Bibliometric analysis of the meibomian gland literature

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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

	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] 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, 10] 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.”

Cover letter

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**
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THEOCULARSURFACE-D-21-00011-R3

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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:

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RESEARCH CORRESPONDENCE

Bibliometric analysis of the meibomian gland literature

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Philip B. Morgan, PhD[c]
Nathan Efron, AC, DSc, PhD[d]

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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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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:

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"))

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.

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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.

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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.

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[12] Nichols JJ. Citation analysis of the dry eye literature. Ocul Surf. 2013;11:35-46.

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.

RESEARCH CORRESPONDENCE

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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.

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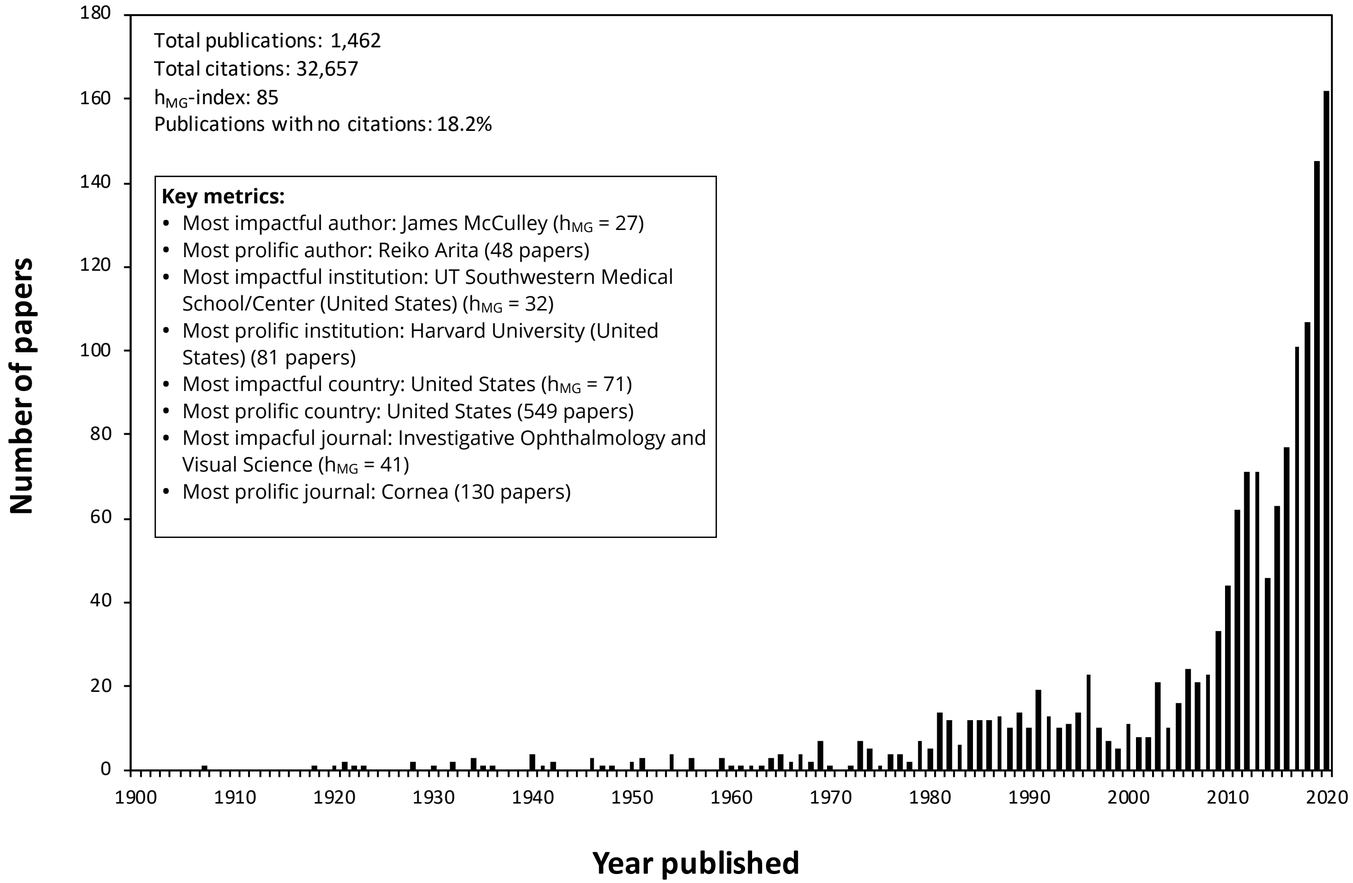
Figure Caption

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.



Supplementary Material

Table 1. Top 25 most highly cited meibomian gland-related articles ranked by number of citations.

Rank	Title	First Author	Journal	Year, Volume & Pages	Citations
1	The international workshop on meibomian gland dysfunction: Report of the subcommittee on anatomy, physiology, and pathophysiology of the meibomian gland	Erik Knop	Investigative Ophthalmology and Visual Science	2011 52; 1938-78	449
2	The international workshop on meibomian gland dysfunction: Executive summary	Kelly Nichols	Investigative Ophthalmology and Visual Science	2011 52; 1922-9	435
3	The international workshop on meibomian gland dysfunction: Report of the definition and classification subcommittee	Daniel Nelson	Investigative Ophthalmology and Visual Science	2011 52; 1930-7	368
4	Noncontact infrared meibography to document age-related changes of the meibomian glands in a normal population	Reiko Arita	Ophthalmology	2008 115; 911-5	352
5	The international workshop on meibomian gland dysfunction: Report of the diagnosis subcommittee	Alan Tomlinson	Investigative Ophthalmology and Visual Science	2011 52; 2006-49	333
6	Ocular surface changes and discomfort in patients with meibomian gland dysfunction	Jun Shimazaki	Archives of Ophthalmology	1995 113; 1266-70	321
7	Meibomian gland dysfunction: A clinical scheme for description, diagnosis, classification, and grading	Gary Foulks	The Ocular Surface	2003 1; 107-26	299
8	The international workshop on meibomian gland dysfunction: Report of the subcommittee on management and treatment of meibomian gland dysfunction	Gerd Geerling	Investigative Ophthalmology and Visual Science	2011 52; 2050-64	296
9	The international workshop on meibomian gland dysfunction: Report of the subcommittee on the epidemiology of, and associated risk factors for, MGD	Debra Schaumberg	Investigative Ophthalmology and Visual Science	2011 52; 1994-2005	265
10	Ocular evaporation in meibomian gland dysfunction and dry eye	William Mathers	Ophthalmology	1993 100; 347-51	231
11	Meibomian gland disease. Classification and grading of lid changes	Anthony Bron	Eye	1991 5; 395-411	224
12	The contribution of meibomian disease to dry eye	Anthony Bron	The Ocular Surface	2004 2; 149-64	223
13	Meibomian gland dysfunction	Paul Driver	Survey of Ophthalmology	1996 40; 343-67	219
14	Classification of chronic blepharitis	James McCulley	Ophthalmology	1982 89; 1173-80	215
15	Meibomian gland studies: comparison of steer and human lipids	Nicholas Nicolaides	Investigative Ophthalmology and Visual Science	1981 20; 522-36	204

16	Targeted disruption of stearoyl-CoA desaturase1 gene in mice causes atrophy of sebaceous and meibomian glands and depletion of wax esters in the eyelid	Makoto Miyazaki	Journal of Nutrition	2001 131; 2260-8	198
17	Meibomian gland dysfunction in patients with Sjogren syndrome	Jun Shimazaki	Ophthalmology	1998 105; 1485-8	192
18	Effect of androgen deficiency on the human meibomian gland and ocular surface	Kathleen Krenzer	Journal of Clinical Endocrinology and Metabolism	2000 85; 4874-82	188
19	The international workshop on meibomian gland dysfunction: Report of the subcommittee on tear film lipids and lipid-protein interactions in health and disease	Kari Green-Church	Investigative Ophthalmology and Visual Science	2011 52; 1979-93	181
20	Contact lens wear is associated with decrease of meibomian glands	Reiko Arita	Ophthalmology	2009 116; 379-84	172
21	Meibomian gland dysfunction in chronic blepharitis	William Mathers	Cornea	1991 10; 277-285	172
22	Proposed diagnostic criteria for obstructive meibomian gland dysfunction	Reiko Arita	Ophthalmology	2009 116; 2058-64	161
23	Revisiting the vicious cycle of dry eye disease: A focus on the pathophysiology of meibomian gland dysfunction	Christophe Baudouin	British Journal of Ophthalmology	2016 100; 300-6	146
24	Pathogenic role of Demodex mites in blepharitis	Jingbo Liu	Current Opinion in Allergy and Clinical Immunology	2010 10; 505-10	144
25	Androgen influence on the meibomian gland	David Sullivan	Investigative Ophthalmology and Visual Science	2000 41;3732-42	143

Table 2. Top 10 most highly cited meibomian gland-related articles of the last 10 years ranked by number of citations.

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

Table 3. Top authors of meibomian gland-related articles, ranked by author h_{MG}-index.

Rank	Author	h_{MG}-index	Paper count
1	James McCulley	27	34
2	David Sullivan	25	47
3	Reiko Arita	21	48
4	Kazuo Tsubota	21	31
5	Igor Butovich	20	29
6	Douglas Borchman	18	31
7	James Jester	18	30
8	Gary Foulks	18	21
9	Shiro Amano	17	23
10	Donald Korb	16	19
11	John Tiffany	16	17
12	Thomas Millar	15	17
13	Ward Shine	14	16
14	Marta Yappert	14	16
15	Kelly Nichols	13	28
16	Caroline Blackie	13	16
17	Anthony Bron	13	15
18	Jun Shimazaki	12	14
19	Nicholas Nicolaides	12	12
20	Tomo Suzuki	11	19

*Authors with ≤ 11 papers and h_{MG} ≤ 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.

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

* Institutions with ≤ 13 papers and h_{MG} ≤ 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).

[a]Includes University of Texas at Dallas.

[b]Includes Harvard Medical School, Schepens Eye Research Institute, Mass Eye and Ear Infirmary, Brigham and Women's Hospital.

[c]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_{MG}-index.

Rank	Country	h_{MG}-index	Paper count
1	United States	71	549
2	Japan	39	149
3	United Kingdom	31	96
4	Germany	27	70
5	Australia	25	69
6	China	18	120
7	South Korea	18	68
8	Italy	18	46
9	Turkey	14	76
10	Spain	13	33

*Countries with ≤ 13 papers but h_{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 h_{MG}-index.

Rank	Journal	h_{MG}-index	Paper count
1	Investigative Ophthalmology and Visual Science	41	117
2	Cornea	39	130
3	American Journal of Ophthalmology	20	55
4	Current Eye Research	20	43
5	British Journal of Ophthalmology	20	38
6	Experimental Eye Research	19	39
7	JAMA Ophthalmology[a]	19	35
8	Ophthalmology	19	30
9	The Ocular Surface	18	70
10	Eye and Contact Lens[b]	18	39

*Journals with ≤18 papers and h_{MG} < 18: Optometry and Vision Science (12), Contact Lens and Anterior Eye (8).

a. Includes Archives of Ophthalmology
b. Includes CLAO Journal

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Corresponding Author's Name: Jason Nichols

5. Manuscript Title: Bibliometric analysis of the meibomian gland literature

6. Manuscript Identifying Number (if you know it)

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2. Surname (Last Name): Efron
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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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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):

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Allergan	☑	☐	☐	☐	
Contamac	☑	☐	☐	☐	
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GL Chemtech	☑	☐	☐	☐	
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Ote	☑	☐	☐	☐		
PS Therapy	☑	☐	☐	☐		
Shire	☑	☐	☐	☐		
Sightglass	☑	☐	☐	☐		
Santen	☐	☑	☐	☐		

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This section asks for information about the work that you have submitted for publication. The time frame 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".

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1. Given Name (First Name): Jason
2. Surname (Last Name): Nichols
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4. Are you the corresponding author? ☑ Yes ☐ No

5. Manuscript Title: Bibliometric analysis of the meibomian gland literature

6. Manuscript Identifying Number (if you know it):

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Thea	☐	☑	☐	☐	Spouse
Tarsus	☐	☑	☐	☐	Spouse
Topivert	☐	☐	☐	☐	Spouse
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RESEARCH CORRESPONDENCE

Bibliometric analysis of the meibomian gland literature

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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:

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"))

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.

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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.