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ORIGINAL RESEARCH

A Bibliometric Study on Research Trends and Characteristics of Pediatric Allergic Conjunctivitis

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Purpose: Pediatric allergic conjunctivitis (PAC) is a prevalent inflammatory eye condition caused by hypersensitivity to allergens. This study performs a scientometric assessment to uncover global research patterns, collaboration networks, and thematic evolution in PAC literature.

Methods: Publications related to PAC from 1963 to 2025 were retrieved from the Web of Science Core Collection database. Data were analyzed and visualized using VOSviewer (version 1.6.20), CiteSpace (version 6.3.R1), and the "bibliometrix" package in R (version 4.3.3).

Results: A total of 378 documents were analyzed, revealing a significant increase in publications over the years, especially after 2010. China led with 99 publications, followed by the USA and Japan. Notable international collaboration was observed, particularly between China and Germany. China Medical University Taiwan, Sun Yat Sen University, and China Medical University Hospital Taiwan were identified as the leading institutions. The journal *Pediatric Allergy and Immunology* was the most prolific, followed by *Allergy*. The most cited authors included Wei CC and Lin CL, with key research themes encompassing asthma, rhinitis, and pediatric allergic diseases. Keyword analysis indicated a growing interest in environmental factors such as air pollution and the comorbidity of PAC with other allergic conditions.

Conclusion: This bibliometric analysis offer valuable insights for future research directions and clinical strategies aimed at enhancing PAC diagnosis and treatment. Future research should evaluate the long-term efficacy of immunotherapy and investigate environmental determinants in PAC pathogenesis. Special emphasis is needed on multicenter studies incorporating regional diversity and standardized methodologies. Diverse regional data was incorporated to enhance global applicability and reduce public health burdens.

Keywords: pediatric allergic conjunctivitis, bibliometrics, allergic diseases, environmental factors, research hotspots

Introduction

Affecting 10–15% of children globally, Pediatric Allergic Conjunctivitis (PAC) is an inflammatory ocular condition resulting from hypersensitivity reactions of the conjunctival tissue to various allergens.[1–3] PAC can be categorized into several subtypes based on clinical presentations and sensitizing agents, including seasonal allergic conjunctivitis, perennial allergic conjunctivitis, atopic keratoconjunctivitis, spring catarrhal conjunctivitis, giant papillary conjunctivitis, and allergic contact conjunctivitis.[4] The pathophysiology of PAC predominantly involves IgE-mediated immediate hypersensitivity reactions, during which mast cells and eosinophils release inflammatory mediators. This cascade of events leads to conjunctival vasodilation, tissue edema, and cellular infiltration.[5] External factors, such as climate change and environmental pollution, significantly exacerbate the prevalence of PAC by increasing allergen exposure.[6] The global burden of allergic diseases, including PAC, has been rising steadily over recent decades, posing substantial challenges to pediatric healthcare systems. Long-term or recurrent PAC can adversely impact visual development, school performance, and psychosocial well-being, further highlighting the significance of effective management and prevention strategies.[2,3]

The diagnosis of PAC primarily hinges on a comprehensive patient history, emphasizing seasonal variations in allergic symptoms, family history of atopy, and individual allergic antecedents.[1] An ocular examination is critical for diagnosis, focusing on identifying conjunctival congestion, edema, papillary hypertrophy, and follicle formation.[7] Furthermore, allergen testing—such as skin prick tests or specific IgE antibody assays—plays a vital role in identifying

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responsible allergens and informing therapeutic interventions.[8] Management strategies for PAC encompass both non-pharmacological and pharmacological approaches.[4] Non-pharmacological interventions prioritize allergen avoidance through measures such as optimizing home environments, employing air purifiers, utilizing protective eyewear, and applying cold compresses to alleviate ocular discomfort. Conversely, pharmacological treatments include antihistamines, mast cell stabilizers, corticosteroid eye drops, and immunosuppressants, which operate through various mechanisms to mitigate the allergic response and alleviate ocular inflammation, thereby improving symptoms in affected pediatric populations.[9,10] Recent advancements in biologic agents have introduced novel therapeutic options for PAC,[11] particularly through specific immunotherapy aimed at incrementally increasing allergen exposure to modulate the patient's immune response and achieve sustained symptom relief.[12]

Scientometric analysis employs quantitative methods to evaluate scholarly output within a specific domain, revealing thematic trends and collaboration networks.[13] Despite significant advancements in clinical research on PAC, bibliometric studies focusing on this condition remain limited. The present study aims to address this deficiency by quantitatively analyzing PAC-related literature to uncover research trends, hotspots, and potential gaps. This analysis is anticipated to yield valuable insights for researchers, clinicians, and policymakers, ultimately facilitating the optimization and refinement of PAC prevention and treatment strategies.

Methods

Search Strategies and Data Source

Data were retrieved from the Web of Science Core Collection (WoSCC) using a targeted search strategy, covering publications from 1963 to 2025. Data retrieval was executed on January 21, 2025, employing the following search formula: ((TS=("allergic conjunctivitis" OR "conjunctivitis, allergic" OR "atopic conjunctivitis" OR "conjunctivitis, atopic" OR "vernal conjunctivitis" OR "conjunctivitis, vernal" OR "keratoconjunctivitis, vernal" OR "giant papillary conjunctivitis" OR "conjunctivitis, giant papillary")) AND TS=(Child* OR infant* OR newborn* OR preschool* OR school* OR adolescent* OR pediatri*)).

Data Analysis and Visualization

For statistical analysis, three complementary bibliometric tools were employed: VOSviewer (version 1.6.20), CiteSpace (version 6.3.R1), and the R package "bibliometrix" (version 4.4.3). These tools facilitated the generation of scientific visualizations and the assessment of academic trends in PAC research. VOSviewer was utilized to map institutional collaborations, author co-authorships, and keyword co-occurrence patterns, effectively illustrating the co-authorship network and relationships among keywords. In this visualization, the size of the nodes represented the volume of publications or citations, while the connecting lines indicated the strength of collaboration or co-occurrence. For network construction in VOSviewer, the full counting method was used, in which each co-authorship or co-occurrence is counted equally for every relevant document. No additional normalization was applied to the network weights, following standard practice in recent scientometric studies.[14] CiteSpace was employed to identify emerging research trends and significant keywords, with parameters set for time slicing from 1994 to 2025 and keywords designated as the node type. A threshold of five occurrences was set for keywords prior to pruning, meaning that only keywords appearing at least five times in the dataset were included in network analyses. This threshold was selected based on established practices in bibliometric literature to balance network complexity and interpretability.[14] Pruning was conducted using pathfinder and clip merge methodologies to visualize emerging trends. This analysis successfully identified key research hotspots over time. The R package "bibliometrix" enabled further statistical examination of the dataset, permitting the analysis of publication distribution across various countries, institutions, and journals. It also provided metrics such as the h-index, which assesses an author's productivity and citation impact; the g-index, which emphasizes highly cited papers; and the m-index, which normalizes the h-index based on an author's career duration.[15,16] Additionally, Journal Citation Reports (JCR) quartiles and Impact Factors (IFs) were employed to evaluate journal influence. JCR quartiles categorize journals into four tiers, with Q1 representing the highest tier, while IF measures the average number of citations per article over the preceding two years, reflecting academic prestige. This analysis incorporated the most recent JCR and IF data available from 2023.

Results

Publication and Citation Trends

A total of 531 studies were initially identified from the WoSCC database, covering publications from 1963 to January 21, 2025 (Figure 1A). After a rigorous screening process based on predefined inclusion and exclusion criteria, a total of 378 studies were retained for the final analysis. Studies were excluded if they were not published in English, or if they were review articles, meeting abstracts, early access publications, editorial materials, proceedings papers, letters, corrections, or reprints. Specifically, the excluded records comprised 91 review articles, 14 meeting abstracts, 5 early access publications, 5 editorial materials, 13 proceedings papers, 5 letters, 2 corrections, 1 reprint, and 27 non-English language articles.

From 1963 to 2025, research on pediatric allergic conjunctivitis has exhibited a substantial increase, resulting in 378 publications during this period and an annual growth rate of 2.26%. Contributions originated from 2,015 authors, with

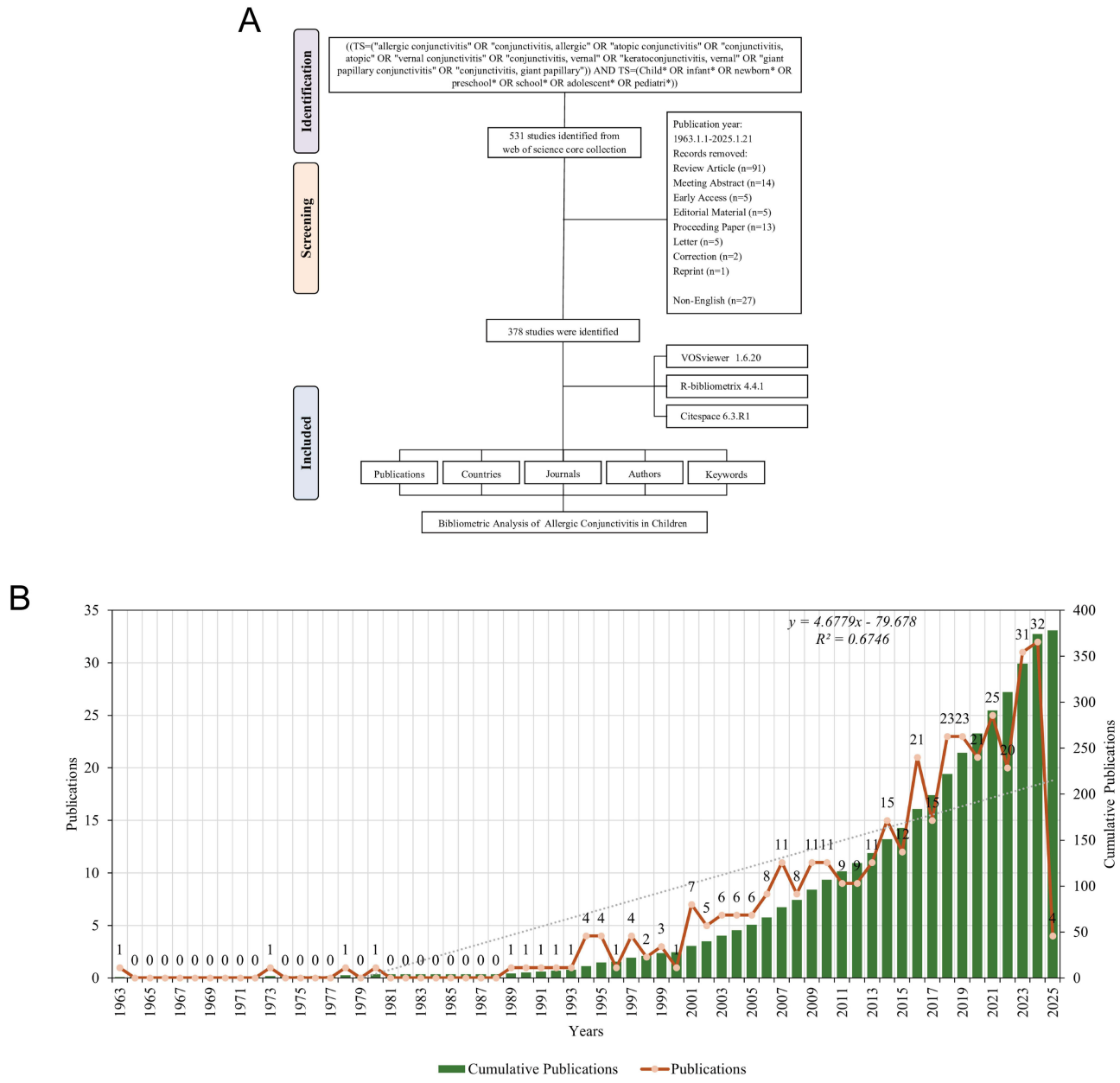

Figure 1 Literature Screening Process and Annual Publication Trends. (**A**) Flowchart of study selection for PAC research. (**B**) Temporal distribution of publications (1963–2025).

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only 8 producing single-authored documents. Notably, 15.34% of the publications involved international co-authorship, and the average number of co-authors per document was 6.37. The publications collectively cite 10,218 references, and 770 unique author keywords were employed to encompass the breadth of research topics. Each document has an average citation count of 23.91, underscoring the academic impact of this body of work. The average age of the documents is 10.7 years, indicating the sustained relevance of foundational studies in the field.

The publication trend reveals three distinct phases of growth (Figure 1B). From 1963 to 1990, the number of publications remained relatively low, averaging fewer than one per year. A gradual upward trajectory commenced in the 1990s, leading to more consistent publication patterns. The most significant growth occurred after 2010, culminating in a peak of 32 publications in 2023. Despite some fluctuations, the overall trend indicates a growing interest in pediatric allergic conjunctivitis, bolstered by collaborative efforts and international engagement.

Analysis of Leading Countries

The global distribution of publications in this domain indicates substantial contributions from a variety of nations. China ranks first with 99 articles (26.20%), followed by the USA with 46 articles (12.20%) and Japan with 28 articles (7.40%) (Figure 2A). Despite its high output, China exhibits a relatively low multiple-country publication (MCP) ratio of 0.121, suggesting limited international collaboration. In contrast, Germany demonstrates a robust MCP ratio of 0.75. Other nations, including Italy (MCP ratio: 0.227) and Finland (0.25), also reflect significant collaborative efforts, underscoring the increasing importance of cross-border research partnerships within this field.

Citation analysis further highlights the considerable impact of the USA, which has amassed a total of 1,510 citations and an average of 32.8 citations per document (Supplementary Table 1). Italy ranks third in total citations, with 1,021, and achieves one of the highest averages at 46.4 citations per document, emphasizing the significant influence of its research output. While China leads in total citations with 1,583, its average citation count of 16 suggests a prioritization of quantity over impact. The international collaboration network reveals several key research clusters (Figure 2B). The Asian cluster, spearheaded by China and Japan, demonstrates strong regional cooperation, whereas European countries constitute another significant cluster, with Germany, Italy, and the United Kingdom exhibiting extensive collaborative links. The USA serves as a bridge between these clusters, maintaining robust connections with both Asian and European research communities.

Analysis of Institutions

Institutional analysis reveals China Medical University Taiwan as the top contributor with 102 articles, followed by China Medical University Hospital - Taiwan (46 articles) and Sun Yat Sen University (24 articles) (Figure 2C). A detailed summary of the top 10 most productive institutions, including the number of documents, total citations, and total link strength, is provided in Supplementary Table 2 for deeper insight into institutional impact and network centrality. These leading institutions collectively account for 45.5% of total publications in the field. The institutional landscape shows significant concentration in East Asia, with 5 of the top 10 institutions located in this region. Analysis of institutional collaboration networks (Figure 2D) reveals distinct patterns of cooperation. China Medical University exhibits extensive connections with both national and international partners, forming a major cluster in the network. Japanese institutions, including Nihon University and Hokkaido University, contribute significantly through dense collaborative networks focused on clinical research and treatment approaches. The network structure identifies three major clusters, centered around Chinese, Japanese, and Western institutions respectively, each specializing in different aspects of pediatric allergic conjunctivitis research.

Analysis of Journals and Co-Citations

The publications analyzed encompass a diverse array of journals, with *Pediatric Allergy and Immunology* leading the field with 15 articles, followed by *Allergy* and *Clinical and Experimental Allergy*, each contributing 10 articles (Supplementary Table 3). These journals predominantly concentrate on the domains of allergy, immunology, and pediatrics, thereby underscoring the principal research areas within this discipline. A review of impact factors reveals varying degrees of influence among the publishing venues. The *Journal of Allergy and Clinical Immunology* possesses the highest impact factor at 11.4 (JCR 2023), while *Allergy* follows closely with an impact factor of 12.6. The JCR quartile distribution indicates a robust concentration of research outputs within Q1 journals, emphasizing the high quality of scholarship in this area.

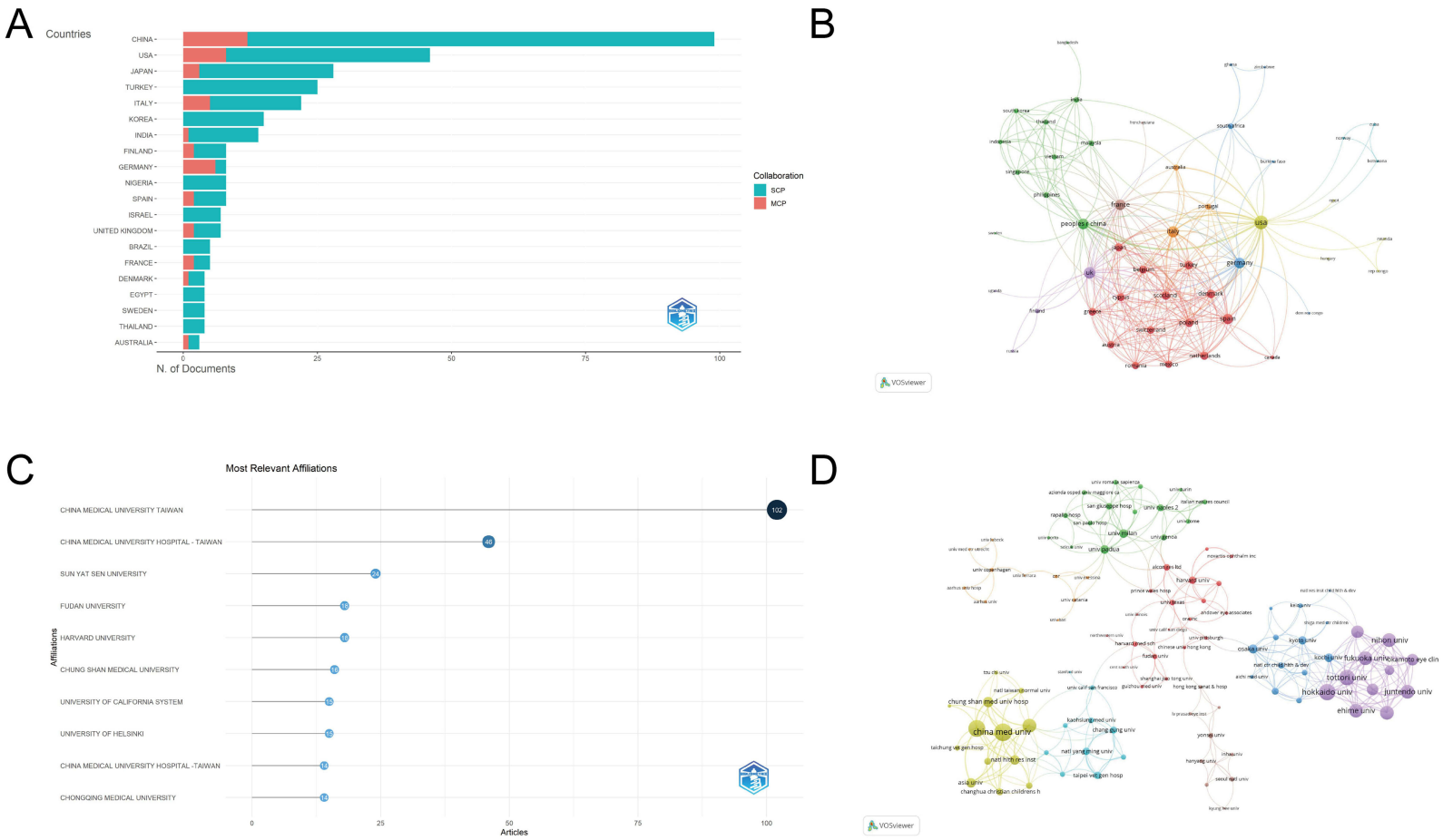

Figure 2 Global Contributions and Collaboration Networks. (**A**) Leading countries by publication volume. SCP: Single County Publications; MCP: Multiple Country Publications. (**B**) International collaboration network. (**C**) Top institutions. (**D**) Institutional collaboration clusters.

The co-occurrence and coupling network of journals (Figure 3A and B) illustrates a complex pattern of knowledge integration across disciplines. This network exhibits several distinct clusters, with journals focused on allergy and immunology constituting one major cluster, while ophthalmology journals form another. Journals such as *Allergy* and *Pediatric Allergy*

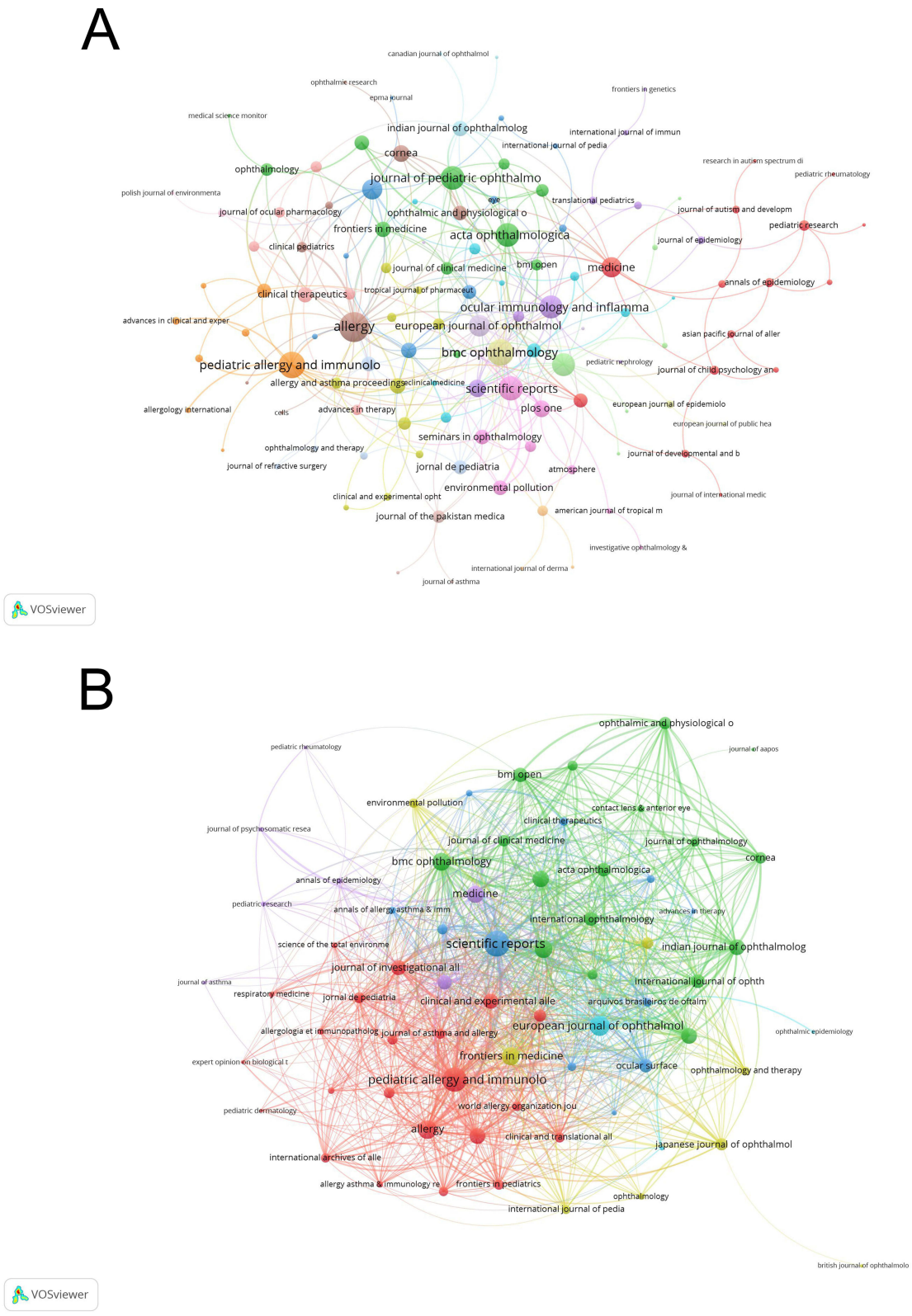

Figure 3 Journal Co-Citation Networks. (**A**) Co-citation clusters of Journal. (**B**) Key bridging journals.

and Immunology serve as pivotal bridges between these disciplinary clusters. Significant co-citation relationships are apparent between the core journals in allergy and ophthalmology, indicating notable intellectual exchange between these fields. This pattern underscores the interdisciplinary nature of research pertaining to pediatric allergic conjunctivitis.

Analysis of Authors and Co-Citations

A total of 2,015 authors have contributed to the research within this field, displaying varying levels of productivity and impact. Wei CC emerges as a prominent figure, having published 12 papers and received 283 citations, which underscores a significant influence in the discipline (Supplementary Table 4). Lin CL and Shen TC closely follow, with 11 and 9 publications, respectively, and have also made noteworthy contributions, particularly in highly cited works. The co-authorship network (Figure 4) visually represents the dense collaboration patterns among these authors, revealing distinct clusters that correspond to specific research subfields. The largest cluster, primarily composed of Italian researchers such as Bianchi and Annamaria, focuses on clinical studies and exhibits strong connections to other leading authors from various geographical regions.

Analysis of Co-Occurrence Keywords and Burst Terms

The keyword analysis delineates principal research domains and emerging trends within the field (Figure 5A). The most frequently cited keywords—"asthma", "rhinitis", and "children"—underscore the primary themes of inquiry. The co-occurrence network elucidates distinct clusters pertaining to clinical manifestations, therapeutic strategies, and epidemiological investigations. The keyword overlay visualization (Figure 5B) illustrates robust interconnections among allergic conditions, thereby indicating the comorbid nature of pediatric allergic conjunctivitis with other allergic disorders. Furthermore, clusters centered on environmental factors and treatment-related terminology suggest an increasing focus on these areas.

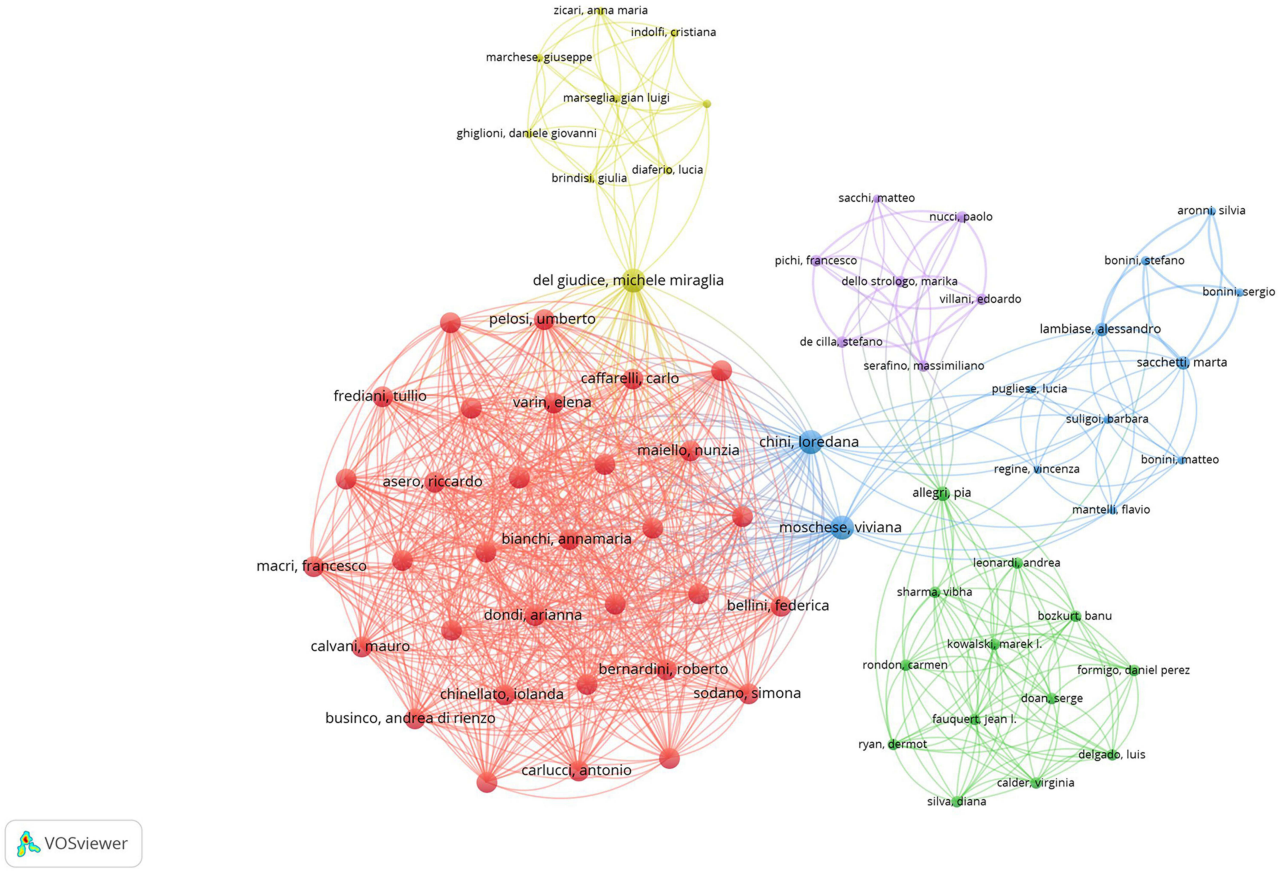

Figure 4 Author Productivity and Collaboration Patterns.

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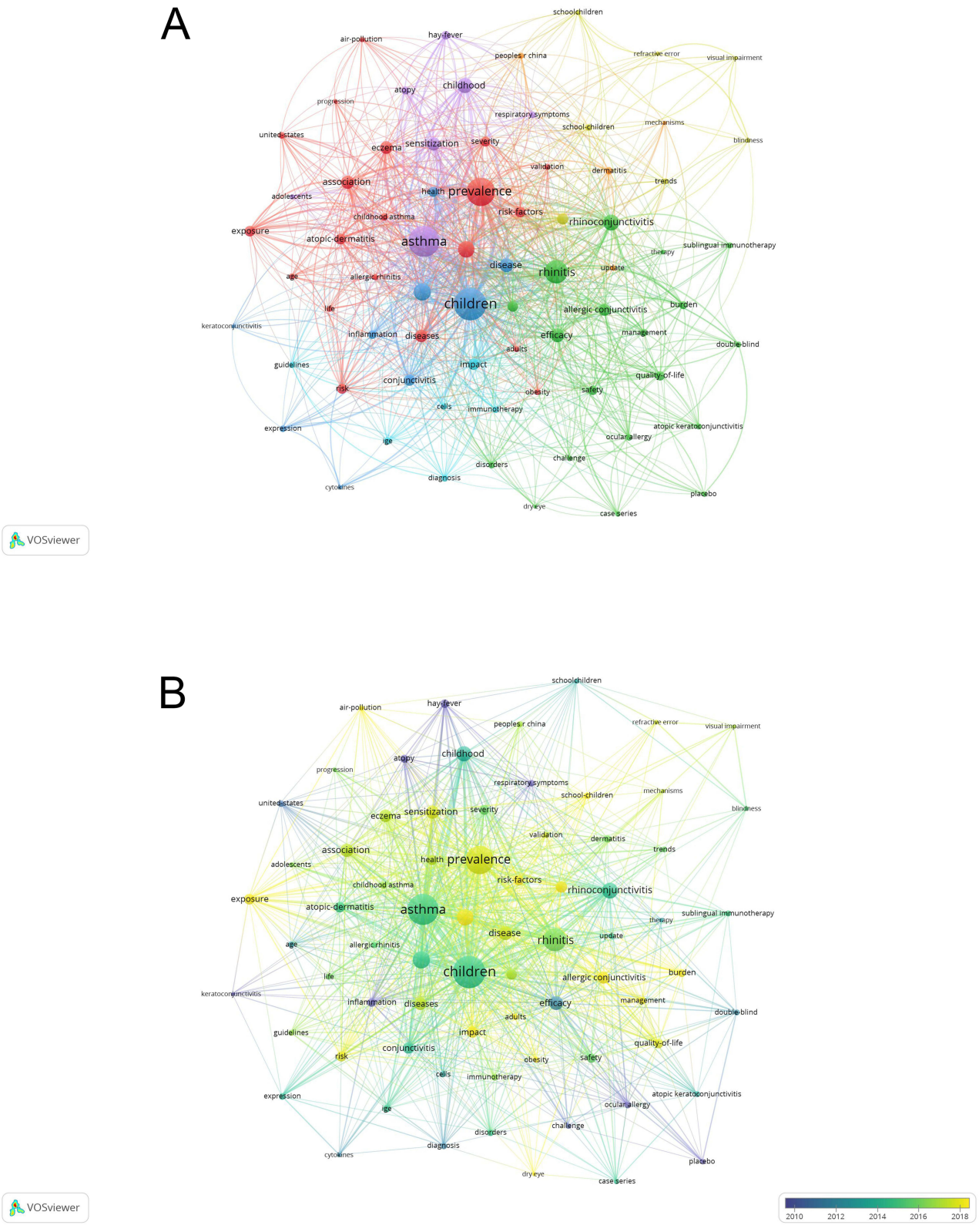

Figure 5 Keyword Co-Occurrence and Evolution. (**A**) Co - occurrence network of keywords. (**B**) Keyword overlay visualization.

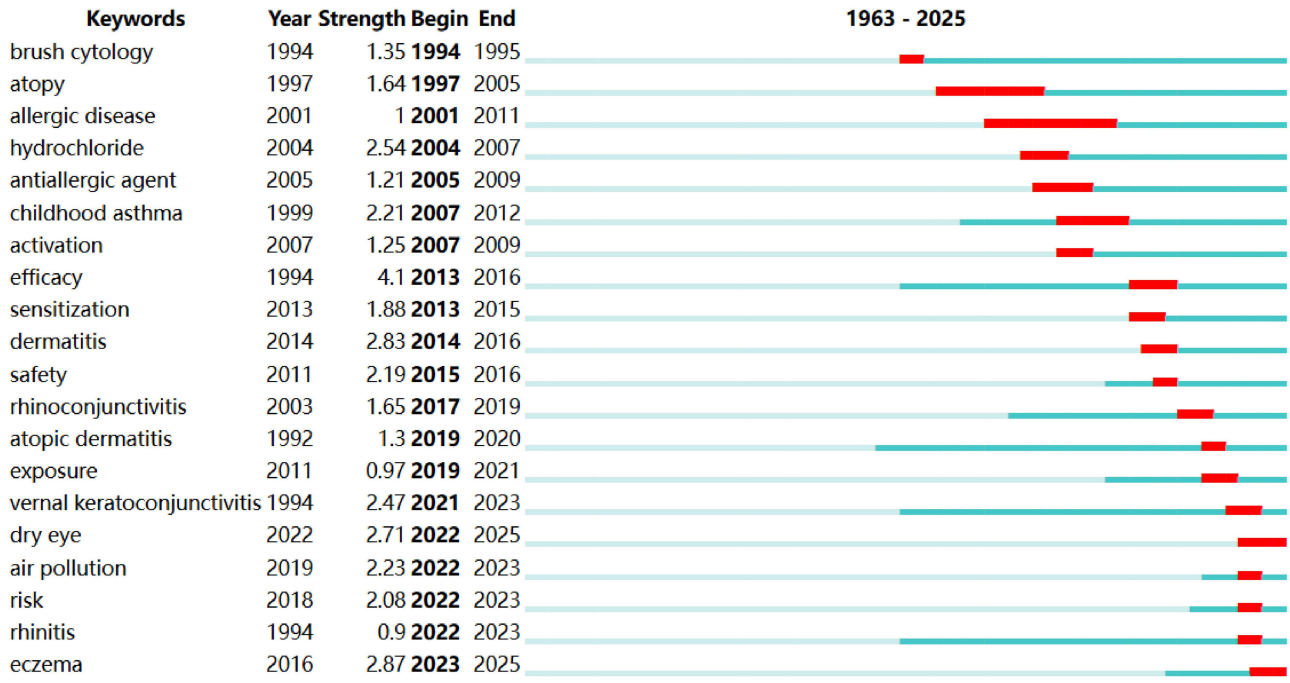

Figure 6 Temporal Burst Keywords. The Top 20 Keywords with the Strongest Citation Bursts.

The analysis of citation bursts reveals notable temporal trends in research concentration (Figure 6). The terms "dry eye" (strength=2.71, 2022–2025) and "eczema" (strength=2.87, 2023–2025) signify the most recent and consequential research priorities. Earlier citation bursts, such as "brush cytology" (1994–1995) and "atopy" (1997–2005), established foundational research domains. Intermediate bursts, including "efficacy" (2013–2016) and "sensitization" (2013–2015), reflect an escalating emphasis on treatment effectiveness and pathophysiological mechanisms. Recent bursts, such as "air pollution" (2022–2023) and "rhinoconjunctivitis" (2017–2019), underscore an increasing acknowledgment of environmental factors and comorbid conditions. These patterns signify a transition from basic diagnostic methodologies towards a more holistic understanding of the environmental and multifactorial dimensions of the disease.

Discussion

This study reveals that PAC research has evolved through distinct thematic shifts—starting from clinical diagnostics toward environmental and molecular determinants over the past sixty years. This evolution mirrors advancements in understanding disease mechanisms alongside broader changes in environmental and public health challenges. The early research phase (1963–1990) was characterized by fundamental clinical observations and basic immunological studies, primarily focused on elucidating the pathophysiology of allergic conjunctivitis. Key works from this period established the foundational understanding of IgE-mediated responses in ocular allergies, which were critical for subsequent developments in diagnostics and therapeutic strategies.[17,18]

The geographical distribution of research contributions highlights significant disparities in knowledge production, research focus, and impact among countries and institutions.[19,20] China leads with 99 publications, underscoring its substantial investment in biomedical research and its focus on environmental factors, such as air pollution, as major triggers for allergic conjunctivitis.[6] However, despite its high output, China exhibits a relatively low ratio of international collaboration. This phenomenon may be attributed to institutional research policies that prioritize domestic output and national collaborations,[21] as well as language barriers and limited participation in multinational projects[22] Furthermore, China's funding structures tend to favor domestic partnerships, which may further restrict opportunities for broader international engagement. In contrast, the USA, with 46 publications, has fewer studies but emphasizes immunotherapy and biologics, reflecting its leadership in innovative treatment development.[12] Japan, with 28 publications, concentrates

on clinical research and diagnostic advancements, supported by its long-standing expertise in ophthalmology.[19] These regional differences illustrate how local challenges—such as urbanization in China, cutting-edge therapies in the USA, and an aging population in Japan—shape research priorities and strengths.

At the institutional level, East Asian contributors, such as China Medical University Taiwan and Sun Yat Sen University, dominate in publication volume but focus heavily on local challenges, which limits global collaboration. Conversely, Western institutions, particularly in the USA and Europe, exhibit more robust international partnerships, enhancing the influence and applicability of their findings.[20] A specific gap remains in East–West collaboration, with bibliometric studies demonstrating relatively few joint research initiatives or co-authored publications bridging these regions.[23] Addressing this imbalance could facilitate knowledge transfer and promote the adoption of best practices globally. These results indicate a need for greater cross-border cooperation to leverage complementary strengths. For instance, China's expertise in environmental health could inform global preventive strategies, while advancements in immunotherapy from the USA could accelerate treatment innovation. Strengthening collaborations and standardizing research protocols could enhance knowledge exchange and lead to more effective clinical practices for pediatric allergic conjunctivitis.

Keyword co-occurrence analysis reveals emerging research frontiers that warrant further exploration. The strong correlation between allergic conjunctivitis and other atopic conditions[24,25] suggests a need for more integrated approaches to allergic diseases in children. Recent emphasis on air pollution and climate change indicates an increasing recognition of environmental factors in disease etiology,[26] implying that future research should focus on understanding gene-environment interactions and developing preventive strategies.[27,28]

The field underwent a significant transformation during the 1990–2010 period, characterized by increased integration of molecular immunology with clinical practice. This shift is evident in the rise of publications linking genetic predisposition to disease manifestation and the emergence of targeted therapeutic approaches. Co-citation analysis reveals how previously distinct research domains—clinical allergology, pediatric ophthalmology, and immunology—began to converge, leading to a more comprehensive understanding of disease mechanisms. This convergence has been influential in developing new therapeutic strategies, as evidenced by breakthrough studies on immunomodulation in pediatric allergic conditions.[11,29–31]

The most recent phase (2011–present) reflects a marked shift toward environmental and public health perspectives, driven by growing global concerns about climate change and pollution. The increase in research linking air pollution to allergic conjunctivitis corresponds with rising urbanization and environmental degradation in many regions, particularly evident in contributions from East Asian institutions, where rapid industrialization has led to a higher prevalence of allergic conditions. The pronounced citation patterns of environmental health studies indicate a growing acknowledgment of the complex interplay between genetic predisposition and environmental triggers.[32–34]

Methodological evolution in the field reveals a clear progression from traditional clinical assessments to sophisticated approaches integrating molecular diagnostics and environmental monitoring.[11] The adoption of standardized protocols and validated outcome measures[35,36] has strengthened the scientific foundation of the field, although challenges remain in harmonizing research methods across different regions. The introduction of new tools and technologies, particularly in molecular diagnostics and environmental monitoring,[37] has created new opportunities for understanding disease mechanisms and developing targeted interventions.

Looking ahead, several key challenges and opportunities emerge from this analysis. First, there is a pressing need for more integrated research approaches that combine clinical, molecular, and environmental perspectives.[38] Second, strengthening international collaboration networks is critical for addressing global health challenges.[39] Third, standardizing research protocols and outcome measures is essential for facilitating comparative studies across different populations and environments.[1]

Limitations of this study include potential gaps in database coverage, as only the WoSCC was utilized; this may have resulted in the exclusion of relevant studies indexed in other databases such as Scopus or PubMed. Additionally, the focus on English-language publications was chosen to ensure consistency and quality in data extraction and interpretation; however, this approach may have inadvertently omitted important regional studies published in other languages, particularly those from countries where research on pediatric allergic conjunctivitis is active but not commonly disseminated in English. As a result, some regional perspectives and locally relevant findings may be underrepresented

in this analysis. The exclusion of certain document types, such as conference papers, gray literature, and early-access publications, may also result in an incomplete representation of the research landscape, especially for emerging topics. Furthermore, it is important to acknowledge that citation-based metrics may undervalue newer, interdisciplinary, or highly innovative work that has not yet had sufficient time to accumulate citations. Such metrics can also introduce bias toward established research areas or well-resourced institutions, potentially overlooking valuable contributions from emerging fields or underrepresented regions. Reliance on publication-based assessments introduces a temporal lag, as recent studies may not yet accurately reflect their impact.

To address these gaps, future research should integrate data from multiple bibliographic databases and include non-English-language studies to better capture regional contributions. Expanding the scope to include gray literature and conference papers could help identify emerging research trends and practical insights from clinical case studies. Moreover, future studies should focus on specific emerging questions, such as the long-term efficacy of immunotherapy in diverse populations and the impact of air pollution on allergic conjunctivitis. Investigating gene-environment interactions through longitudinal studies or multi-center clinical trials could provide deeper insights into disease mechanisms and inform personalized treatment strategies. Finally, developing standardized methodologies to assess intervention outcomes across diverse populations and contexts would enhance the comparability and applicability of findings, ultimately improving clinical care for pediatric allergic conjunctivitis.

Conclusion

This comprehensive analysis suggests that research on PAC is entering a new phase characterized by an enhanced integration of clinical, molecular, and environmental approaches. This evolution is consistent with broader trends in medical research, which emphasize a more holistic understanding of disease processes, particularly the interplay between genetic predisposition and environmental factors. These insights hold significant implications for clinical practice, research priorities, and public health policies aimed at addressing this increasingly prevalent condition.

Looking ahead, future research on PAC should prioritize several key directions. First, there is a pressing need to advance clinical research by examining the long-term efficacy and safety of immunotherapy and other therapeutic modalities across diverse populations and healthcare settings. Equally important are environmental studies that investigate the impact of air pollution and other environmental exposures on the pathogenesis and progression of PAC, ideally through longitudinal and multicenter study designs. In addition, exploring gene–environment interactions will be essential to understand how genetic susceptibility and environmental triggers jointly influence disease onset and severity, thereby informing the development of more personalized prevention and treatment strategies. Finally, expanding research efforts to incorporate standardized methodologies for evaluating treatment outcomes, while integrating data from underrepresented regions, will be crucial for enhancing the global applicability and equity of future findings. By addressing these priorities, PAC research can advance toward more effective prevention, diagnosis, and treatment strategies, ultimately improving patient outcomes and alleviating the burden of this condition on public health systems.

Data Sharing Statement

All data generated or analyzed during this study are included in this published article.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests in this work.

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