• Bibliometric Research •

Bibliometric and visualized analysis of research hotpots and future prospects in lacrimal duct obstruction disease (1900 to 2024)

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Abstract

● **AIM:** To reveal the research hotspots, trends, and future prospects of lacrimal duct obstruction disease (LDOD) from 1900 to 2024 through the bibliometric and visualized analysis, providing a directional guidance for research in this field.

● **METHODS:** The Web of Science Core Collection database was used to retrieve relevant literature. Data analysis and visualization were conducted using VOSviewer 1.6.20 and CiteSpace 6.3.1, including annual publication volume, trends, research areas, country/region and institution distribution, journal and co-cited journal analysis, author and co-cited author analysis, keyword and burst keyword analysis, *etc*.

● **RESULTS:** The study included a total of 1481 articles, revealing an overall upward trend in research on LDOD, with ophthalmology being the predominant field. While the United States previously led research efforts, India and China have emerged as key contributors since 2015. Mohammad Javed Ali stands out as the most influential author in this research area. *Ophthalmic Plastic and Reconstructive Surgery* has published the highest number of related articles, whereas *Ophthalmology* has the highest co-citation. The current focal points of research include minimally invasive and precise modifications to dacryocystorhinostomy, along with intubation, new materials for stents, and disease pathogenesis.

● **CONCLUSION:** LDOD research has garnered widely attention and exhibits a steady upward trend. Since 1900, the United States, China, and India have been the leading contributors to this field. Ophthalmologists continue to be the primary driving force behind LDOD research. The findings of this study suggest that at the forefront of LDOD research, our focus has long been on refining and innovating surgical treatment. The minimally invasive and precise modification of lacrimal surgery, represented by dacryocystorhinostomy, is the ongoing developmental direction of this field. Rapid interdisciplinary integration and in-depth exploration of pathogenesis and allergic inflammation will lead to the emergence of new materials, innovative technologies, and safer clinical treatment protocols.

● **KEYWORDS:** lacrimal duct obstruction disease; dacryocystorhinostomy; lacrimal drainage system; tear drainage system; bibliometric analysis

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INTRODUCTION

The lacrimal drainage system comprises the lacrimal puncta, lacrimal canaliculi, lacrimal sac, and nasolacrimal duct, responsible for draining tears from the eye to the nasal cavity[1-2]. Unobstructed flow through the lacrimal duct is essential for tear drainage to the nasal cavity[3]. Any obstruction or constriction in any part of the tear duct system may lead to tearing symptoms, which are a common manifestation of lacrimal duct obstruction disease (LDOD)[4]. LDOD is a prevalent and frequently-occurring disease in ophthalmology, and approximately 3% of patients seen in ophthalmologic clinics are affected by this condition according to some reports[5]. Obstructive lacrimal drainage system result in inflammation[6], leading to symptoms such as purulent discharge from the eye and ocular irritation[7], significantly impacting patients' physical and mental well-

being. Among these situations, one common consequence of nasolacrimal duct obstruction is causing dacryocystitis, which may lead to acute inflammation with redness and pain around the inner canthus of the eye[8] and carries a risk of developing orbital cellulitis, orbital abscess or intracranial infection[9-10]. Therefore, restoring patency to the lacrimal drainage system through surgery is crucial for treating LDOD. In response to this challenge, ongoing innovation and development in lacrimal surgery have included dacryocystoplasty[11] and dacryocystorhinostomy[12]. Dacryocystorhinostomy was first proposed by Toti[13] in 1904 and has undergone over a century's worth of development becoming currently considered as an optimal solution for treating dacryocystitis induced by nasolacrimal duct obstruction[14-15]. However, due to complexities associated with ocular and nasal structures[16-18], implementing dacryocystorhinostomy still presents challenges[19]. In recent years, the advancement of technologies, like endoscopic navigation and laser[20-23], has propelled dacryocystorhinostomy towards achieving more precise, effective, and minimally invasive outcomes. Furthermore, the exploration into the pathogenesis of LDOD has provided us with a better understanding of the formation of lacrimal concretion[24-25] and the occurrence of nasolacrimal duct obstruction[26].

Utilizing bibliometric analysis enables us to visually depict not only present developments but also emerging themes and prospective direction for investigation within a specific area of study. Bibliometrics has been extensively applied in ophthalmologic and surgical research[27-30], steering advancements in associated disciplines while enriching scholars' comprehension regarding their professional landscape. Nevertheless, despite an abundance of studies on LDOD, there remains a dearth in terms of bibliometric scrutiny pertaining to its development tendency as well as contributing nations, prominent authors, key concepts, and citation. What are the primary subjects and future directions in investigations of LDOD? Does dacryocystorhinostomy continue to represent a promising avenue for research? What role does lacrimal stent play in treating LDOD? What is the LDOS's pathogenesis? These inquiries hold critical significance necessitating further exploration. Consequently, we undertook an inaugural bibliometric examination focused on LDOD employing specialized analytical tools with an objective to synthesize prevailing investigative tendencies and pivotal subject matters within this domain. Through meticulous scrutiny, our aspiration is to unveil this field's knowledge framework, identify principal scholarly institutions, authors, and nations, as well as probe prevalent keywords and co-citations, to ultimately aim at furnishing guidance for subsequent lines of research.

Table 1 Summary of data source and selection

Category	Specific standard requirements
Research database	Web of Science Core Collection
Citation indexes	Science Citation Index Expanded (SCI-EXPENDED)
Searching period	1900-01-01 to 2024-07-11
Languages	English
Searching Keywords	TS=[lacrimal AND (obstruction OR obstructive)]
Document types	"Article" or "Review Article"
Sample size	1481

MATERIALS AND METHODS

Bibliometrics Bibliometrics originated in the early 20th century and was established as a distinct discipline in 1969[31]. It is widely employed for literature analysis across various fields[32], offering quantitative methods for examining articles within specific domains[33] and conducting comprehensive performance analysis[34] through detailed bibliometric analysis of author keywords, institutions, and references. Furthermore, with the continuous advancement of computer technology, visualization analysis using modern software can enhance data interpretation, resulting in more comprehensive outcomes[35].

Data Sources and Search We chose Web of Science Core Collection, a high-quality digital literature resource database widely recognized internationally, as the data source. Clarivate Analytics is considered the most suitable database for bibliometric analysis and has been widely used[36]. We used "TS=[lacrimal AND (obstruction OR obstructive)]" as the search term to search all articles from 1900 to the present, and selected research articles and review articles written in English. The detailed search situation and flow chart are shown in Table 1 and Figure 1.

Data Analysis and Visual Analysis The documents retrieved from the Web of Science Core Collection were downloaded in "Plain text file" and "Tab delimited file" formats for data analysis. Subsequently, Research Areas, Times Cited, and Publications Over Time were analyzed using Web of Science's "Analyze Result" and "Citation Report". The authors, countries or regions, institutions, keywords, and cited references were then analyzed and visualized using VOSviewer 1.6.20 and CiteSpace 6.3.1 for the "Plain text file" format data. Meanwhile, the data in "Tab delimited file" format was imported into the "Bibliometric Online Analysis Platform" (https://bibliometric.com) to analyze annual changes in the number of articles of each country as well as cooperation relationships between countries. Additionally, the data processed by VOSviewer 1.6.20 was analyzed using Scimago Graphica 1.0.43 to generate a visual map of country distribution and country-to-country collaboration. We used Microsoft Excel (Redmond, WA, USA) to create a table that presents the author, country or region, institution, and reference information.

Table 2 Top 10 countries and institutions with publications on LDOD

Rank	Country	Count (%)	Citation	Institution	Count (%)	Citation
1	USA	318 (21.47)	8169	L.V. Prasad Eye Institute	72 (4.86)	1009
2	Turkey	133 (8.98)	1889	The University of Adelaide	29 (1.96)	434
3	India	131 (8.85)	1478	Royal Adelaide Hospital	25 (1.69)	536
4	China	114 (7.70)	1292	Korea University	19 (1.28)	136
5	South Korea	105 (7.09)	1429	Moorfields Eye Hospital	19 (1.28)	608
6	Japan	100 (6.75)	1194	University of Ulsan	19 (1.28)	493
7	United Kingdom	99 (6.68)	2661	Tel Aviv University	15 (1.01)	128
8	Australia	78 (5.27)	1729	Harvard University	14 (0.95)	454
9	Germany	59 (3.98)	833	University of California-Los Angeles	14 (0.95)	468
10	Italy	57 (3.85)	688	The Catholic University of Korea	13 (0.88)	214

RESULTS

Annual Publications, Trends and Research Areas A total of 1481 scholarly publications were analyzed; comprising of research articles (*n*=1394) and review articles (*n*=87), originating from diverse geographic locations encompassing over 60 countries and 1427 academic institutions. The comprehensive annual publications spanning from 1900 to 2024 for literature pertaining to LDOD is visually depicted in Figure 2A. It reveals a generally upward trend including two different peaks, the minor one in 1970S and 1980s and the major one Since the 1990s which culminates at its zenith around 2020 and subsequently taper off. Concurrently, citations also increased rapidly after 1990, reached its peak in 2020, and finally fell gradually, showing a similar trend with annual publications. Among the literature pertaining to LDOD, a total of 860 articles were categorized under ophthalmology, followed by surgery (*n*=320) and otorhinolaryngology (*n*=232; Figure 3).

Issuance by Country/Regions and Institutions The data covers 60 countries/regions, and the annual publication changes of the top 10 countries in the term of total publication number are shown in Figure 2B. The United States occupied the dominant position in the field of LDOD research before 2015, but India and China began to surpass the United States in this term after 2015 and gradually became the main force in LDOD research. The intercountry cooperation is shown in Figure 2C, in which the United States is the country that participates in intercountry cooperation the most, but overall, there is less intercountry cooperation in LDOD. Among the continents, North America, Asia, Europe, and Oceania are active in this research. Figures 4A and 4B show the connections between countries and institutions, with the size of the circles indicating the number of publications, and the thickness of the lines indicating the degree of closeness of the connections between these entities. The United States is the country with the highest total number of publications, primarily focused on the period before the 2010s. However, after the 2010s, Asian countries such as India and China gradually became the main sources

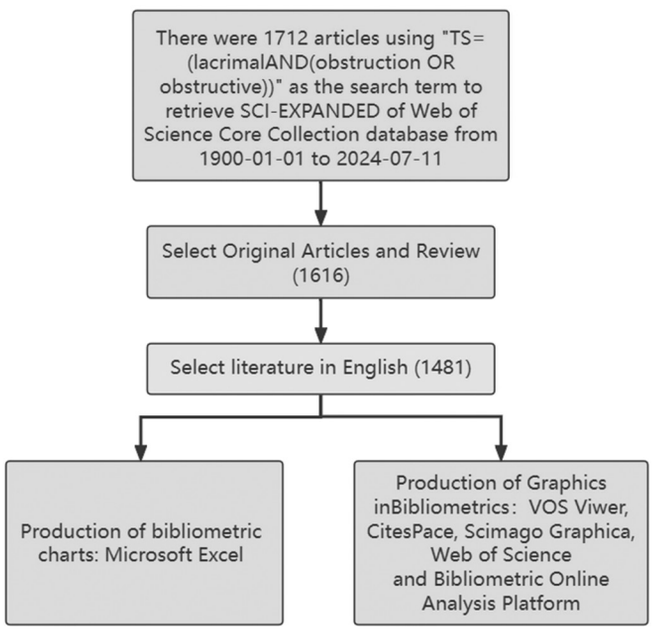

Figure 1 Flowchart of research.

of articles. The top 10 countries and institutions in the term of total publication number are listed in Table 2, and L.V. Prasad Eye Institute is the institution with both the highest number of publications and the highest number of citations, and its publications are concentrated in the past decade. Among the 1427 institutions, the top 10 institutions come from 6 countries, with 3 institutions from South Korea, 2 institutions from the United States, and 2 institutions from Australia. In the term of total publication number, the top 10 institutions did not match the top 5 countries (Table 2), which may be related to the fact that China and Turkey have more publications but their institutions are more dispersed.

Analysis of Journals and Co-cited Journals By July 11, 2024, a total of 269 journals had published literature related to LDOD. *Ophthalmic Plastic and Reconstructive Surgery* (*n*=191, 12.90%) had the highest number of publications, followed by *Ophthalmology* (*n*=64, 3.32%), *British Journal of Ophthalmology* (*n*=54, 3.65%), *American Journal of Ophthalmology* (*n*=53, 3.58%), and *Journal of Craniofacial*

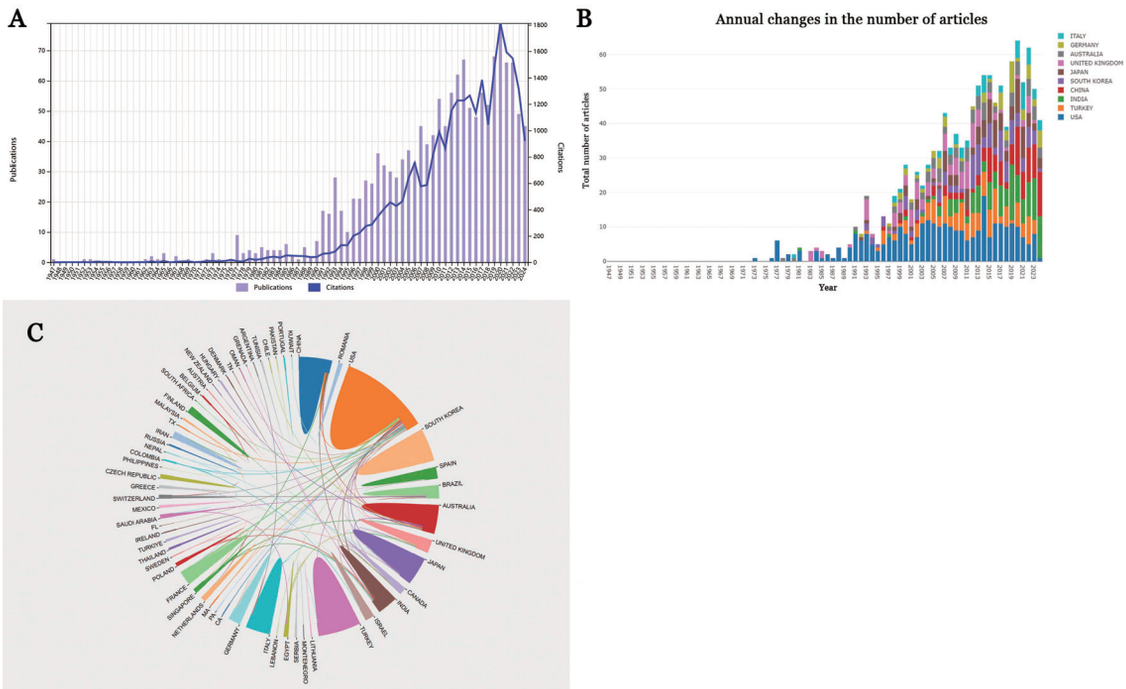

Figure 2 Trends and countries of issuance.

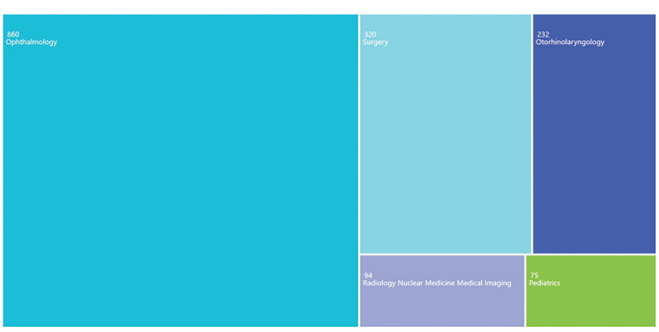

Figure 3 Top 5 research areas (from Web of Science).

Surgery (*n*=43, 2.90%). Among the top 15 journals with the most articles related to LDOD, *Ophthalmology* [impact factor (IF)=13.1] has the highest IF in 2023, followed by *American Journal of Ophthalmology* (IF=4.1) and *British Journal of Ophthalmology* (IF=3.7; Table 3), all of which are among the top 5 journals in terms of publication volume. Of these 15 journals, 8 journals (53.33%) are classified as Q2 by the Journal Citation Reports (JCR), and there is not any journal classified as Q4 (Table 3). The total number of publications in *Ophthalmic Plastic and Reconstructive Surgery* is much higher than that in *Ophthalmology*, but the citations of the two are similar, which ranks first (*n*=3160) and second (*n*=3140) respectively (Table 3). The majority of the top 10 journals by total publication number, including *Ophthalmic Plastic and Reconstructive Surgery*, primarily published in the 2010s or before (Figure 5A). Some of the journals with lower total publication number, such as *International Ophthalmology* and *Indian Journal of Ophthalmology*, primarily published in the past decade (Figure 5A). Among the top 15 co-cited journals for LDOD, *Ophthalmology* (2689) the most frequently cited, followed by *American Journal of Ophthalmology* (*n*=1980) and *Ophthalmic Plastic and Reconstructive Surgery* (*n*=1732). Furthermore, among these 15 journals, 10 journals are in Q1, with only *Orbit* in Q4 (Table 4, Figure 5B).

Analysis of Authors and Co-cited Authors Among all authors who have published literature related to LDOD from 1900 to the present, Table 5 lists the top 10 authors by publication volume and co-citation frequency. Mohammad Javed Ali has the highest publication volume (*n*=65), followed by Selva (*n*=31) and Baek (*n*=19). In research of LDOD, the author network with co-citations is shown in Figure 6, where node size is related to the number of articles published, and line thickness is related to the degree of author interaction. The three most co-cited author are Ali, Song, and Hurwitz (Table 5). In addition, we found that Mohammad Javed Ali from India ranked first in both authorship and co-cited authorship, mainly around 2020, indicating that this author is the most active and influential scholar recently in the field of LDOD globally.

Analysis of Co-cited References The co-cited references were visualized by adjusting the size of the nodes and the thickness of the connecting lines (Figure 7A). Table 6 shows the 10 most frequently co-cited references[13,37-45]. The articles we included was in English, but the co-cited references in those papers were not all in English. Therefore, the non-English co-cited references were retained to truly demonstrate the studies making the significant contributions to the field, without contradicting the aforementioned content. Among them, "Primary acquired nasolacrimal duct obstruction—a clinicopathological report and biopsy technique" stands out as the article with the highest citation (*n*=127).

Table 3 Top 15 journals of publications on LDOD (2023)

Rank	Journal	Count (%)	Citation	IF	Q (JCR)
1	*Ophthalmic Plastic and Reconstructive Surgery*	191 (12.90)	3160	1.2	3
2	*Ophthalmology*	64 (4.32)	3140	13.1	1
3	*British Journal of Ophthalmology*	54 (3.65)	1611	3.7	1
4	*American Journal of Ophthalmology*	53 (3.58)	1761	4.1	1
5	*Journal of Craniofacial Surgery*	43 (2.90)	308	1.0	3
6	*European Journal of Ophthalmology*	39 (2.63)	273	1.4	3
7	*Eye*	38 (2.57)	792	2.8	1
8	*Graefes Archive for Clinical and Experimental Ophthalmology*	30 (2.03)	313	2.4	2
9	*International Ophthalmology*	29 (1.96)	72	1.4	3
10	*International Journal of Pediatric Otorhinolaryngology*	25 (1.69)	420	1.2	3
11	*Archives of Ophthalmology*	23 (1.55)	840	4.399 (2014)[a]	1[a]
12	*Indian Journal of Ophthalmology*	23 (1.55)	204	2.1	2
13	*Journal of Laryngology and Otology*	22 (1.49)	281	1.1	3
14	*Canadian Journal of Ophthalmology-Journal Canadien D Ophtalmologie*	21 (1.42)	220	3.3	1
15	*European Archives of Oto-Rhino-Laryngology*	21 (1.42)	242	1.9	2

[a]The edition is the latest one showed in Web of Science. IF: Impact factor; JCR: Journal Citation Reports.

Table 4 Top 15 co-cited journals (2023)

Rank	Journal	Co-citations	IF	Q (JCR)
1	*Ophthalmology*	2689	13.1	1
2	*American Journal of Ophthalmology*	1980	4.1	1
3	*Ophthalmic Plastic and Reconstructive Surgery*	1732	1.2	3
4	*Archives of Ophthalmology*	1546	4.399 (2014)[a]	1[a]
5	*British Journal of Ophthalmology*	1358	3.7	1
6	*Ophthalmic Surgery Lasers & Imaging*	995	1.318 (2013)[a]	3[a]
7	*Ophthalmic Plastic and Reconstructive Surgery*	770	1.2	3
8	*Orbit*	760	0.9	4
9	*Radiology*	709	12.1	1
10	*Laryngoscope*	675	2.2	1
11	*Eye*	604	2.8	1
12	*Otolaryngology-Head and Neck Surgery*	378	2.6	1
13	*Canadian Journal of Ophthalmology-Journal Canadien D Ophtalmologie*	362	3.3	1
14	*Journal of AAPOS*	342	1.2	3
15	*Investigative Ophthalmology & Visual Science*	340	5.0	1

[a]The edition is the latest one showed in Web of Science. IF: Impact factor; JCR: Journal Citation Reports.

In addition, we carried out co-citation analysis on the references on the timeline (Figure 7B), and the size of nodes was related to the number of co-citations. A total of 18 clusters are showed, which can be divided into 4 types: surgical technique studies (cluster 0, 1, 2, 5, 6, 7, 12, 14), therapeutic effect studies (cluster 4, 9, 13), etiological pathology studies (clusters 15, 16, 18), and others (cluster 3, 8, 10, 11). Figure 7B shows that surgical technique studies were carried out throughout the entire timeline, but were mainly concentrated before 2005, while treatment effect studies and etiological pathology studies were mainly distributed after 2000. At the same time, we have observed that since the beginning of the 21st century, Major hotspots in the study of lacrimal duct obstructive diseases include “mitomycin C” (cluster 0), “paediatric endoscopic endonasal dacryocystorhinostomy (EnDCR)” (cluster 2), “prospective” comparison (cluster 4), punctal stenosis (cluster 1), systematic review (cluster 3).

Table 5 Ranking of the top 10 authors and co-cited authors

Rank	Authors	Count	Co-cited authors	Citations
1	Ali, MJ	65	Ali, MJ	499
2	Selva, D	31	Song, HY	290
3	Baek, S	19	Hurwitz, JJ	248
4	Song, HY	16	Jones, LT	233
5	Kakizaki, H	15	Linberg, JV	228
6	Naik, Milind N	13	Welham, RAN	200
7	Paulsen, F	12	Tsirbas, A	198
8	Singh, S	12	Becker, BB	195
9	Takahashi, Y	12	Kashkouli, MB	189
10	Trimarchi, M	12	Hartikainen, J	180

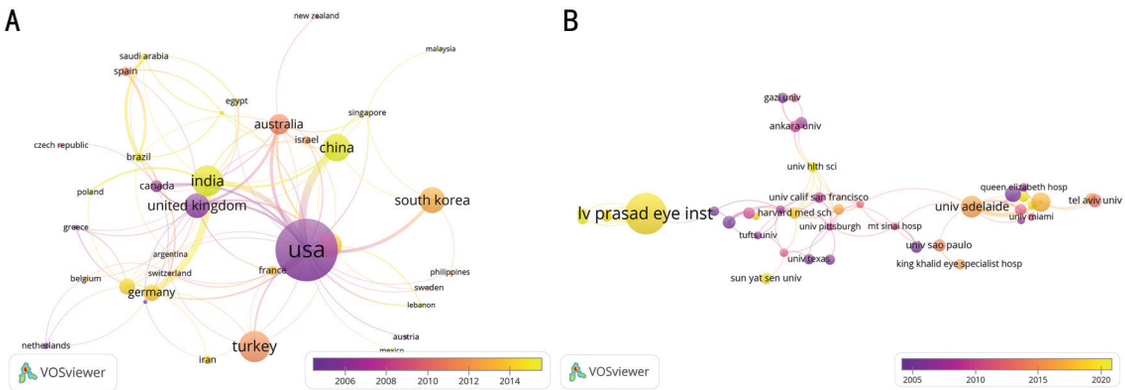

Figure 4 Visual analysis of the sending country and institution.

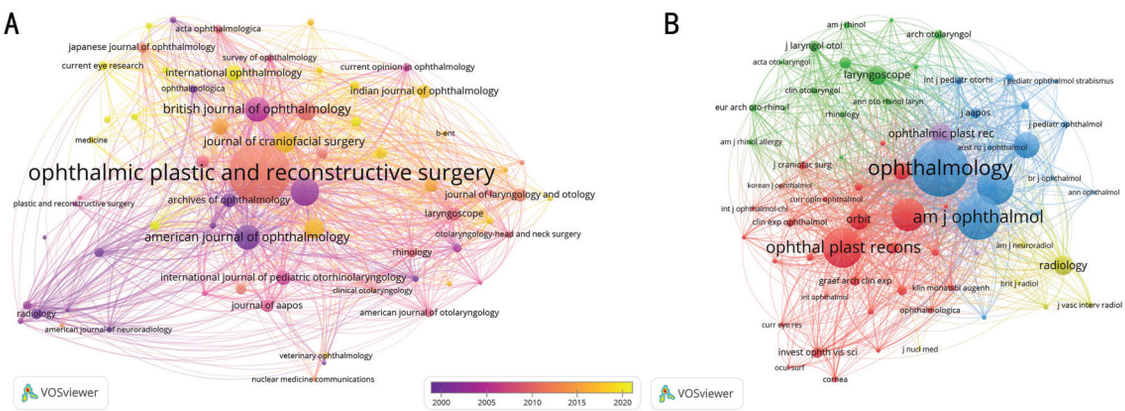

Figure 5 Visual analysis of journals and co-cited journals.

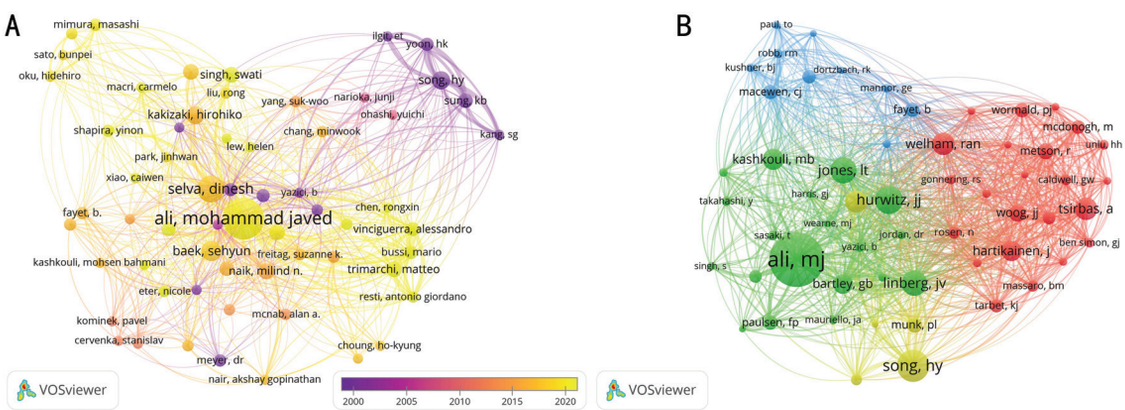

Figure 6 Visual analysis of authors and co-cited authors.

Double-map superposition of journals enables the visualization of topic distribution and orientation within academic journals. On either side of the graph are the citing journals and the cited journals (Figure 8). This curve is the cited curve, which indicates the source of the subject and show the fields advancing the LDOD research. “Dentistry/dermatology/surgery”, “medicine/medical/clinical” and “neurology/sport/ophthalmology” is derived from “ophthalmology/ophthalmic/ophthalmologica”, “health/nursing/medicine” and “dermatology/dentistry/surgery”. In addition, “neurology/sport/ophthalmology” research also from “molecular/biology/genetics”.

Analysis of Keywords and Burst Keywords VOSviewer is used to analyze the frequency of keywords and the strength of their associations, with the aim of revealing the core topics and potential trends in the research field. With the set parameters, the minimum appearance frequency of keywords is 15, and the statistical result shows that a total of 91 keywords have been included. Subsequently, in order to focus on the core concepts more clearly, we increased the threshold for the appearance frequency to 22, at which point, the number of keywords was reduced to 60. The most frequently occurring keywords are dacryocystorhinostomy (n=302), followed by nasolacrimal duct obstruction (n=291), epiphora (n=242), management (n=194), and obstruction (193; Figure 9).

In order to further analyze the research frontier, we use CiteSpace to identify keywords that suddenly appear in the academic literature and quickly attract attention, the so-called “burst keyword”. Of the top 25 cited burst words (Figure 10),

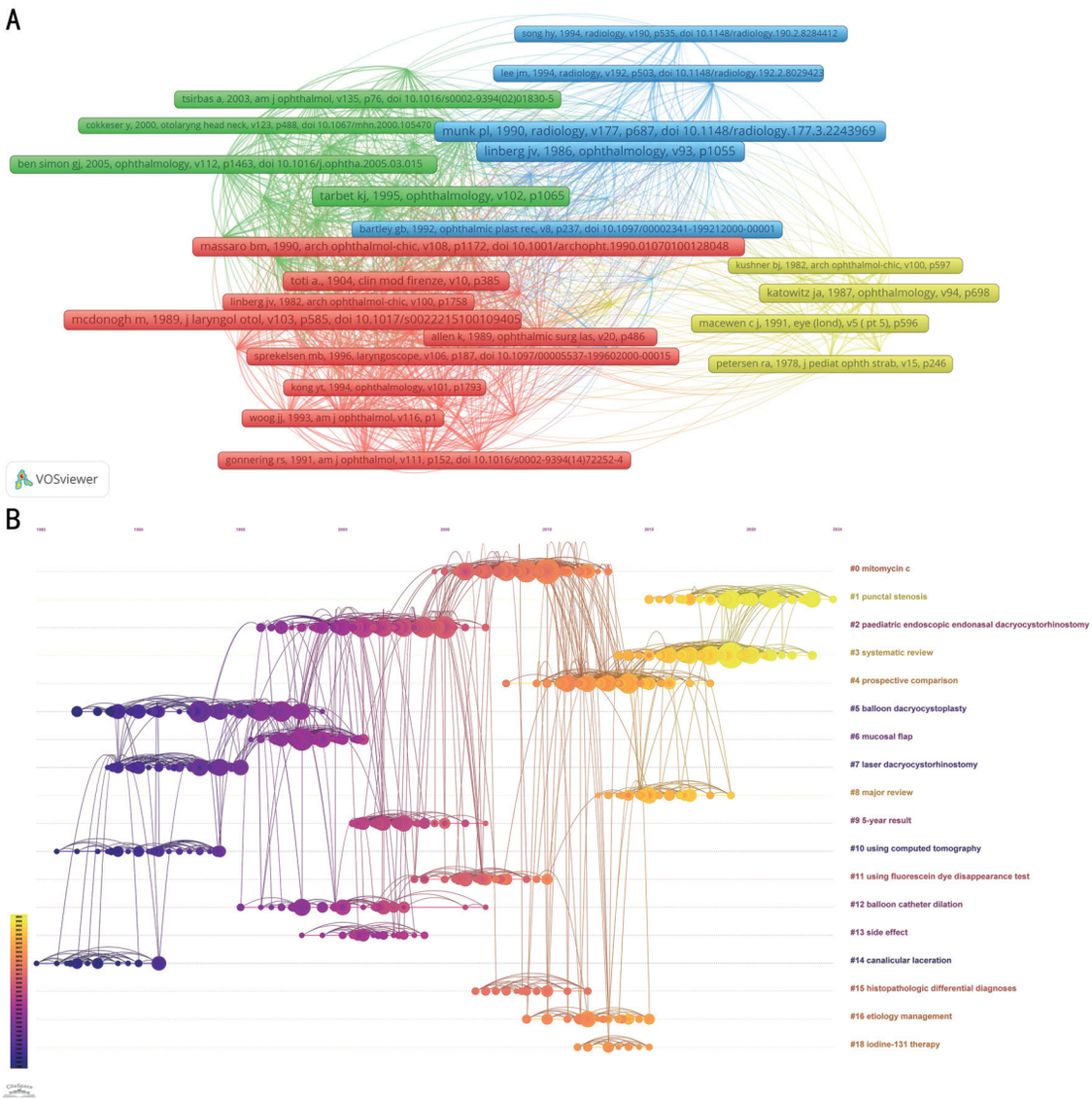

Figure 7 Visual analysis of co-cited references.

Table 6 Top 10 co-cited references

Rank	Title	Citation	Publication year	First author	Journal, IF	Quartile in category
1	Primary acquired nasolacrimal duct obstruction—a clinicopathological report and biopsy technique	127	1986	Linberg, JV	*Ophthalmology* (IF=13.1)	1
2	Epiphora: treatment by means of dacryocystoplasty with balloon dilation of the nasolacrimal drainage apparatus	122	1990	Munk, PL	*Radiology* (IF=12.1)	1
3	External dacryocystorhinostomy—surgical success, patient satisfaction, and economic cost	114	1995	Tarbet, KJ	*Ophthalmology* (IF=13.1)	1
4	Endoscopic transnasal dacryocystorhinostomy	107	1989	Mcdonogh, M	*Journal of Laryngology and Otology* (IF=1.1)	3
5	Nuovo metodo conservatore di cura radicale delle suppurazioni croncihe del sacco lacrimale (dacriocistorinostomia)	97	1904	Toti, A	*Clinica Moderna (Firenze)* (No IF)	None
6	Endonasal laser dacryocystorhinostomy. A new approach to nasolacrimal duct obstruction	96	1990	Massaro, BM	*Archives of Ophthalmology* (IF=4.399, 2014)[a]	1[a]
7	Timing of initial probing and irrigation in congenital nasolacrimal duct obstruction	84	1987	Katowitz, JA	*Ophthalmology* (IF=13.1)	1
8	Management of unsuccessful lacrimal surgery	79	1987	Welham, RAN	*British Journal of Ophthalmology* (IF=3.7)	1
9	Prospective randomized comparison of external dacryocystorhinostomy and endonasal laser dacryocystorhinostomy	75	1998	Hartikainen, J	*Ophthalmology* (IF=13.1)	1
10	Dacryocystorhinostomy failure—association with nasolacrimal silicone intubation	74	1989	Allen, K	*Ophthalmic Plastic and Reconstructive Surgery* (IF=1.2)	3

[a]The edition is the latest one showed in Web of Science. IF: Impact factor.

The top 3 words for explosive strength were “lacrimal gland and duct” (strength of 14.88), “dacryocystoplasty” (strength of 10.6), and “lacrimal surgery” (strength of 10.08). Breakout words that lasted 10y or more were “dilation” (14y), “outcome”

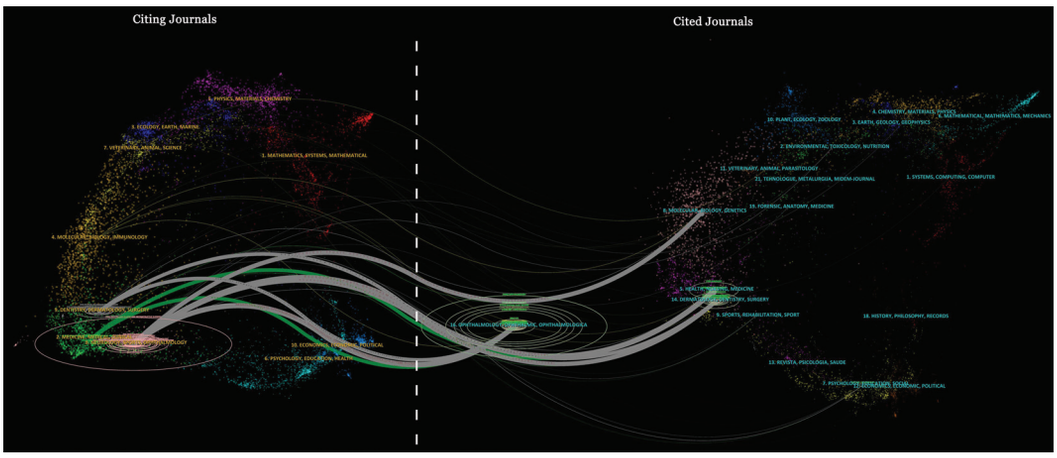

Figure 8 Double graph superposition of periodicals.

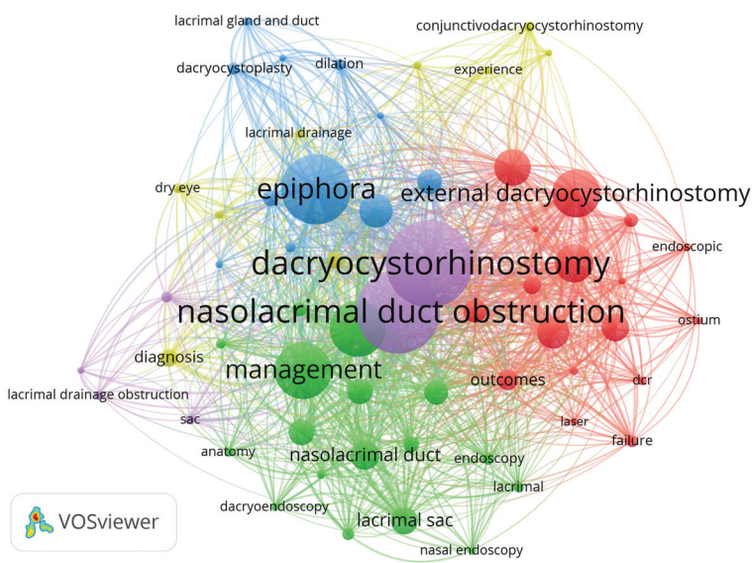

Figure 9 Visual analysis of keyword.

Top 25 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	1990 - 2024
drainage	1991	5.05	1991	1998	
lacrimal gland and duct	1993	14.88	1993	2003	
dilation	1993	9.97	1993	2007	
interventional procedure	1994	6.76	1994	2001	
dacryocystoplasty	1995	10.6	1995	2005	
system	1996	8.98	1996	2006	
balloon dilation	1996	5.95	1996	2003	
stents and prostheses	1996	4.28	1996	2003	
lacrimal surgery	1991	10.08	1997	2005	
assisted dacryocystorhinostomy	1997	4.26	1997	2002	
endonasal laser dacryocystorhinostomy	1995	7.08	1999	2006	
nonsurgical placement	2001	6.05	2001	2006	
polyurethane stent	2001	4.86	2001	2007	
nasal endoscopy	2003	5.16	2003	2010	
laser dacryocystorhinostomy	1998	8.79	2008	2014	
endonasal dacryocystorhinostomy	1994	7.43	2009	2016	
endoscopic dacryocystorhinostomy	1999	4.98	2010	2013	
intubation	1991	5.72	2012	2019	
outcm	2011	8.27	2013	2024	
experience	1992	4.57	2015	2018	
dry eye	1998	5.89	2017	2024	
lacrimal sac	1992	5.92	2019	2024	
diagnosis	1991	5.51	2019	2022	
nasolacrimal duct	1992	4.23	2019	2022	
silicone tube intubation	2020	4.19	2020	2024	

Figure 10 Analysis of keyword burst.

(11y), "dacryocystoplasty" (10y), and "system" (10y). We have paid special attention to keywords that have burst in recent years. These include "outcome" (strength of 8.27), "dry eye" (strength of 5.89), "lacrimal sac" (strength of 5.92), and "silicone tube. Intubation" (strength of 4.19).

DISCUSSION

Basic Information Exploration We searched and obtained 1481 articles related to LDOD published since 1900, the majority of which were released after 1970, with a significant surge in publication emerging after 1990. The general trend indicates a gradual increase in publication. The lacrimal drainage system, as a structure at the junction of the eye and the nose, has been paid much attention by the academic circles of ophthalmology and otolaryngology. However, through the analysis of research fields, we found that ophthalmology occupies a clear dominant position, with the highest proportion of 58.11%. By analyzing the number and trends of publications by country, we find that the United States is the clear leader in terms of the overall number of publications, with 21.47%. Its number of publications is higher than the combined total of Turkey and India, which are ranked second and third respectively, and its citations are significantly higher than the combined total of other top 5 countries. In terms of timeline and geographical distribution, the United States gradually

declined after 2015, while Asian countries represented by India and China gradually became the research center of LDOD. The finding suggests that some Asian countries have progressively surpassed North America and European nations in this particular research domain recently, and are anticipated to emerge as the future frontrunners.

Among the top 10 global publishing institutions, 90% are from developed countries, with only L.V. Prasad Eye Institute coming from a developing country. But L.V. Prasad Eye Institute has the highest number of publications and citations to become the most influential institution globally. This shows that developed countries, represented by the United States, still play a key role in research on LDOD, while developing countries, represented by India, have great potential for development and growing influence. Although Turkey and China are among the top 5 countries in publication, their research institutions are not among the top 10 institutions in publication. Therefore, research institutions in Turkey and China are widely distributed, and their cooperation networks are not tight.

Ali (n=65) published the most articles on LDOD, and is also the author with the highest number of co-citations, indicating that he is the most influential author in the field of LDOD. By July 11, 2024, 269 journals had published 1481 articles related to LDOD. *Ophthalmic Plastic and Reconstructive Surgery* (12.90%, 3160) has the most related articles and citations, followed by *Ophthalmology* (4.32%, 3140). Although the former has about three times as many articles as the latter, *Ophthalmology* has a similar number of citations with the former and the most co-citations. Therefore, researchers can find the most research and potential collaborators in the field in *Ophthalmic Plastic and Reconstructive Surgery*, while it is easier to learn about high-quality research in this field in *Ophthalmology*. In addition, among the top 15 journals in publication volume, *Journal of Craniofacial Surgery*, *International Ophthalmology*, and *Indian Journal of Ophthalmology*, have a high frequency of articles on this field in recent years, which can also help researchers understand related progress.

In the analysis of co-cited references, the cited references were categorized into 18 clusters, which can be further classified into four types. It can be seen from the timeline that surgical technique studies have always been the focus of research on LDOD, while the research on therapeutic effects and pathogenesis and physiology has gradually gained importance since the 21st century. By sorting and analyzing the top 10 cited articles, we found that the term "dacryocystorhinostomy" appeared repeatedly in the titles (60%), which is a widely used method for treating nasolacrimal duct obstruction and dacryocystitis, and has always been a subject of interest. To understand the hotpots and scope of academic discussions in the field of LDOD, we used VOSviewer and Citespace to conduct the analysis of keywords and burst keywords on the data we obtained. We found that 60% of the top 5 burst keywords were related to surgical techniques, and that surgery-related words have repeatedly appeared since the 1990s, further indicating that this direction of research has always been a hotpot in the field of LDOD. Meanwhile, "dilation" (14y), "outcome" (11y), and "dacryocystoplasty" (10y) have persisted for 10y or more, which to some extent reflects the need for a longer period of practice and discussion for surgical techniques and scientific efficacy evaluation for tear duct obstructive diseases. The burst keywords "outcome", "dry eye", "lacrimal sac", and "silicone tube intubation" appeared after 2013 and have continued to the present, indicating that scientific evaluation of treatment outcomes, the relationship between LDOD and dry eye, the management of different types of lacrimal sacs and their etiological studies, and the materials and applications of intubation may become hotpots in the future. High-frequency keywords such as "dacryocystorhinostomy", "nasolacrimal duct obstruction", "epiphora", "management", and "obstruction" suggest that discussions on nasolacrimal duct obstruction and its treatments and efficacy are the focus of research on LDOD, and are also a direction worthy of further exploration and in-depth study in the future.

When focusing on research conducted in the past 20y, a large number of studies on therapeutic effect studies and etiological pathology studies have been cited, particularly in terms of long-term effects, safer treatments, and disease mechanisms, reflecting the future development direction of LDOD research that is becoming increasingly deepened. At the same time, in the burst keywords of the past 20y, the words "endonasal", "endoscopic", and "laser" have been closely associated with "dacryocystorhinostomy", indicating that research on dacryocystorhinostomy is developing towards minimally invasive direction in order to reduce appearance damage and pursue smaller injuries and better outcomes.

Dacryocystorhinostomy Dacryocystorhinostomy in the modern sense has been proposed for 120y[12], has been tested in many clinical practices, and has been widely recognized as the standard treatment option for nasolacrimal duct obstruction[46]. The surgical approaches include transcutaneous, transnasal and transcanalicular approaches[46], so dacryocystorhinostomy can be divided into transcutaneous external dacryocystorhinostomy (ExDCR) and endoscopic dacryocystorhinostomy[47]. ExDCR is a classic and versatile surgical approach that uses an open approach, which is less restricted by factors such as nasal cavity, fractures, and tumors[48-49]. It has a high success rate and is considered the gold standard for surgical treatment of

LDOD[50]. It is often designed as a control group in the research of new surgical techniques[46,51].

Compared with ExDCR, endoscopic dacryocystorhinostomy has the advantage of no facial scar and has attracted wide attention[52]. EnDCR has a good effect on the treatment of LDOD[53-54], and a few studies showed superior results than ExDCR[55]. Meanwhile, EnDCR has also achieved significant results in the study of pathological or special lacrimal sacs[56-57]. With the development of endoscopic navigation and virtual reality technology, EnDCR has great potential in treating traumatic and congenital nasolacrimal duct obstruction[58-60]. Transcanalicular dacryocystorhinostomy requires assistance from an endoscope and a laser device. During the procedure, the optical fiber cable was inserted into the lacrimal sac via the lacrimal canaliculus, and then a passage connecting the lacrimal sac to the nasal cavity was established with assistance from a nasal endoscope. In recent years, many studies have shown that this technology has great potential, but the success rate varies greatly in different studies[61-63], indicating that further research is still needed on the factors affecting the success rate. The fibrosis and stenosis of the newly established passage pose significant challenges in the postoperative management of dacryocystorhinostomy. Studies have demonstrated that the application of mitomycin can effectively inhibit the formation of inflammatory granulation and enhance surgical success rates[64-65].

Intubation Intubation is a commonly performed surgical procedure for treating LDOD, involving the insertion of a lacrimal stent into the lacrimal drainage system. It can be utilized independently[66] or in conjunction with other surgical techniques to address obstructions or constrictions at various points within the system, including the lacrimal punctum, lacrimal canaliculi, or nasolacrimal duct. Research on combining intubation with dacryocystoplasty or dacryocystorhinostomy has produced numerous favorable outcomes[11,66-67]. Nevertheless, some studies have indicated that the impact of stents on surgical success rates remains contentious[68-69].

In response to various situations in the treatment of LDOD, lacrimal stents have undergone continuous improvement, including the development of mini-Monoka stents[70], Crawford stents[71], and others. Furthermore, the ideal material for tear duct stents should possess biocompatibility, resistance to biofilm formation, and elasticity for self-expansion[72]. Silicone stents are widely used in clinical practice due to their excellent material properties. Additionally, new types of stents composed of polymer materials have demonstrated significant advantages. These include Shape Memory Polymer stent[73] with improved anti-biofilm formation and self-expanding elasticity, as well as more cost-effective polyurethane stents. Moreover, the novel stent with drug-carrying coating can impart anti-inflammatory, antifibrotic, antibacterial, and antithrombotic properties. This has been validated in rabbit experiments showing a reduction in postoperative stenosis of the nasolacrimal duct after intubation[74].

Current Understanding of the Etiopathogenesis of LDOD Research on the pathogenesis of LDOD is of great significance for treatment and prevention[75]. However, the specific pathogenesis of LDOD is still unknown. Primary acquired nasolacrimal duct obstruction (PANDO) disease is the most prevalent form of LDOD[76], and there is active research into its pathogenesis[26]. Its primary pathological manifestations involve recurrent inflammation and fibrosis of the lacrimal duct, ultimately resulting in dysfunction of the lacrimal drainage system[77-78]. Meanwhile, PANDO has a multifaceted etiology, encompassing anatomical constriction, microbial influence, and alterations in tear protein profiles, among other contributing factors[79-81]. These elements interact and collectively impact the functionality and health of the nasolacrimal duct. Some researches indicate that prolactin and prolactin receptors may play a significant role in the pathogenesis of PANDO, suggesting that they could serve as crucial targets for further investigation[80,82]. There is evidence to suggest that PANDO is linked with allergic conjunctivitis, allergic rhinitis, and gastroesophageal reflux disease[83-85]. Furthermore, PANDO has also been associated with the administration of radiation therapy and the utilization of specific medications[86-91].

Obstruction of lacrimal canaliculi and lacrimal punctum can result from various factors, such as congenital anomalies, infections, tumors, concretion, and medications[92-95]. Research shows that the etiology plays a crucial role in surgical management of canalicular obstruction, as different etiological types respond differently to specific surgical interventions[96]. Additionally, genetic research on congenital LDOD has provided new insights for the treatment and prevention of the disease. Zhang *et al*[97] and Wang *et al*[98] discovered that mutations in the IGSF3 gene and FGF10 gene are linked to congenital LDOD, while Feng *et al*[99] observed that mutations in the FGF10 gene can result in obstructive nasolacrimal duct stenosis, indicating a potential significant role of these genes in lacrimal duct development. Furthermore, the ongoing research on tear proteinomics, lacrimal system concretion, and microbiological profiles is continuously advancing the academic community's understanding of the pathogenesis of LDOD[24,80,97,100-102].

LDOD and Allergic Inflammation The lacrimal duct is closely connected with the conjunctiva and nasal mucosa, especially the similarity between the epithelial cells of the lacrimal duct and fornical conjunctiva[103], which indicates

a strong correlation between the health of conjunctiva and nasal cavity and the health of the lacrimal drainage system. Especially when allergic inflammation affects the nose or conjunctiva, the incidence and treatment difficulty of LDOD significantly increase[83,104]. Due to the anatomical relationship, allergic inflammation in the nasal cavity or sinuses can cause swelling, which can block the opening of the nasolacrimal duct, leading to LDOD[105-106]. Additionally, several studies have shown that this type of LDOD is predominantly unilateral[105]. The pathological process may start with an allergic inflammation that leads to functional blockage, gradually progressing to fibrosis induced by inflammation, and finally resulting in a complete anatomical obstruction[106-107]. Meanwhile, nasal allergic inflammation can affect the effect of lacrimal surgery[108]. When allergic inflammation is not properly managed, the risk of LDOD recurrence increases. However, anti-allergic treatment before and after surgery may improve outcomes[109]. It is worth noting that some of these patients can alleviate the symptom of tearing by receiving anti-allergic treatment only[110], therefore, the timing of surgical treatment needs further discussion. It is evident that the prevention and treatment of LDOD caused by nasal sinusitis is a problem that needs to be solved.

In 1988, there was a report in the article linking allergic conjunctivitis to LDOD[111], and subsequent studies found that many chronic allergic conjunctivitis patients survived stenosis of lacrimal punctum[112]. Recent studies suggest that silicone stent exhibited good performance in for the management of LDOD in patients with allergic conjunctivitis[113-114], but unresolved conjunctival inflammation increases the risk of surgical failure or LDOD recurrence. In addition, the available evidence suggests a potential remission of conjunctivitis and epiphora after intubation[115], indicating that the relationship between LDOD and allergic conjunctival disease may be intricate and necessitates further investigation. Nasal or conjunctival inflammation can cause eye symptoms similar to LDOD, such as tears, red eyes, etc., which can easily lead to clinical misdiagnosis[116]. Therefore, it is very important to develop the further research on the relationship between LDOD and allergic inflammation, which is of great significance for clinical diagnosis and treatment.

Possible Future Trends and Directions in Research of LDOD Upon summarizing and analyzing the aforementioned data, we posit the forthcoming trends and avenues for LDOD research to be as follows: 1) Dacryocystorhinostomy is a significant lacrimal surgery, and the ongoing trend towards minimally invasive and precise enhancements holds significant importance. Consequently, improving the therapeutic efficacy of endoscopic dacryocystorhinostomy and its application in complex cases will remain the primary focus of long-term research. 2) The utilization of intubation and the advancement of novel stents warrant further deliberation. 3) The in-depth investigation into the pathogenesis of LDOD is in its early stages and will continue to advance at the cellular, protein, and genetic levels, particularly in research related to PANDO. 4) From a current clinical perspective, exploring the link between LDOD and allergic inflammation, as well as their impact on diagnosis and treatment, will also be a challenging and highly relevant topic. 5) The integration of medicine and engineering is an emerging trend, with computer science, materials science, tissue engineering, and other disciplines playing the roles in advancing the prevention and treatment of LDOD.

Advantages and Disadvantages Due to the relatively limited scope of keyword indexing, our research is somewhat constrained in its comprehensiveness. We have exclusively relied on data from the Web of Science platform and focused on English literature exploration. While it's possible that not all relevant studies were included in our specific data source selection, this approach ensures a thorough and professional analysis. Nonetheless, employing bibliometric analysis methods has produced highly reliable results with excellent reproducibility features, offering trustworthy data support and the evidence for the academic community.

In conclusion, at the forefront of LDOD research, our focus has long been on refining and innovating surgical treatment. As a result, the minimally invasive and precise modification of lacrimal surgery, represented by dacryocystorhinostomy, will be the future direction of development in this field. With rapid interdisciplinary integration and in-depth exploration of pathogenesis and allergic inflammation, novel materials, innovative technologies, and new solutions will offer more effective and safe treatment options for clinical practice in the future.

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