

Scleral Contact Lens Research in Keratoconus: A Bibliometric Analysis

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ABSTRACT

This bibliometric study evaluated research trends on binocular vision dysfunction in keratoconus, with particular emphasis on knowledge gaps related to scleral contact lenses. A comprehensive Scopus search identified English-language original articles and reviews published between 2000 and 2025. Bibliometric mapping was performed using VOS viewer. A total of 334 publications were analyzed. Research output increased substantially after 2019, reflecting growing interest in scleral lens technology, lens design, corneal optics, and optical correction. Approximately 15 highly productive authors contributed prominently, with most studies published in specialized contact lens journals. However, keyword co-occurrence analysis revealed minimal focus on binocular visual function, with terms such as stereopsis, vergence anomalies, binocular coordination, and binocular dysfunction largely absent. These findings highlight a significant knowledge gap and underscore the need for future studies evaluating binocular visual outcomes in keratoconus patients fitted with scleral lenses.

Keywords: Keratoconus, Contact Lenses, Vision, Binocular, Bibliometrics.

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INTRODUCTION

Keratoconus is one of the most common corneal ectatic disorders and significantly impairs visual function and quality of life.¹ Scleral contact lenses have become a primary modality for visual rehabilitation in keratoconus, providing improved visual acuity and comfort by masking corneal irregularities.² Binocular dysfunction encompasses abnormalities of binocular vision, vergence, and accommodation that may further compromise visual performance and quality of life.^{3,4} Given the complex visual demands of patients with keratoconus and the rapid advancements in scleral contact lens technology,

interest has grown in understanding the relationship between scleral lens rehabilitation and binocular visual function. However, the extent to which this topic has been explored in the scientific literature remains unclear, highlighting the need to evaluate existing research and identify gaps that may guide future investigations.

The use of bibliometric analysis provides researchers and clinicians the opportunity to map out a given research landscape, identify established collaborations or networks of investigators involved in similar research, and identify emerging trends within a particular domain of science.⁵ This methodology has been successfully applied across various ophthalmology subspecialties, including corneal biomechanics⁶, dry eye disease⁷, refractive surgery⁸, contact lenses⁹ and genetic retinal diseases.¹⁰ However, a comprehensive bibliometric analysis specifically examining the intersection of keratoconus, scleral contact lens applications, and binocular dysfunction has not been previously reported.

The rationale for the current bibliometric analysis

arises from the important clinical gap while managing keratoconus. Evidence suggests that scleral contact lenses can restore the normal monocular vision in each eye, but does not guarantee functional binocular vision.^{11,12,13} Despite normal monocular visual function, an individual can experience vergence, accommodation disorders which can cause diplopia, other as then opic symptoms, and impaired quality of life.¹⁴ A higher-order aberration caused by coma or spherical aberration leads to anisometropia and aniseikonia, ultimately challenging the binocularity.^{11,15} Clinicians often neglect the binocular vision assessment.

The purpose of this study is to conduct a systematic bibliometric analysis of research publications spanning scleral contact lenses and binocular vision over the past decade using the Scopus database. The main objectives were to map publication trends, geographic distribution, and research productivity. Identify key researchers, collaboration patterns, and influential works. Analyze thematic emphasis and research priorities through keyword networks, quantify the extent of binocular vision research integration, and identify critical research gaps requiring future investigation. By systematically mapping research trends, collaborative networks, and thematic emphasis over the past decade, this analysis aims to identify whether binocular visual function has received adequate research attention alongside advances in optical correction technology.

METHODS

A broad search of existing literature was conducted via the Scopus database on 18/8/2025. Following terminologies were used: “(“keratoconus” OR “corneal ectasia” OR “pellucid marginal degeneration” OR “keratectasia” OR “kerato-conus”) AND TITLE-ABS-KEY(“binocular vision disorder” OR “binocular vision dysfunction” OR “convergence insufficiency” OR “convergence excess” OR “vergence dysfunction” OR “accommodative dysfunction” OR “vergence anomalies”)” OR TITLE-ABS-KEY(“scleral lens” OR “scleral contact lens” OR “scleral lenses” OR “scleral contact lenses” OR “scleral CL” OR “large diameter contact lens” OR “large-diameter gas permeable”) AND PUBYEAR > 1999 AND PUBYEAR < 2026”. This provided peer-reviewed journal articles and reviews that had been published since 2000 and are still relevant today.¹⁶

All primary studies, including original research articles and review articles (which included systematic reviews and meta-analyses) that had been written in the English language were selected for inclusion. Conference abstracts, editorials, proceedings papers, letters to the editor and book chapters were excluded. All searches were checked manually by title, abstract and keywords for verification. The downloaded datasets were imported into VOS viewer v.1.6.20 to create and display the networks.¹⁶ The analytical options were:

Auto Referencing Analysis: We set a minimum number of documents authored by an individual author of 2 so that meaningful collaborations could be identified.

K-Words Co-Occurrence Analysis: We set a minimum of five occurrences of a keyword so that important topics being researched could be captured.

Node sizes within the networks were representative of the frequency metrics (number of documents or keyword occurrences) used to construct them; Node colours represented clustering of nodes; Link thickness represented the strength of relationships between authors or concept nodes. Along with the publication trends and collaborative patterns among authors, the co-occurrences of keywords within networks and the thematic clustering were examined according to standard methods in bibliometrics.^{17,18}

RESULTS

The overall search returned 334 publications, dating from 2000 to 2025. The timeline illustrated in Figure 1 clearly demonstrates an increase in publication volume over time. The increase has accelerated since 2019,

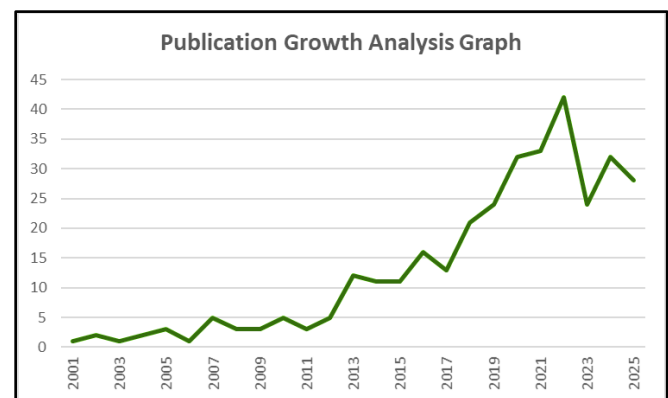


Figure 1: Publication trends graph showing growth from 2014 to 2024, total n=334.

which can be seen as an indicator of increased scholarly interest in the intersection of keratoconus, scleral contact lenses, and binocular dysfunction.⁹ It can also be interpreted as evidence of the maturing of the field as well as greater recognition of the clinical importance of these interrelated research areas.

As shown in Table 1, among the top 15 prolific researchers who have significantly impacted the field of study, Marsack JD was found to be the most productive researcher, having authored 12

Table 1: *Top 15 Most Prolific Authors.*

Rank	Author	Number of Publications
1.	Marsack JD	12
2.	Applegate RA	11
3.	Jacobs DS	11
4.	Rathi VM	10
5.	Shorter E	10
6.	Hastings GD	9
7.	Nau A	9
8.	Vincent SJ	9
9.	Carracedo G	8
10.	Dumpati S	8
11.	González-Méijome JM	8
12.	Harthan J	8
13.	Iqbal A	8
14.	Mandathara PS	8
15.	Nguyen LC	8

publications; followed by Applegate RA, and Jacobs DS, each of whom authored 11 publications.

Co-authorship Network Analysis (Figure 2) highlighted three distinct collaborative groups within the research community. As indicated by the figure, the largest group consisted of researchers working together under Santodomingo-Rubido and included Maharana and Severinsky. This group demonstrated stable and ongoing international partnerships since 2013–2025. A European-based collaboration group consisting of researchers Van der Worp and Schornack with Barnett demonstrated cooperative relationships between institutions. Two smaller groups surrounding Sabesan, Carracedo, and Kumar represented specific sub-specialties of research. Overall, the configuration of this co-authorship network suggested a diverse research landscape defined by both established research centers along with emergent international collaborations providing opportunity for further internationalization.

Co-citation analysis used in this study allowed us to identify important papers that have had a direct impact on advancing our understanding of scleral contact lenses. Papers from early stages of development provided foundational principles of scleral lenses.^{17,18} Publications from mid-term stages progressed to further develop lens technologies and

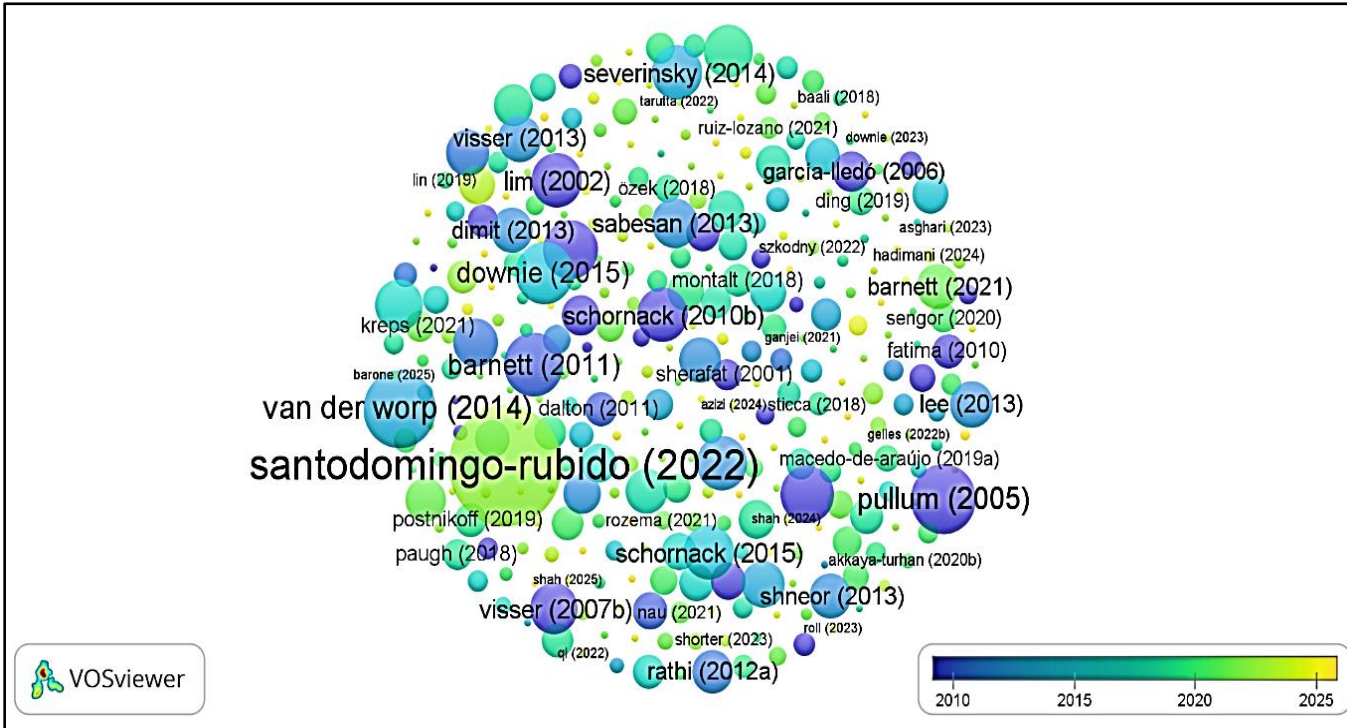


Figure 2: Co-authorship network showing collaborative clusters among researchers.

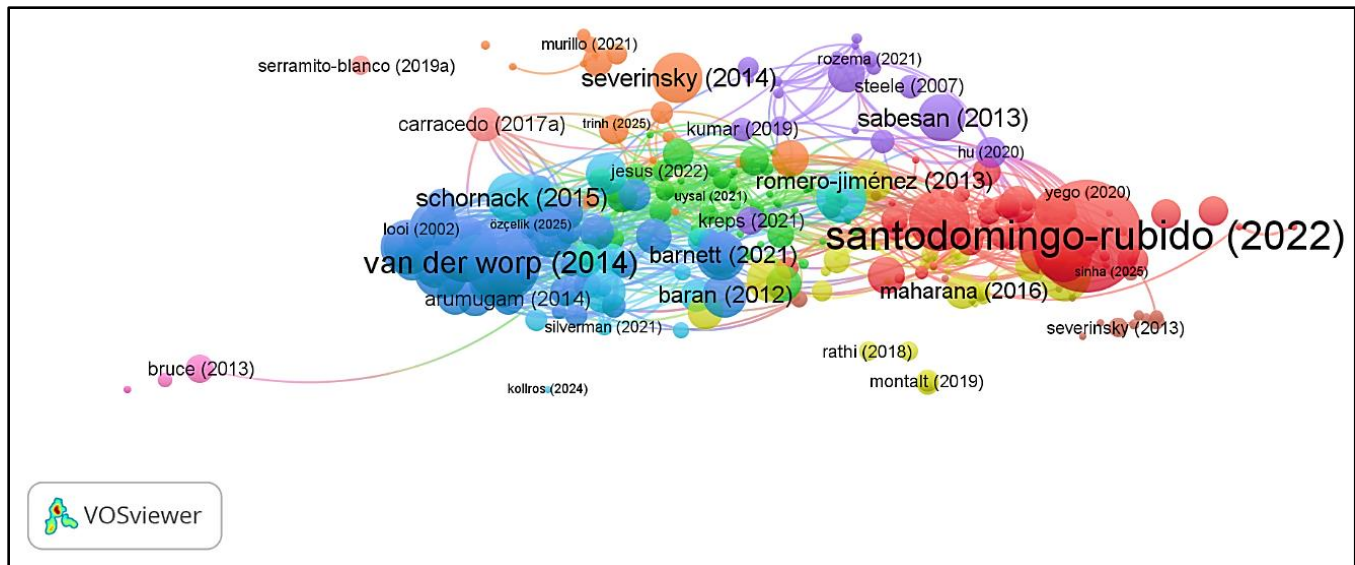


Figure 3: Co-citation network showing influential authors and temporal evolution of research.

Table 2: Top 10 Journals by Publication Output.

Rank	Journal	Number of Publications	Percentage
1.	Eye and Contact Lens	56	16.8%
2.	Contact Lens and Anterior Eye	52	15.6%
3.	Optometry and Vision Science	29	8.7%
4.	Clinical and Experimental Optometry	13	3.9%
5.	Cornea	12	3.6%
6.	Eye Glaz	9	2.7%
7.	Indian Journal of Ophthalmology	9	2.7%
8.	Journal Français d'Ophtalmologie	9	2.7%
9.	Current Opinion in Ophthalmology	6	1.8%
10.	Keratoconus: A Comprehensive Guide to Diagnosis and Treatment	6	1.8%

their application in clinical settings.¹⁹ Most recent papers have represented the forefronts of current research in this area.^{7,8} The transition from foundational blue nodes to transitional cyan/green to contemporary yellow nodes indicate continued progression of the field towards developing new knowledge.

Using the bibliometric analysis data presented above, it can be determined that the 334 publications analyzed were spread across many specialty journals related to contact lenses and vision science. Of these journals, Eye and Contact Lens published the greatest number of publications at 56 (16.8%), followed closely by Contact Lens and Anterior Eye at 52 (15.6%) as shown in Table 2.

The concentration of research in specialty journals focused specifically on contact lenses clearly indicates that a great deal of effort is being devoted to studying this area of ophthalmology. Specifically, when

combining the efforts of Eye & Contact Lens and Contact Lens & Anterior Eye (which account for 108 or approximately 32.4% of total publications), demonstrate that these two journals are serving as the major outlets for publishing research in this very specialized discipline.

The geographic representation of the research data collected and analyzed in this study reveals a vast amount of international research efforts occurring in multiple countries (Table 3).

The results of keyword co-occurrence analyses are illustrated in Figure 6, where VOS viewer was used to illustrate the interconnectedness of the overall research landscape and the main thematic groupings in the field. The network diagram clearly illustrates how many central keywords, such as “keratoconus,” “contact lens,” and “vision,” act as “bridge” terms between many other specializations in the area.

Table 3: Top 12 Countries by Publication Output.

Rank	Country	Number of Publications	Percentage
1.	United States	106	31.7%
2.	India	44	13.2%
3.	Spain	26	7.8%
4.	Australia	22	6.6%
5.	United Kingdom	20	6.0%
6.	Russian Federation	19	5.7%
7.	Brazil	18	5.4%
8.	Turkey	17	5.1%
9.	Netherlands	16	4.8%
10.	Canada	13	3.9%
11.	China	12	3.6%
12.	Portugal	11	3.3%

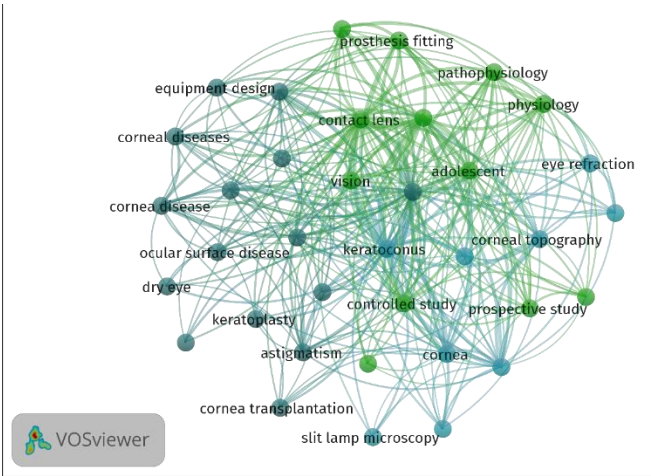


Figure 4: VOS viewer keyword co-occurrence network

Several thematic groupings have emerged from the data analysis.

Clinical Research & Methods (the Light Blue Grouping)

This group has an emphasis on evidence-based research methodologies. Some of the most frequently occurring words within this grouping were “controlled study,” “prospective study,” “corneal topography,” and “cornea.” The presence of methodology-related words suggested a strong commitment to conducting high-quality studies using modern methods for assessing and monitoring keratoconus.

Core Keratoconus Treatment & Visual Rehabilitation (the Green Grouping)

A large group of words were present that related to treatments for keratoconus and visual rehabilitation.

These included “contact lens,” “prosthetic fitting,” “adolescent,” “physiology,” “pathophysiology,” and “eye refraction.” The green cluster provided insight into how clinicians managed keratoectasia through contact lenses. It also highlighted the age demographics of patients who typically experienced keratoconus.

Corneal Disease & Treatments (the gray cluster)

In addition to treating keratoconus, researchers and practitioners were studying other forms of corneal disease and their treatments. Words such as “corneal diseases,” “corneal disease,” “design of equipment,” “keratoplasty,” “astigmatism,” and “corneal transplant” reflected both the range of treatment options available for more severe cases of keratoconus, and the importance placed upon understanding the etiologies behind several types of corneal disease.

Diagnostic Technology (cyan/blue nodes)

Throughout the network were scattered several words related to diagnostics, such as “slit lamp microscopy,” “corneal topography,” and “prospective study”—all examples of how researchers utilized new technologies to advance our understanding of keratoconus.

Ocular Surface & Associated Disorders (peripheral gray nodes)

Several words existed in the network which described disorders associated with the ocular surface, e.g., “dry eyes” and “ocular surface disorder,” reflecting awareness that many patients’ experiencing keratoconus might also be suffering from dry eye or other ocular surface disorders.

Collectively, the structure of the network showed a strong connection between clinical practice and research. Researchers have developed a systematic approach to diagnosing keratoconus and managing its symptoms and consequences. They emphasized the use of current technology to diagnose keratoconus, fit patients for contact lenses, and develop long-term treatment plans that incorporate contact lens therapy and/or surgery.

DISCUSSION

In the last decade, we have identified an evolving and enlarging body of research on keratoconus and scleral lens fitting. In recent years, this body of research has grown exponentially, especially since 2019. This increase can be related to the growing acknowledgment of clinicians of the importance of using a multidisciplinary approach in treating keratoconus and providing binocular vision treatment, as well as the increased use of scleral lenses as a first-line therapy for keratoconus.

The continuous expansion in publishing activity shows a continued source of research funding, growing clinician interest, and a developing body of evidence showing the effectiveness of scleral lenses as a therapeutic option for keratoconus.^{9,13,19}

The geographical location data clearly show USA as the major contributor to research in this field (31.7 percent of publications), with USA having several of the most productive authorship and top research institutes involved in vision science. While India represents the second largest number of contributors (13.2 percent) to this body of research, it is also important to note the significant difference in the number of publications produced by India (44) compared to those published in the USA (106).

Given the large population in India, the high incidence rate of keratoconus within this population, and the availability of scleral contact lenses within India, there is obviously a considerable opportunity for India to expand their current level of research production. Furthermore, the disparity in research levels between the USA and India provides numerous opportunities for original investigations by Indian researchers into topics that are currently under-researched internationally. For example, one area that remains relatively unexplored worldwide involves assessing binocular vision defects associated with patients wearing scleral contact lenses who have been diagnosed with keratoconus.^{20,21} Therefore, because they have easy access to large patient populations and diverse clinical manifestations of keratoconus, Indian research institutions would likely provide valuable insights into the association among corneal ectasia, contact lens rehabilitation, and binocular vision performance.

The heavy participation of European countries, including Spain (7.8 percent), the United Kingdom (6.0 percent), the Netherlands (4.8 percent), and

Portugal (3.3 percent), can be attributed to long-standing traditions of conducting contact lens research and practicing clinical optometry in Europe. Additionally, there is evidence that contact lens research is being conducted in Australia (6.6 percent), Brazil (5.4 percent), Turkey (5.1 percent), Russia (5.7 percent), Canada (3.9 percent), and China (3.6 percent); thus, demonstrating a growing international commitment to vision science research.

However, while 50 percent or more of all publications were generated in only two countries (the USA, 44.9 percent, plus India, 6 percent) provides opportunities for additional collaborative efforts among researchers around the world and potentially enhances access to evidence-based methods for managing keratoconus worldwide through strengthened research networks between established vision science institutions and emerging institutions.

The geographically dispersed nature of the most productive authors – representing research institutions within the USA, India, Spain, Portugal, and Australia—supports the concept that there exists distributed expertise in the area of research related to contact lenses, versus being limited to several centers.^{18,22} For the field, this is positive since it allows for the opportunity to bring diverse views together to facilitate multicenter clinical trials; promote knowledge sharing among differing health care delivery models; and allow for knowledge to be transferred among varying patient populations.

Analysis of co-authorship and co-citations revealed a mature field with distinguishable collaborative clusters and defined lines of research. The emphasis of current citations demonstrated in citation networks also shows that knowledge is rapidly evolving. Sustained progression over time, in addition to both networks demonstrating progressive movement in time, confirms that the field has evolved continuously and at a steady rate, rather than experiencing paradigm shifts. Finally, this will provide the opportunity for increased collaboration between established and emerging research groups around the world.

Publications appearing primarily in journals focused on contact lens issues -- particularly *Eye and Contact Lens* (16.8%) and *Contact Lens and Anterior Eye* (15.6%) -- reflect the technical and clinical nature of research being conducted. Combined, these two journals represent approximately one-third (32.4%) of

all publications published, thereby providing the scientific communities practicing/ researching contact lens-related issues a common knowledge base upon which they can rely when conducting their work.

Publications appearing in Optometry and Vision Science (8.7% of publications) reflect the broad optometric view that ensures the dissemination of research findings to a wider audience of optometrists who practice in primary care settings caring for keratoconus patients before referral to specialists. Publications appearing in Cornea (3.6%) and Current Opinion in Ophthalmology (1.8%) further indicate success in integrating contact lens management into mainstream ophthalmologic literature, which will foster better working relationships between optometrists and ophthalmologists in delivering comprehensive keratoconus care.

Regionally specific journals are important in identifying population-specific aspects of keratoconus epidemiology; culturally related issues associated with treatment compliance; differences in access to health care systems; and barriers to obtaining specialty contact lens care in regions where such services are limited or unavailable.

Publication venue specialization while limiting the number of non-specialized journals where articles appear may limit greater awareness among general ophthalmologists, optometrists, and other policy makers regarding the benefits of scleral lenses for improving patient outcomes. Efforts to publish significant findings in higher-impact-factor medical journals would increase visibility of findings supporting improved accessibility of scleral lenses for patients.

This analysis identifies a clear research community focused primarily upon clinical application and patient care within the broader context of keratoconus. This is reinforced by the centrality of key words such as “keratoconus,” “contact lens,” and “vision.” These are clearly the base keywords that link together multiple research themes in the area. The fact that several key methodological terms (“controlled study,” “prospective study,” and “corneal topography”) were identified as being prominent in this research synthesis demonstrates the maturation of this research community towards an evidence-based model which places a high premium on establishing diagnostic accuracy and objectively measuring outcomes.¹⁶

The inclusion of terms associated with both conservative management (e.g., contact lens fitting and prosthetic fitting) and surgical interventions (e.g., keratoplasty and corneal transplantation) demonstrates that the current understanding of managing keratoconus encompasses a continuum of therapeutic options. Increasingly, modern practitioners consider scleral contact lenses to be the primary form of therapeutic option for patients suffering from visual impairment due to keratoconus; however, surgical intervention is often considered when patients have failed contact lens wear or if their disease has progressed to threaten the structural integrity of the cornea.^{9,13}

The prominence of the keyword “adolescent” in this analysis indicates that most individuals experience the onset of keratoconus during adolescence and young adulthood.^{20,21} Clinical relevance of this demographic factor relates to how clinicians determine the best course of treatment for adolescents and young adults who suffer from keratoconus, how clinicians develop long-term plans for management, and how clinicians assess the impact of keratoconus on an individual's quality of life regarding education/career development/socioeconomic functioning.²³ Therefore, conducting research specifically addressing pediatric/adolescent populations is important for determining optimal timing for intervention and minimizing the risk of vision loss during critical periods of development.

In addition to demonstrating the importance of optical correction, the prominence of terms relating to ocular surface disease and dry eye indicates that successful scleral lens wear relies heavily on maintaining healthy ocular surfaces. While scleral lenses can potentially offer therapeutic benefits to patients experiencing either dry eye or exposure keratitis concurrently with keratoconus, there are many potential clinical challenges associated with wearing scleral lenses, including deposit formation on lenses, solution hypersensitivity reactions, stagnated post-lens tear film and corneal hypoxia.^{24,25} Thus, contemporary research is increasingly addressing these complex clinical issues.

The emerging bibliometric trends in this study suggest there are several ways that the clinical practice of managing keratoconus has evolved. The increased presence of controlled studies, as well as prospective research design methodologies, indicates an increase toward standardized, evidence-based practices for the

process of fitting patients with scleral lenses. Additionally, modern clinical practices are increasingly utilizing validated assessment methods for fitting scleral lenses, objective computer-assisted fitting programs, and routine monitoring of patient outcomes to guide decisions regarding which approach will best serve each patient's needs.

The use of advanced technologies such as corneal topography, anterior segment OCT, and scleral profiling is becoming increasingly common.¹⁵ The application of these tools facilitates accurate diagnosis, allows clinicians to monitor disease progression in patients, enables the creation of custom-designed contact lenses tailored to the unique shape of each individual's cornea, and improves overall outcomes for patients suffering from keratoconus.

The integration of terms related to both diagnosis and treatment options represents an acknowledgement by researchers and practitioners that providing effective care to individuals affected by keratoconus requires integrated, coordinated management strategies. This means that optimal care for patients involves early detection and identification of disease; timely initiation of contact lens therapy; regular monitoring of disease progression; and timely referral to surgical specialists if necessary.

Research conducted over recent years suggests that successful treatment extends far beyond simply improving visual acuity. Successful treatment also includes restoring functionally relevant aspects of vision; ensuring comfortable wearability and handling capabilities of contact lenses; minimizing disruptions to daily functioning due to eye problems; and conducting patient-reported outcomes and quality of life assessments as part of clinical trials or evaluation of patient outcomes.

The short-term effects of scleral lenses are very well documented; however, long-term study outcomes (i.e., 5 to 10 years), which evaluate the safety of the use of scleral lenses, long-term changes to corneal health, as well as sustained improvements in visual performance, will be important to assist in making clinical recommendations and educating patients.

Adolescents are commonly affected by keratoconus, but there is still a lack of research regarding the specific challenges associated with scleral lens fitting in pediatric populations, as well as the difficulties associated with compliance among younger patients. Developing age-appropriate fitting

procedures and developing family-centered approaches to providing care for these young patients are additional areas that need to be explored through additional research.

Conducting head-to-head comparative effectiveness studies evaluating various design parameters, materials used in the manufacture of scleral lenses, as well as comparative philosophies associated with fitting, will allow for evidence-based selection options to be made by clinicians for each unique patient.

Integrating wavefront guided design principles into scleral lenses, utilizing topography-based manufacturing processes to create custom-designed lenses, and integrating AI-assisted fitting algorithms into the process represent exciting emerging technologies that require extensive evaluation and validation before being utilized clinically.

Additional research efforts focused on identifying barriers to accessing care in low-resource settings, developing training opportunities for eye care professionals practicing in resource-poor areas, and developing strategies to increase access to specialized eye care services will help promote greater global equity in eye health.

Relatively few keywords related to binocular dysfunction were identified in the network analysis conducted in conjunction with this review, indicating that this represents another area of research that has received relatively little attention. Since keratoconus can affect one eye differently from the other eye, investigating binocular vision challenges and rehabilitation strategies may provide researchers with a promising new direction for their research in countries such as India that have large patient populations and well-established research infrastructures.

CONCLUSION

This bibliometric analysis of 334 publications spanning 2014-2024 reveals keratoconus, scleral contact lens, and binocular dysfunction research as a dynamic, expanding field characterized by consistent growth, established research leadership, and strong clinical focus.

The authors' review of available literature was unable to locate a prior study that conducted a systematic and empirical examination of correlations

(or the lack thereof) between scleral contact lens studies and investigations into binocular vision function in keratoconus. Thus, an opportunity exists to fill this void as it relates to the clinical implications of binocular vision function (and the critical role that such function plays in achieving optimal functional vision), while most of the existing research focus has been directed toward monocular optical outcome measures.

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Conflict of Interest: Authors declared no conflict of interest.

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