21st century citation analysis of the field of contact lenses

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21st century citation analysis of the field of contact lenses

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Keywords:	bibliometrics, 21st century, citations, contact lenses, publication metrics
Abstract:	<p>Clinical relevance: The scientific foundations for clinical contact lens practice are rooted in the ophthalmic literature. This analysis of contact lens papers celebrates contemporary research achievements in the contact lens field.</p> <p>Background: This work aims to assemble contact lens-related publication metrics so as to identify the most impactful papers published so far this century, as well the top countries, authors, institutions and journals.</p> <p>Methods: A search was undertaken of the titles of papers on the Scopus database to identify contact lens-related articles published this century. The ten most highly cited papers were determined from the total list of 4,164 papers found. Rank-order lists by count were assembled for the 'top 25' in each of four categories: authors, institutions, countries and journals. A 20-year subject-specific contact lens h-index (hCL-20-index) was derived for each author, institution, country and journal to serve as a measure of impact in the field. The top 10 constituents (of the top 25) of each category were ranked by hCL-20-index and tabulated for consideration.</p> <p>Results: The most highly cited paper this century is entitled "Soft contact lens polymers: An evolution", by Nicholson and Vogt. Lyndon Jones is the most impactful author, with a hCL-20-index of 32. The University of New South Wales (Australia) produces the most impactful contact lens-related papers, and the United States is the most highly-ranked country. Optometry and Vision Science is the most impactful journal in the contact lens field.</p> <p>Conclusions: Contact lens materials and lens-associated keratitis are topics of high interest in the contemporary contact lens literature, with an emerging interest in orthokeratology for myopia control and glucose monitoring. Impactful 21st century authors, institutions, countries and journals are identified. Optometry is revealed as the leading profession in relation to the publication of impactful contact lens-related papers.</p>

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RESEARCH

21st century bibliometric analysis of the contact lens field

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[Abstract]

Clinical relevance: The scientific foundations for clinical contact lens practice are rooted in the ophthalmic literature. This analysis of contact lens papers celebrates contemporary research achievements in the contact lens field.

Background: This work aims to assemble contact lens-related publication metrics so as to identify the most impactful papers published so far this century, as well the top countries, authors, institutions and journals.

Methods: A search was undertaken of the titles of papers on the Scopus database to identify contact lens-related articles published this century. The ten most highly cited papers were determined from the total list of 4,164 papers found. Rank-order lists by count were assembled for the ‘top 25’ in each of four categories: authors, institutions, countries and journals. A 20-year subject-specific contact lens h-index (h_{CL-20} -index) was derived for each author, institution, country and journal to serve as a measure of impact in the field. The top 10 constituents (of the top 25) of each category were ranked by h_{CL-20} -index and tabulated for consideration.

Results: The most highly cited paper this century is entitled “Soft contact lens polymers: An evolution”, by Nicholson and Vogt. Lyndon Jones is the most impactful author, with a h_{CL-20} -index of 32. The University of New South Wales (Australia) produces the most impactful contact lens-related papers, and the United States is the most highly-ranked country. *Optometry and Vision Science* is the most impactful journal in the contact lens field.

Conclusions: Contact lens materials and lens-associated keratitis are topics of high interest in the contemporary contact lens literature, with an emerging interest in orthokeratology for myopia control and glucose monitoring. Impactful 21st century authors, institutions, countries and journals are identified. Optometry is revealed as the leading profession in relation to the publication of impactful contact lens-related papers.

Introduction

In 2011, two of the authors of this paper (NE, JJN) conducted a citation analysis of the contact lens field,¹ essentially surveying papers published over the previous 110 years. That analysis (which was published in 2012) provided fascinating insights from an essentially historical perspective; however, the contact lens field continues to evolve, with new lens materials and designs frequently being introduced, along with novel paradigms such as myopia control and the incorporation of micro-electronics into contact lenses. Furthermore, an earlier generation of prominent contact lens researchers is gradually making way for a new breed of academics, sometimes emerging from countries not traditionally associated with contact lens research.

Subsequent bibliometric analyses of the contact lens literature have been published following on from the original work of Efron et al.¹ Cardona and Sanz^{2,3} assessed the metrics of contact lens papers published in a single year – 2011 – to gauge topics of interest at that time. Wood and Dutta⁴ used publication metrics to generally reflect upon developments in the contact lens field over the past 50 years. Alvarez-Peregrina et al⁵ examined the literature specifically relating to bifocal contact lenses, and Villar-Collar et al⁶ and Nichols et al⁷ have undertaken a bibliometric analyses of the field of orthokeratology.

The aim of this paper is to undertake a bibliometric analysis of the 21st century contact lens literature, focusing in particular on the most highly cited papers; the most impactful authors and the institutions and countries where they work; and the most prominent journals publishing these articles.

Methods

The search protocol used here was similar to that used for the 2011 analysis of Efron et al,¹ except that the present work was undertaken using the Scopus database (Elsevier). The search was restricted to all research and review articles published in English between January 1, 2001 and October 14, 2020. A search term was derived to ensure (a) high sensitivity, including a wide capture of articles with “contact lenses” as the primary theme, and (b) high specificity, so as to rule out irrelevant or peripherally related articles.

Multiple iterations of search terms were investigated, including a variety of fields, but the final strategy employed was to search TITLE only (rather than abstract, key words or ‘all fields’), employing the following search term:

TITLE({contact lens} OR {contact lenses} OR {orthokeratology} AND NOT {implantable contact lens}) AND (PUBYEAR>2000) AND (LIMIT-TO(SRC,”j”)) AND (LIMIT-TO(DOCTYPE, “AR”) OR LIMIT-TO(DOCTYPE, “re”)) AND (EXCLUDE(PUBYEAR, 2021)) AND (LIMIT-TO,”English”)

1 The search revealed 4,164 contact lens-related papers; of these, 13.6% have not received any citations, and the
2 rest have in total been cited 74,361 times. The top 10 most cited papers were determined by simple sorting
3 within Scopus.
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8 The 4,164 contact lens-related papers also served as the database from which a targeted analyses were
9 conducted in respect of the following four additional categories: authors, institutions, countries and journals.
10 The first step was to generate a list of the top 25 in each of these categories by paper count, e.g. for the category
11 ‘authors’, the author who had published the most papers in the pool of 4,164 contact lens-related papers was
12 listed first, and so on, down to 25 authors.
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19 Quality was assessed using the concept of h-index¹ – a single metric that combines productivity (number of
20 papers) and impact (number of citations). This metric can be applied to any category; for example, the h-index
21 of an author is defined as the maximum value of h, such that the author has published h papers that have each
22 been cited at least h times. To continue with the example of ‘authors’ – a 20-year subject-specific contact lens h-
23 index (the “h_{CL}-20-index”) was derived for each author, to serve as a measure of the *impact* that each author has
24 had in the field.
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31 The h_{CL}-20-index of a given author was determined by sorting the subset of contact lens-related publications for
32 that author by rank order of citations (from highest to lowest) and working down the list, starting with the paper
33 that had the highest number of citations, to determine the first paper with a paper rank number that was larger
34 than its number of citations. The h_{CL}-20-index for that author was identified as the number of the entry above
35 the identified paper. This was repeated for each of the 25 most prolific authors; the top 10 were then identified
36 and ranked in order of h_{CL}-20-index, with tied ranks broken in favour of a higher number of published papers.
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41 The same approach was applied for the analysis of institutions, countries and journals.
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45 **Results**

46 The h_{CL}-20-index for all contact lens-related papers published this century was determined to be 100.
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50 The ten most highly cited papers⁸⁻¹⁷ are listed in Table 1. Five of these papers were published in ophthalmic
51 journals, two in materials science journals, and one each in a general medical, ‘natural sciences’ and
52 engineering journal.
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57 Table 2 lists the 10 most impactful authors, ranked by h_{CL}-20-index, along with the total count of contact lens-
58 related papers published since 2001, and the ranking of each author (by paper count) from the 2011 analysis of
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Efron et al.¹ Lyndon Jones is the top-ranked author, with the next three authors each separated by one h_{CL-20} -index point from the previous author.

The top 10 institutions from which papers emanated are listed in Table 3, ranked by h_{CL-20} -index, along with the total paper count and the ranking of each institution from the 2011 analysis of Efron et al.¹ The University of New South Wales is the leading institution, as it was in 2011.

Table 4 lists the top 10 countries, ranked by h_{CL-20} -index, along with the total paper count and ranking of each country from the 2011 analysis of Efron et al.¹ The United States retains top ranking, followed by Australia, then the United Kingdom.

The reason that the total paper count for Australian *institutions* exceeds that for Australia as a *nation* is because individual authors often list multiple institutions, e.g. in Australia, some authors designate that they work at both the University of New South Wales and the Brien Holden Vision Institute. When tallying data, a single-author paper stating this dual affiliation would result in one count for each of those two Australian institutions (i.e. two counts for Australian institutions), but only one count for the nation of Australia.

The top 10 journals publishing contact lens articles in the 21st century are listed in Table 5, ranked by h_{CL-20} -index, as well as the total paper count, and the ranking of each journal from the 2011 analysis of Efron et al.¹ *Optometry and Vision Science* is the top-ranked journal. However, an obvious trend in publications in journals that has emerged in the last five years is a marked drop in contact lens publications in *Optometry and Vision Science*, and a significant increase in *Contact Lens and Anterior Eye*. It will be interesting to monitor this trend as it relates to the impact of these journals in the field going forward.

Discussion

This analysis reveals the most impactful articles, authors, institutions, countries and journals in relation to the 21st century contact lens literature. A number of significant changes are evident when comparing these contemporary rankings with the analysis published by Efron et al.¹ in 2011, the latter being more of an historic 'all time' overview of the contact lens literature, dating back to the year 1900.

An advantage of undertaking this contemporary analysis, compared with the earlier historic analysis,¹ is that the search findings and consequent comparisons *within* each analysis are not confounded by factors such as differences in the capacity of more senior academics to accrue superior publication metrics by virtue of having worked in the field for a longer time span, or certain journals to do the same as a result of having been in

1 existence for a greater number of years. That is, the 20-year survey period puts all parameters considered on a
2 “level playing field”.
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7 It should be noted when comparing the present rankings of authors, institutions, countries and journals with the
8 rankings derived by Efron et al in 2011,¹ that the present rankings relate to *impact* (i.e. ranking by h_{CL}-20-
9 index) whereas the 2011 rankings related to *productivity* (i.e. ranking by paper count).
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14 **Highly cited papers**

15 Analysis of the ten most highly cited papers⁸⁻¹⁷ listed in Table 1 necessarily favours papers published earlier in
16 the survey window, which have had a greater opportunity to accrue more citations. The top-ranked paper traces
17 the evolution of soft contact lens polymers from hydrogels, developed in the 1960s, to silicone hydrogels,⁸
18 which became available around the turn of the century. The high citation count of this paper can be attributed to
19 the keen interest in this new technology, which now dominates the market, whereby 72% of all contact lenses
20 fitted today are made from silicone hydrogel materials.¹⁸
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27 It is interesting to observe how the top ranked 21st century papers in Table 1 compare to those tabulated in
28 2011,¹ the latter perhaps relating more to contact lens practice in the 20th century. Two papers listed in 2011¹
29 concerned corneal oxygen availability and hypoxic complications during lens wear; papers dealing with such
30 topics do not appear in the current listing because silicone hydrogels have largely obviated concerns about
31 hypoxia.¹⁹ Similarly, one paper listed in 2011¹ was concerned with contact lens-induced papillary
32 conjunctivitis. This condition was observed in patients wearing some 20th century reusable hydrogel lenses, but
33 is far less prevalent today²⁰ because of the ubiquity of disposable lenses;¹⁸ accordingly, there are no papers
34 concerning papillary conjunctivitis in the current listing.
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43 Although silicone hydrogel lenses have solved hypoxic problems, they have not reduced the incidence of
44 keratitis, which remains an issue of concern. There were five papers addressing this problem in the 2011
45 listing,¹ and there are four in the current listing in Table 1, in relation to epidemiology^{9,10} (those papers ranked
46 #2 and #3), bacterial lens contamination¹¹ (#4) and risk factors for keratitis¹⁵ (#8).
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52 Other papers in the current listing reflect topics of emerging interest in the field, including two papers on the
53 use of orthokeratology to arrest the progression of myopia,^{12,13} both by Cho and co-workers (#5 and #6), and
54 two papers describing smart electronics incorporated into contact lenses for wireless biological sensing^{14,17} (#7
55 and #10). Contact lens discomfort remains an intractable problem, with the paper by Nichols and Sinnott¹⁶ (#9)
56 reflecting this concern.
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Impactful authors

Eight esteemed colleagues who appeared in the 2011 listing¹ have been displaced by a new generation of contact lens researchers, as listed in Table 2. Mark Willcox (rank #2) and Nathan Efron (#4) still appear high in the rankings, as they were in 2011 (then ranked #2 and #3, respectively). Fiona Stapleton (#3), Brien Holden (#8) and Dwight Cavanagh (#10) are the other names remaining from the 2011 listing.

A new name appears at the top of the current ranking – Lyndon Jones. He is a prolific author, who has also published the highest number of contact lens-related papers by a wide margin from the second most prolific author, Nathan Efron. Professor Jones heads the Centre for Ocular Research & Education (CORE) – a large and active group that undertakes contractual research and consulting for the contact lens industry, as well as undertaking independent fundamental contact lens and solutions research.

Other new names in Table 2 include Philip Morgan (#5), Anuj Chauhan (#6), Pauline Cho (#7) and Jason Nichols (#9). Professors Chauhan and Nichols only entered academia and commenced publishing around the turn of the century, which is essentially the beginning of this survey period; their listing in the top 10 is therefore a remarkable achievement.

It is noteworthy that seven of the top 10 authors are optometrists; Mark Willcox (#2) is a microbiologist, Anuj Chauhan (#6) an engineer and Dwight Cavanagh (#10) an ophthalmologist. This observation attest to the leading professional standing of optometry in the contact lens literature.

Top institutions

All nine universities listed in Table 3 are essentially the parent institutions to optometry departments. The University of New South Wales (basically the School of Optometry and Vision Science) and the Brien Holden Vision Institute – although housed in the same building on the same university campus in Sydney, Australia – are distinct organisational entities and are therefore listed separately. As was the case in 2011,¹ these two institutions remain highly ranked in the present listing, at #1 and #3, respectively. The University of Waterloo, Canada (#2) and University of Manchester, United Kingdom (#4) are home to internationally-acclaimed contact lens research facilities – CORE, as noted earlier, headed by Lyndon Jones (rank #1 in Table 2), and Eurolens Research, headed by Philip Morgan (#5), respectively.

The 2011 top 10 listing¹ only contained institutions from Australia, Canada, the United Kingdom and the United States. Institutions from three additional countries appear in the current listing – The University of Minho (Portugal) (#7), Hong Kong Polytechnic University (Hong Kong) (#8) and the University of Valencia (Spain) (#10) – signalling the emergence of these three institutions as internationally-recognised centres of

1 excellence for contact lens research. The Queensland University of Technology (Australia) (#6) is another new
2 entrant to the listing, built upon a broad foundation of research into lens design, optics, anterior eye physiology,
3 advanced ophthalmic imaging and myopia control. The Ohio State University (#5), which was one of five
4 United States-based institutions featured in the 2011 listing,¹ is now the only United States school among the
5 top 10 institutions.
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12 **Leading countries**

13 There has only been a slight redistribution of rankings among the top eight countries included in Table 4
14 compared to the 2011 listing.¹ However, two countries that were ranked #8 and #9 in 2011 – France and The
15 Netherlands – have been displaced by Portugal and Turkey at ranks #9 and #10, respectively. That the United
16 States is producing the most impactful contact lens papers as well as the highest number of papers is
17 unsurprising in view of the large number of optometry schools in that country, many of which are located in
18 high-ranking research-led institutions. As well, the headquarters of many of the major contact lens and solution
19 companies are housed in the United States, facilitating more immediate interaction between these companies
20 and university research departments, at many levels. Australia (#2) continues to perform disproportionately
21 well in relation to its relatively small population size.
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31 **Prominent journals**

32 The most impactful journals publishing contact lens-related papers are presented in Table 5. The journals *Eye*
33 *and Contact Lens* and *Contact Lens and Anterior Eye* primarily publish papers relating to contact lenses, as
34 indicated by their titles, so is is not surprising that they rank #1 and #2, respectively, in terms of paper counts.
35 However, they are not the most *impactful* journals, and are ranked #3 and #4 by h_{CL-20} -index, respectively.
36 These two journals only commenced publishing in the 1970s, compared with some of the more established
37 journals listed in Table 5, which have been in existence for over a century. This partly explains why *Eye and*
38 *Contact Lens* and *Contact Lens and Anterior Eye* did not feature in the top 10 journals by paper count in the
39 2011 listing,¹ which considered contact lens papers published over the previous 110 years.
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48 There are currently four major optometry journals in the world, and all appear in this top 10 ranking list –
49 *Optometry and Vision Science* (United States) (#1), *Ophthalmic and Physiological Optics* (United Kingdom)
50 (#6), *Clinical and Experimental Optometry* (Australia) (#7), and *Journal of Optometry* (Spain) (# 10). Table 2
51 lists only two journals with “ophthalmology” in their titles – *Investigative Ophthalmology and Visual Science*
52 and *American Journal of Ophthalmology*, ranked #2 and #8, respectively.
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Conclusions

This contemporary examination of the contact lens literature reveals a heightened interest in topics such as orthokeratology for myopia control and wireless biosensing contact lenses. There is also a notable ‘changing of the guard’ in terms of individual researchers, with Lyndon Jones heading the table as the most impactful author of contact lens-related papers. Two new countries (Portugal and Turkey) and five new institutions appear in the top 10 listings.

Although the two dedicated contact lens journals – *Contact Lens and Anterior Eye* and *Eye and Contact Lens* – are, unsurprisingly, custodians of the greatest *number* of contact lens-related papers published in the 21st century, they are not the most *impactful* journals in the contact lens field. The journals *Optometry and Vision Science* (#1) and *Investigative Ophthalmology and Visual Science* (#2) have the highest h_{CL} -indices and are thus deemed to have the highest impact of all journals publishing papers relating to contact lenses.

A proclamation of the lead author of this work (NE) in 2010, made without any real evidence at the time, was that “Of all the fields of clinical activity in which optometrists are engaged, contact lens research is perhaps the only field of which optometry can claim true ownership.”²¹ The current analysis confirms this notion, as evidenced by the dominance of optometric authors, and institutions housing optometry departments, in these top 10 rankings.

The lead author (NE) also wrote in 2015: “... it is likely that ... [the Spanish publication *Journal of Optometry*] ... and Spanish authors and institutions will hold prominent positions in international ranking tables if ... citation analyses are repeated in the next few years.”²² The present analysis demonstrates that this prediction has been realised, and it is gratifying to see the tremendous advances that our Iberian colleagues have made in the contact lens field this century.

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Table 1. Top 10 most cited contact lens articles published in the 21st century, ranked by citation count

Rank	Title	First Author	Journal	Year	Citations
1	Soft contact lens polymers: An evolution ⁸	Nicolson PC	Biomaterials	2001	484
2	Multistate outbreak of Fusarium keratitis associated with use of a contact lens solution ⁹	Chang DC	Journal of the American Medical Association	2006	407
3	The incidence of contact lens-related microbial keratitis in Australia ¹⁰	Stapleton F	Ophthalmology	2008	353
4	Bacterial adhesion to surface hydrophilic and hydrophobic contact lenses ¹¹	Bruinsma GM	Biomaterials	2001	306
5	The longitudinal orthokeratology research in children (LORIC) in Hong Kong: A pilot study on refractive changes and myopic control ¹²	Cho P	Current Eye Research	2005	300
6	Retardation of myopia in orthokeratology (ROMIO) study: A 2-year randomized clinical trial ¹³	Cho P	Investigative Ophthalmology and Visual Science	2012	269
7	Wearable smart sensor systems integrated on soft contact lenses for wireless ocular diagnostics ¹⁴	Kim J	Nature Communications	2017	239
8	Risk factors for microbial keratitis with contemporary contact lenses. A case-control study ¹⁵	Dart JKG	Ophthalmology	2008	228
9	Tear film, contact lens, and patient-related factors associated with contact lens-related dry eye ¹⁶	Nichols JJ	Investigative Ophthalmology & Visual Science	2006	225
10	A 3- μ W CMOS glucose sensor for wireless contact-lens tear glucose monitoring ¹⁷	Liao Y-T	IEEE Journal of Solid-State Circuits	2012	215

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Table 2. Top 10 authors of contact lens articles published in the 21st century, ranked by author h_{CL}-20-index.

Rank	Author	h _{CL} -20-index	Paper count	Rank in 2011 ¹
1	Lyndon Jones	32	140	NR
2	Mark Willcox	31	102	2
3	Fiona Stapleton	30	88	8
4	Nathan Efron	29	103	3
5	Philip Morgan	26	91	NR
6	Anuj Chauhan	24	49	NR
7	Pauline Cho	23	84	NR
8	Brien Holden	23	50	1
9	Jason Nichols	21	58	NR
10	Dwight Cavanagh	21	37	10

NR = not ranked

For Review

Table 3. Top 10 institutions from where contact lens articles were published in the 21st century, ranked by institution h_{CL} -20-index.

Rank	Institution	Country	h_{CL} -20-index	Paper count	Rank in 2011 ¹
1	University of New South Wales	Australia	48	305	1 ^a
2	University of Waterloo	Canada	39	191	6
3	Brien Holden Vision Institute	Australia	39	175 ^b	NR ^a
4	University of Manchester	United Kingdom	33	147	10
5	The Ohio State University	United States	31	119	5
6	Queensland University of Technology	Australia	24	114	NR
7	University of Minho	Portugal	23	100	NR
8	Hong Kong Polytechnic University	Hong Kong	23	96	NR
9	Aston University	United Kingdom	21	87	NR
10	University of Valencia	Spain	17	81	NR

NR = not ranked.

- a. in the 2011 listing, counts for the Brien Holden Vision Institute and the Co-operative Research Centre for Eye Research and Technology were combined into a single count together with, and listed as, the University of New South Wales.
- b. count includes papers attributed to the Co-operative Research Centre for Eye Research and Technology.

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Table 4. Top 10 countries from where contact lens articles were published in the 21st century, ranked by country h_{CL}-20-index.

Rank	Country	h _{CL} -20-index	Paper count	Rank in 2011 ¹
1	United States	79	1,229	1
2	Australia	56	499	2
3	United Kingdom	52	524	3 ^a
4	Canada	39	284	4
5	Spain	37	356	6
6	Japan	34	239	5
7	China	30	267	7
8	India	26	148	10
9	Portugal	26	127	NR
10	Turkey	18	131	NR

a. the 2011 ranking related to England only, and did not count papers from the rest of the UK.
NR = not ranked.

Table 5. Top 10 journals publishing contact lens articles in the 21st century, ranked journal h_{CL}-20-index.

Rank	Journal	h _{CL} -20-index	Paper count	Rank in 2011 ¹
1	Optometry and Vision Science	49	377	1
2	Investigative Ophthalmology and Visual Science	46	143	6
3	Eye and Contact Lens	40	602	NR
4	Contact Lens and Anterior Eye	38	525	NR
5	Cornea	34	153	5
6	Ophthalmic and Physiological Optics	25	84	10
7	Clinical and Experimental Optometry	24	139	NR
8	American Journal of Ophthalmology	22	46	2
9	Current Eye Research	19	72	9
10	Journal of Optometry	11	46	NR

NR = not ranked.