over the last 3 years. Also, Dr. Kelly Nichols is the spouse of Dr. Jason Nichols, extending her declarations to him. In the past 12 months, Dr. Kelly Nichols has consulted for and received honorarium from: Bruder, Dompe, Kala, Novartis/Shire (Medical Exchange International), Osmotica, Oyster Point, Sight Sciences, Tear Film Innovations/Alcon/Acquiom, Thea, Tarsus, and TopiVert. She has received research funding from: Allergan, Kala, and Tear Science.

Phillip Morgan: Nothing to declare.

Lyndon Jones: Over the past 3 years Dr Jones’ research group (CORE) or he personally has received research support or lectureship honoraria from: Alcon, Allergan, CooperVision, GL Chemtec, iMed Pharma, J&J Vision, Lubris, Menicon, Nature’s Way, Novartis, Ote, PS Therapy, Safilens, Santen, Shire, SightGlass and Visioneering. Dr Jones is also a consultant and/or serves on an advisory board for Alcon, CooperVision, J&J Vision, Novartis and Ophtecs.

Nathan Efron: Nothing to declare.

REFERENCES


Figure Caption

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Nathan Efron: Nothing to declare.

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Figure Caption

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Total publications: 1,462
Total citations: 32,657
h-index: 85
Publications with no citations: 18.2%

Key metrics:
- Most impactful author: James McCulley (h-index = 27)
- Most prolific author: Reiko Arita (48 papers)
- Most impactful institution: UT Southwestern Medical School/Center (United States) (h-index = 32)
- Most prolific institution: Harvard University (United States) (81 papers)
- Most impactful country: United States (h-index = 71)
- Most prolific country: United States (549 papers)
- Most impactful journal: Investigative Ophthalmology and Visual Science (h-index = 41)
- Most prolific journal: Cornea (130 papers)
Table 1. Top 25 most highly cited meibomian gland-related articles ranked by number of citations.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Title</th>
<th>First Author</th>
<th>Journal</th>
<th>Year, Volume &amp; Pages</th>
<th>Citations</th>
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<tbody>
<tr>
<td>1</td>
<td>The international workshop on meibomian gland dysfunction: Report of the subcommittee on anatomy, physiology, and pathophysiology of the meibomian gland</td>
<td>Erik Knop</td>
<td>Investigative Ophthalmology and Visual Science</td>
<td>2011; 52; 1938-78</td>
<td>449</td>
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<td>2</td>
<td>The international workshop on meibomian gland dysfunction: Executive summary</td>
<td>Kelly Nichols</td>
<td>Investigative Ophthalmology and Visual Science</td>
<td>2011; 52; 1922-9</td>
<td>435</td>
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<td>3</td>
<td>The international workshop on meibomian gland dysfunction: Report of the definition and classification subcommittee</td>
<td>Daniel Nelson</td>
<td>Investigative Ophthalmology and Visual Science</td>
<td>2011; 52; 1930-7</td>
<td>368</td>
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<td>4</td>
<td>Noncontact infrared meibography to document age-related changes of the meibomian glands in a normal population</td>
<td>Reiko Arita</td>
<td>Ophthalmology</td>
<td>2008; 115; 911-5</td>
<td>352</td>
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<td>6</td>
<td>Ocular surface changes and discomfort in patients with meibomian gland dysfunction</td>
<td>Jun Shimazaki</td>
<td>Archives of Ophthalmology</td>
<td>1995; 113; 1266-70</td>
<td>321</td>
</tr>
<tr>
<td>7</td>
<td>Meibomian gland dysfunction: A clinical scheme for description, diagnosis, classification, and grading</td>
<td>Gary Foulks</td>
<td>The Ocular Surface</td>
<td>2003; 1; 107-26</td>
<td>299</td>
</tr>
<tr>
<td>8</td>
<td>The international workshop on meibomian gland dysfunction: Report of the subcommittee on management and treatment of meibomian gland dysfunction</td>
<td>Gerd Geerling</td>
<td>Investigative Ophthalmology and Visual Science</td>
<td>2011; 52; 2050-64</td>
<td>296</td>
</tr>
<tr>
<td>10</td>
<td>Ocular evaporation in meibomian gland dysfunction and dry eye</td>
<td>William Mathers</td>
<td>Ophthalmology</td>
<td>1993; 100; 347-51</td>
<td>231</td>
</tr>
<tr>
<td>11</td>
<td>Meibomian gland disease. Classification and grading of lid changes</td>
<td>Anthony Bron</td>
<td>Eye</td>
<td>1991; 5; 395-411</td>
<td>224</td>
</tr>
<tr>
<td>12</td>
<td>The contribution of meibomian disease to dry eye</td>
<td>Anthony Bron</td>
<td>The Ocular Surface</td>
<td>2004; 2; 149-64</td>
<td>223</td>
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<td>13</td>
<td>Meibomian gland dysfunction</td>
<td>Paul Driver</td>
<td>Survey of Ophthalmology</td>
<td>1996; 40; 343-67</td>
<td>219</td>
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<tr>
<td>14</td>
<td>Classification of chronic blepharitis</td>
<td>James McCulley</td>
<td>Ophthalmology</td>
<td>1982; 89; 1173-80</td>
<td>215</td>
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<tr>
<td></td>
<td>Title</td>
<td>Author</td>
<td>Journal</td>
<td>Year</td>
<td>Volume</td>
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<tr>
<td>16</td>
<td>Targeted disruption of stearoyl-CoA desaturase1 gene in mice causes atrophy of sebaceous and meibomian glands and depletion of wax esters in the eyelid</td>
<td>Makoto Miyazaki</td>
<td>Journal of Nutrition</td>
<td>2001</td>
<td>131</td>
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<td>18</td>
<td>Effect of androgen deficiency on the human meibomian gland and ocular surface</td>
<td>Kathleen Krenzer</td>
<td>Journal of Clinical Endocrinology and Metabolism</td>
<td>2000</td>
<td>85</td>
</tr>
<tr>
<td>20</td>
<td>Contact lens wear is associated with decrease of meibomian glands</td>
<td>Reiko Arita</td>
<td>Ophthalmology</td>
<td>2009</td>
<td>116</td>
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<tr>
<td>21</td>
<td>Meibomian gland dysfunction in chronic blepharitis</td>
<td>William Mathers</td>
<td>Cornea</td>
<td>1991</td>
<td>10</td>
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<tr>
<td>22</td>
<td>Proposed diagnostic criteria for obstructive meibomian gland dysfunction</td>
<td>Reiko Arita</td>
<td>Ophthalmology</td>
<td>2009</td>
<td>116</td>
</tr>
<tr>
<td>23</td>
<td>Revisiting the vicious cycle of dry eye disease: A focus on the pathophysiology of meibomian gland dysfunction</td>
<td>Christophe Baudouin</td>
<td>British Journal of Ophthalmology</td>
<td>2016</td>
<td>100</td>
</tr>
<tr>
<td>24</td>
<td>Pathogenic role of Demodex mites in blepharitis</td>
<td>Jingbo Liu</td>
<td>Current Opinion in Allergy and Clinical Immunology</td>
<td>2010</td>
<td>10</td>
</tr>
</tbody>
</table>
Table 2. Top 10 most highly cited meibomian gland-related articles of the last 10 years ranked by number of citations.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Title</th>
<th>First Author</th>
<th>Journal</th>
<th>Year, Volume &amp; Pages</th>
<th>Citations</th>
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<tbody>
<tr>
<td>1</td>
<td>Revisiting the vicious circle of dry eye disease: A focus on the pathophysiology of meibomian gland dysfunction</td>
<td>Christophe Baudouin</td>
<td>British Journal of Ophthalmology</td>
<td>2016 100; 300-6</td>
<td>147</td>
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<tr>
<td>2</td>
<td>A new system, the LipiFlow, for the treatment of meibomian gland dysfunction</td>
<td>Stephen Lane</td>
<td>Cornea</td>
<td>2012 31; 396-404</td>
<td>121</td>
</tr>
<tr>
<td>3</td>
<td>Evaluation of lipid layer thickness measurement of the tear film as a diagnostic tool for meibomian gland dysfunction</td>
<td>David Finis</td>
<td>Cornea</td>
<td>2013 32; 1549-53</td>
<td>108</td>
</tr>
<tr>
<td>4</td>
<td>Comparison of subjective grading and objective assessment in meibography</td>
<td>Heiko Pult</td>
<td>Contact Lens and Anterior Eye</td>
<td>2013 36; 22-7</td>
<td>102</td>
</tr>
<tr>
<td>5</td>
<td>Infrared imaging of the meibomian gland structure using a novel keratography</td>
<td>Sruthi Srinivasan</td>
<td>Optometry and Vision Science</td>
<td>2012 89; 788-94</td>
<td>102</td>
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<tr>
<td>6</td>
<td>Prospective trial of intense pulsed light for the treatment of meibomian gland dysfunction</td>
<td>Jennifer Craig</td>
<td>Investigative Ophthalmology and Visual Science</td>
<td>2015 56; 1965-70</td>
<td>101</td>
</tr>
<tr>
<td>7</td>
<td>Intense pulsed light treatment for dry eye disease due to meibomian gland dysfunction; a 3-year retrospective study</td>
<td>Rolando Toyos</td>
<td>Photomedicine and Laser Surgery</td>
<td>2015 33; 41-6</td>
<td>97</td>
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<tr>
<td>8</td>
<td>Correlation between quantitative measurements of the tear film lipid layer thickness and meibomian gland loss in patients with obstructive meibomian gland dysfunction and normal controls</td>
<td>Youngsub Eom</td>
<td>American Journal of Ophthalmology</td>
<td>2013 155; 1104-10</td>
<td>95</td>
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<td>9</td>
<td>Interventions for chronic blepharitis</td>
<td>Kristina Lindsley</td>
<td>Cochrane database of systematic reviews</td>
<td>2012</td>
<td>88</td>
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<tr>
<td>10</td>
<td>Topical azithromycin and oral doxycycline therapy of meibomian gland dysfunction: A comparative clinical trial and spectroscopic pilot study</td>
<td>Gary Foulks</td>
<td>Cornea</td>
<td>2013 32; 44-53</td>
<td>85</td>
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</tbody>
</table>
Table 3. Top authors of meibomian gland-related articles, ranked by author h\textsubscript{MG}-index.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Author</th>
<th>h\textsubscript{MG}-index</th>
<th>Paper count</th>
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<tbody>
<tr>
<td>1</td>
<td>James McCulley</td>
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<td>2</td>
<td>David Sullivan</td>
<td>25</td>
<td>47</td>
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<tr>
<td>3</td>
<td>Reiko Arita</td>
<td>21</td>
<td>48</td>
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<tr>
<td>4</td>
<td>Kazuo Tsubota</td>
<td>21</td>
<td>31</td>
</tr>
<tr>
<td>5</td>
<td>Igor Butovich</td>
<td>20</td>
<td>29</td>
</tr>
<tr>
<td>6</td>
<td>Douglas Borchman</td>
<td>18</td>
<td>31</td>
</tr>
<tr>
<td>7</td>
<td>James Jester</td>
<td>18</td>
<td>30</td>
</tr>
<tr>
<td>8</td>
<td>Gary Foulks</td>
<td>18</td>
<td>21</td>
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<tr>
<td>9</td>
<td>Shiro Amano</td>
<td>17</td>
<td>23</td>
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<tr>
<td>10</td>
<td>Donald Korb</td>
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<tr>
<td>11</td>
<td>John Tiffany</td>
<td>16</td>
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<tr>
<td>12</td>
<td>Thomas Millar</td>
<td>15</td>
<td>17</td>
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<tr>
<td>13</td>
<td>Ward Shine</td>
<td>14</td>
<td>16</td>
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<tr>
<td>14</td>
<td>Marta Yappert</td>
<td>14</td>
<td>16</td>
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<td>15</td>
<td>Kelly Nichols</td>
<td>13</td>
<td>28</td>
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<td>16</td>
<td>Caroline Blackie</td>
<td>13</td>
<td>16</td>
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<tr>
<td>17</td>
<td>Anthony Bron</td>
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<td>15</td>
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<tr>
<td>18</td>
<td>Jun Shimazaki</td>
<td>12</td>
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<tr>
<td>19</td>
<td>Nicholas Nicolaides</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>20</td>
<td>Tomo Suzuki</td>
<td>11</td>
<td>19</td>
</tr>
</tbody>
</table>

*Authors with $\leq$ 11 papers and $h_{\text{MG}} \leq$ 11: Louis Tong (11), Norihiko Yokoi (11), Donald Brown (10), Michael Dougherty (10), Murat Dogru (10), Wendy Kam (10), Poonam Mudgil (10), Ronald Smith (10), Yang Liu (9), Naoyuki Morishige (9), Jason Nichols (9), Frank Schirra (9), Rika Shirakawa (9), Jennifer Craig (8), Shima Fukuoka (8), Sruthi Srinivasan (8), Lyndon Jones (7), Ho-sik Hwang (5)
Table 4. Top institutions of meibomian gland-related articles, ranked by institution \( h_{mg} \)-index.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Institution</th>
<th>Country</th>
<th>( h_{MG} )-index</th>
<th>Paper count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UT Southwestern Medical School/Center(^a)</td>
<td>United States</td>
<td>32</td>
<td>55</td>
</tr>
<tr>
<td>2</td>
<td>Harvard University(^b)</td>
<td>United States</td>
<td>31</td>
<td>81</td>
</tr>
<tr>
<td>3</td>
<td>Keio University/School of Medicine</td>
<td>Japan</td>
<td>24</td>
<td>37</td>
</tr>
<tr>
<td>4</td>
<td>University of Oxford(^c)</td>
<td>United Kingdom</td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td>5</td>
<td>University of Louisville</td>
<td>United States</td>
<td>19</td>
<td>36</td>
</tr>
<tr>
<td>6</td>
<td>Ohio State University</td>
<td>United States</td>
<td>16</td>
<td>27</td>
</tr>
<tr>
<td>7</td>
<td>Western Sydney University</td>
<td>Australia</td>
<td>15</td>
<td>22</td>
</tr>
<tr>
<td>8</td>
<td>Keio University School of Medicine</td>
<td>Japan</td>
<td>14</td>
<td>22</td>
</tr>
<tr>
<td>9</td>
<td>Tokyo Dental College</td>
<td>Japan</td>
<td>14</td>
<td>19</td>
</tr>
<tr>
<td>10</td>
<td>Kyoto Prefectural University of Medicine</td>
<td>Japan</td>
<td>13</td>
<td>26</td>
</tr>
</tbody>
</table>

\(^a\)Institutions with \( \leq 13 \) papers and \( h_{MG} \leq 13 \): Itoh Clinic (13), Korb Associated (13), University of California, Irvine (12), University of New South Wales (11), University of Southern California (11), National University of Singapore\(^d\) (10), Fudan University/Eye ENT Hospital (9), Friedrich-Alexander-Universitat Erlangen-Nurnberg (9), University of Auckland (8), University of Waterloo (8), TearScience Inc (8), University of Alabama at Birmingham (7), University of Houston (7), Catholic University of Korea (5).

\(^b\)Includes University of Texas at Dallas.

\(^c\)Includes Harvard Medical School, Schepens Eye Research Institute, Mass Eye and Ear Infirmary, Brigham and Women’s Hospital.

\(^d\)Includes University of Oxford Medical Sciences Division.

\(^d\)Includes National University of Singapore; Faculty of Medicine, Singapore Eye Research Institute; Singapore National Eye Centre; Duke-NUS Medical School Singapore; and Yong Loo Lin School of Medicine.
Table 5. Top countries of meibomian gland-related articles, ranked by country h\textsubscript{MG}-index.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>h\textsubscript{MG}-index</th>
<th>Paper count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>United States</td>
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<td>549</td>
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<td>2</td>
<td>Japan</td>
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<td>149</td>
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<td>3</td>
<td>United Kingdom</td>
<td>31</td>
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<td>China</td>
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<td>7</td>
<td>South Korea</td>
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<td>8</td>
<td>Italy</td>
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<td>9</td>
<td>Turkey</td>
<td>14</td>
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<tr>
<td>10</td>
<td>Spain</td>
<td>13</td>
<td>33</td>
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</tbody>
</table>

*Countries with ≤ 13 papers but h\textsubscript{MG} < 13: France (11), India (10), Canada (9), Singapore (11), Poland (10), Israel (8), New Zealand (8).
Table 6. Top journals for meibomian gland-related articles, ranked by journal hMG-index.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Journal</th>
<th>hMG-index</th>
<th>Paper count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Investigative Ophthalmology and Visual Science</td>
<td>41</td>
<td>117</td>
</tr>
<tr>
<td>2</td>
<td>Cornea</td>
<td>39</td>
<td>130</td>
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<tr>
<td>3</td>
<td>American Journal of Ophthalmology</td>
<td>20</td>
<td>55</td>
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<tr>
<td>4</td>
<td>Current Eye Research</td>
<td>20</td>
<td>43</td>
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<tr>
<td>5</td>
<td>British Journal of Ophthalmology</td>
<td>20</td>
<td>38</td>
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<tr>
<td>6</td>
<td>Experimental Eye Research</td>
<td>19</td>
<td>39</td>
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<tr>
<td>7</td>
<td>JAMA Ophthalmology&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>35</td>
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<tr>
<td>8</td>
<td>Ophthalmology&lt;sup&gt;b&lt;/sup&gt;</td>
<td>19</td>
<td>30</td>
</tr>
<tr>
<td>9</td>
<td>The Ocular Surface</td>
<td>18</td>
<td>70</td>
</tr>
<tr>
<td>10</td>
<td>Eye and Contact Lens&lt;sup&gt;lb&lt;/sup&gt;</td>
<td>18</td>
<td>39</td>
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</table>

<sup>a</sup>Journals with ≤18 papers and hMG < 18: Optometry and Vision Science (12), Contact Lens and Anterior Eye (8).

<sup>b</sup>a. Includes Archives of Ophthalmology
b. Includes CLAO Journal
ICMJE Form for Disclosure of Potential Conflicts of Interest

Instructions

The purpose of this form is to provide readers of your manuscript with information about your other interests that could influence how they receive and understand your work. The form is designed to be completed electronically and stored electronically. It contains programming that allows appropriate data display. Each author should submit a separate form and is responsible for the accuracy and completeness of the submitted information. The form is in six parts.

1. Identifying information.

2. The work under consideration for publication.

This section asks for information about the work that you have submitted for publication. The timeframe for this reporting is that of the work itself, from the initial conception and planning to the present. The requested information is about resources that you received, either directly or indirectly (via your institution), to enable you to complete the work. Checking "No" means that you did the work without receiving any financial support from any third party -- that is, the work was supported by funds from the same institution that pays your salary and that institution did not receive third-party funds with which to pay you. If you or your institution received funds from a third party to support the work, such as a government granting agency, charitable foundation or commercial sponsor, check "Yes".

3. Relevant financial activities outside the submitted work.

This section asks about your financial relationships with entities in the biomedical arena that could be perceived to influence, or that give the appearance of potentially influencing, what you wrote in the submitted work. You should disclose interactions with ANY entity that could be considered broadly relevant to the work. For example, if your article is about testing an epidermal growth factor receptor (EGF) antagonist in lung cancer, you should report all interactions with entities pursuing diagnostic or therapeutic strategies in cancer in general, not just in the area of EGF or lung cancer.

Report all sources of revenue paid (or promised to be paid) directly to you or your institution on your behalf over the 36 months prior to submission of the work. This should include all monies from sources with relevance to the submitted work, not just monies from the entity that sponsored the research. Please note that your interactions with the work's sponsor that are outside the submitted work should also be listed here. If there is any question, it is usually better to disclose a relationship than not to do so.

For grants you have received for work outside the submitted work, you should disclose support ONLY from entities that could be perceived to be affected financially by the published work, such as drug companies, or foundations supported by entities that could be perceived to have a financial stake in the outcome. Public funding sources, such as government agencies, charitable foundations or academic institutions, need not be disclosed. For example, if a government agency sponsored a study in which you have been involved and drugs were provided by a pharmaceutical company, you need only list the pharmaceutical company.


This section asks about patents and copyrights, whether pending, issued, licensed and/or receiving royalties.

5. Relationships not covered above.

Use this section to report other relationships or activities that readers could perceive to have influenced, or that give the appearance of potentially influencing, what you wrote in the submitted work.

Definitions.

Entity: government agency, foundation, commercial sponsor, academic institution, etc.

Grant: A grant from an entity, generally (but not always) paid to your organization

Personal Fees: Monies paid to you for services rendered, generally honoraria, royalties, or fees for consulting, lectures, speakers bureaus, export testimony, employment, or other affiliations.

Non-Financial Support: Examples include drugs/equipment supplied by the entity, travel paid by the entity, writing assistance, administrative support, etc.

Other: Anything not covered under the previous three boxes

Pending: The patent has been filed but not issued

Issued: The patent has been issued by the agency

Licensed: The patent has been licensed to an entity, whether earning royalties or not

Royalties: Funds are coming in to you or your institution due to your patent
ICMJE Form for Disclosure of Potential Conflicts of Interest

Section 1. Identifying Information

<table>
<thead>
<tr>
<th>1. Given Name (First Name)</th>
<th>2. Surname (Last Name)</th>
<th>3. Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philip</td>
<td>Morgan</td>
<td>12-January-2021</td>
</tr>
</tbody>
</table>

4. Are you the corresponding author?  
   - Yes ☐  
   - No ☑

Corresponding Author's Name  
Jason Nichols

5. Manuscript Title  
Bibliometric analysis of the meibomian gland literature

6. Manuscript Identifying Number (if you know it)

---

Section 2. The Work Under Consideration for Publication

Did you or your institution at any time receive payment or services from a third party (government, commercial, private foundation, etc.) for any aspect of the submitted work (including but not limited to grants, data monitoring board, study design, manuscript preparation, statistical analysis, etc.)?  
Are there any relevant conflicts of interest?  
   - Yes ☐  
   - No ☑

---

Section 3. Relevant financial activities outside the submitted work.

Place a check in the appropriate boxes in the table to indicate whether you have financial relationships (regardless of amount of compensation) with entities as described in the instructions. Use one line for each entity; add as many lines as you need by clicking the "Add +" box. You should report relationships that were present during the 36 months prior to publication.  
Are there any relevant conflicts of interest?  
   - Yes ☐  
   - No ☑

---

Section 4. Intellectual Property -- Patents & Copyrights

Do you have any patents, whether planned, pending or issued, broadly relevant to the work?  
   - Yes ☐  
   - No ☑
ICMJE Form for Disclosure of Potential Conflicts of Interest

Section 5. Relationships not covered above

Are there other relationships or activities that readers could perceive to have influenced, or that give the appearance of potentially influencing, what you wrote in the submitted work?

☐ Yes, the following relationships/conditions/circumstances are present (explain below):

☑ No other relationships/conditions/circumstances that present a potential conflict of interest

At the time of manuscript acceptance, journals will ask authors to confirm and, if necessary, update their disclosure statements. On occasion, journals may ask authors to disclose further information about reported relationships.

Section 6. Disclosure Statement

Based on the above disclosures, this form will automatically generate a disclosure statement, which will appear in the box below.

Dr. Morgan has nothing to disclose.

Evaluation and Feedback

Please visit http://www.icmje.org/cgi-bin/feedback to provide feedback on your experience with completing this form.
ICMJE Form for Disclosure of Potential Conflicts of Interest

Instructions

The purpose of this form is to provide readers of your manuscript with information about your other interests that could influence how they receive and understand your work. The form is designed to be completed electronically and stored electronically. It contains programming that allows appropriate data display. Each author should submit a separate form and is responsible for the accuracy and completeness of the submitted information. The form is in six parts.

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   Report all sources of revenue paid (or promised to be paid) directly to you or your institution on your behalf over the 36 months prior to submission of the work. This should include all monies from sources with relevance to the submitted work, not just monies from the entity that sponsored the research. Please note that your interactions with the work's sponsor that are outside the submitted work should also be listed here. If there is any question, it is usually better to disclose a relationship than not to do so.
   For grants you have received for work outside the submitted work, you should disclose support ONLY from entities that could be perceived to be affected financially by the published work, such as drug companies, or foundations supported by entities that could be perceived to have a financial stake in the outcome. Public funding sources, such as government agencies, charitable foundations or academic institutions, need not be disclosed. For example, if a government agency sponsored a study in which you have been involved and drugs were provided by a pharmaceutical company, you need only list the pharmaceutical company.
   This section asks about patents and copyrights, whether pending, issued, licensed and/or receiving royalties.
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Pending: The patent has been filed but not issued
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Licensed: The patent has been licensed to an entity, whether earning royalties or not
Royalties: Funds are coming in to you or your institution due to your patent
ICMJE Form for Disclosure of Potential Conflicts of Interest

Section 1. Identifying Information

1. Given Name (First Name)  
   Nathan

2. Surname (Last Name)  
   Efron

3. Date  
   13-January-2021

4. Are you the corresponding author?  
   ☐ Yes  ☑ No  
   Corresponding Author's Name
   Jason J Nichols

5. Manuscript Title  
   Bibliometric analysis of the meibomian gland literature

6. Manuscript Identifying Number (if you know it)

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Dr. Efron has nothing to disclose.

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Jones

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12-January-2021

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   Nichols

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RESEARCH CORRESPONDENCE

Bibliometric analysis of the meibomian gland literature

Jason J. Nichols, OD, MPH, PhD

Lyndon W. Jones, DSc, FCOptom

Philip B. Morgan, PhD

Nathan Efron, AC, DSc, PhD

a. School of Optometry, The University of Alabama at Birmingham, Birmingham, Alabama, United States.
b. Centre for Ocular Research & Education (CORE), School of Optometry and Vision Science, University of Waterloo, Waterloo, Ontario, Canada and Centre for Eye and Vision Research (CEVR), 17W Hong Kong Science Park, Hong Kong
c. Eurolens Research, Division of Pharmacy and Optometry, The University of Manchester, Manchester, United Kingdom
d. School of Optometry and Vision Science, Queensland University of Technology, Kelvin Grove, Queensland, Australia

Key Words: bibliometric analysis, citations, impact, meibomian gland, meibum, publication metrics

Word Count (text only): 1,209

References: 11

Figures: 1

Supplementary Tables: 6

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Financial support

This work did not receive any public or private extramural financial support.

Short title

Bibliometric analysis of the meibomian gland literature
There is a rich history of interest in the sebaceous glands located posterior to the tarsal plates in the eyelids, to which we refer today as the meibomian glands (MGs). Although there is acknowledgement of the MGs preceding the work of Johann Heinrich Meibom in the 1600’s, he is credited with advancing our knowledge and study of these glands.[1]

The MGs produce a distinct lipid secretion (‘meibum’) made up of a variety of lipid classes, mostly composed of nonpolar wax and cholesterol esters, although other nonpolar and polar lipids are certainly known to exist in the meibum.[2] The normal function of meibum is to make its way to the tear film lipid layer, ultimately forming a resistive barrier to evaporation of the aqueous component of the tear film. In disease, the MGs lose their ability to secrete a normal meibum composition and/or are impeded due to factors such as atrophy of the MGs, keratinization of the orifice of the gland from which the meibum is secreted onto the eyelid margin, or bacterial colonization of the eyelid, altering the secretion itself once expressed.[3, 4] These conditions today are known as blepharitis, including anterior and posterior blepharitis (which includes meibomian gland dysfunction).[5]

Given the extensive study of MGs, a bibliometric analysis is warranted to acknowledge and celebrate those contributing to this important part of ophthalmic research.

A bibliometric search was undertaken on January 5, 2021 of the titles of papers on the Scopus database. The goals of the search were to identify the most relevant meibomian gland-related documents published in peer-reviewed journals that are primarily meibomian gland driven, rather than to include secondary MG themes in this search; thus,
only ‘title’ identifiers were used to capture this field of research with the highest sensitivity and specificity. To identify MG-related articles, the following search terms was used:

\[
\text{TITLE(meibum) OR TITLE(meibomian) OR TITLE(blepharitis) OR TITLE(meibomitis) OR TITLE(blepharon-conjunctivitis) OR TITLE(meibography*) AND (LIMIT-TO(SRCTYPE, "j") AND (LIMIT-TO(LANGUAGE, "English")))}
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The 25 most highly cited papers were determined from the total list of 1,462 papers found. The search term above was also limited to the last 10 years to determine the top contemporary articles in the field of meibomian gland research. A subject-specific meibomian gland-related h-index (h_{MG}-index) was derived for authors, institutions, countries and journals to serve as a measure of impact in the field.[6] The top constituents of each category were ranked by h_{MG}-index and tabulated for consideration.

The h_{MG}-index of the field was determined to be 85. The 1,462 papers have been cited a total of 32,657 times, and 18.2% of these papers have never been cited. The number of papers in the field published each year between 1849 and 2020 is shown in Figure 1, with a rapid increase evident from 2008.

The 25 most highly cited papers are listed in Table 1 of the Supplementary Data. Seven of the top 25 papers are affiliated with the International Workshop on Meibomian Gland Dysfunction conducted under the auspices of the Tear Film and Ocular Surface Society (TFOS), including the paper ranked #1 by first author Erik Knop (“anatomy, physiology, and pathophysiology of the meibomian glands”).[7] Outside of this, six cover MG
physiology or pathophysiology, six relate to clinically oriented research (meibography, evaporation, clinical outcomes), and five cover grading and classification schemes.

There is undoubtedly keen interest in defining and classifying MGD, as noted by the number of Top 25 articles devoted to this topic and diagnostic criteria associated with the condition. Further to this, another key theme of the Top 25 articles is that of the study of MG physiology and pathophysiology, particularly as these relate to MG function and meibum secretion. Several papers report on various basic science concepts, while others describe clinical techniques (such as meibography) that are used to assess either MG health and/or the lipid layer of the tear film. Others describe less common but important related assessments such as evaporimetry. Further to this, several of these papers address the apparent overlap between dry eye (aqueous deficiency) and evaporative diseases, such as MGD and blepharitis. It is clear that the TFOS International Workshop on Meibomian Gland Dysfunction has had a substantial impact, in that 7 of the Top 25 articles are among the Top 25.

Table 2 shows the top 10 contemporary articles related to the study of the meibomian glands. It is clear that the top cited contemporary literature relates to the treatment of meibomian gland dysfunction (5 of 10 articles) and assessment of the meibomian glands and/or lipid layer (4 of 10 articles); the remaining (and top cited) article is focused on the pathophysiology of meibomian gland dysfunction.

While citation analyses can be helpful in identifying trends in research, they do have limitations. For instance, older research is more likely to have higher citation counts than more recent research simply due to time, which itself allows for the accumulation of
citations. Along these lines, it is clear from the most current research in MGD that, particularly over the very most recent years, therapeutic and diagnostic approaches are key areas of research in MGD. For instance, there is no doubt that innovations in imaging approaches (e.g., optical coherence tomography, meibography, confocal microscopy) are of vital importance to the field of MGD research, particularly through their utility in diagnosis and follow-up, once treatment is initiated. Likewise, new diagnostic imaging approaches that are able to detect MGD absent of symptoms are of significant interest, as recent studies and reviews have suggested that asymptomatic MGD is much more frequent than is traditionally thought.[8-10] Further to this, newer understandings of the biochemical composition of the meibum and tear film lipids as key biomarkers or therapeutic targets are of substantial importance to the field going forward. In particular, the O-acyl-ω-hydroxy fatty acids (OAHFAs) have shown themselves recently to play major functional roles in allowing the tear film to structure itself properly as highly effective surfactants.[9, 11] While lipid emulsions are available for tear supplementation, most contain large, hydrophobic lipids such as mineral or caster oils, not present in human meibum otherwise. The OAHFAs could serve as potential therapeutic supplements along these lines, as they naturally occur in the meibum and tear film. There is much to be considered along these lines for the future of research associated with MGD.

Tables 3, 4, 5, and 6 of the Supplementary Data lists the 10 most impactful authors, institutions, countries, and journals publishing meibomian gland-related articles, respectively. This is also summarized in Figure 1.

This bibliometric analysis has summarized the most important papers and themes in the field of the study of the meibomian glands. It is clear that the TFOS International Workshop
on Meibomian Gland Dysfunction has had a substantial impact on the field of meibomian
gland research. Based on a prior bibliometric analysis of the entire dry eye field, it is clear
from the current bibliometric analysis of the MG-related literature that while there is some
overlap in content and top-ranked authors, the MG field is distinct in contributions and
growing perhaps at an equivalent rate to that of the entire dry eye literature.[12]

Notwithstanding the rich history of the study of MGs, current research activities appear to
be growing exponentially, so a re-analysis of this area of research in the years to come is
certainly warranted.
FINANCIAL DISCLOSURES

Jason Nichols: In 2019 and 2020, Dr. Jason J. Nichols has received honoraria from Paragon Vision Sciences and CooperVision. He has also received research funding from Alcon, Bruder, Johnson and Johnson Vision, and Mallinckrodt over the last 3 years. Also, Dr. Kelly Nichols is the spouse of Dr. Jason Nichols, extending her declarations to him. In the past 12 months, Dr. Kelly Nichols has consulted for and received honorarium from: Bruder, Dompe, Kala, Novartis/Shire (Medical Exchange International), Osmotica, Oyster Point, Sight Sciences, Tear Film Innovations/Alcon/Acquiom, Thea, Tarsus, and TopiVert. She has received research funding from: Allergan, Kala, and Tear Science.

Phillip Morgan: Nothing to declare.

Lyndon Jones: Over the past 3 years Dr Jones’ research group (CORE) or he personally has received research support or lectureship honoraria from: Alcon, Allergan, CooperVision, GL Chemtec, iMed Pharma, J&J Vision, Lubris, Menicon, Nature’s Way, Novartis, Ote, PS Therapy, Safilens, Santen, Shire, SightGlass and Visioneering. Dr Jones is also a consultant and/or serves on an advisory board for Alcon, CooperVision, J&J Vision, Novartis and Ophtecs.

Nathan Efron: Nothing to declare.

REFERENCES


Figure Caption

Figure 1. Number of publications and summary information in the field of meibomian gland research published each year between 1849 and 2020. For brevity, the Figure is truncated to works occurring on or after 1900.