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Original Article

Exploring the Role of Ocular Surface Disease in the Development of Pediatric Astigmatism

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ABSTRACT

Background: Ocular surface disease may accompany pediatric refractive disorders through tear-film instability, ocular allergy, and habitual eye rubbing; however, its relationship with clinically significant astigmatism remains insufficiently characterized in Pakistani children. Objective: To determine whether ocular surface disease and related clinical factors were associated with astigmatism among children aged 5–14 years. Methods: This case-control study included 160 children attending ophthalmology services in Peshawar, Pakistan, comprising 80 children with astigmatism of at least 1.00 diopter and 80 controls with cylinder power below 0.50 diopter. Visual acuity, refraction, slit-lamp findings, tear-film break-up time, ocular symptoms, screen exposure, and eye rubbing were assessed. Group differences were evaluated using appropriate comparative tests, and crude odds ratios with 95% confidence intervals were calculated. Results: Ocular surface disease was present in 62.5% of children with astigmatism and 28.8% of controls (OR, 4.13; 95% CI, 2.13–8.01). Allergic conjunctivitis, dry eye disease, and meibomian gland dysfunction were more frequent among cases. Frequent eye rubbing occurred in 58.8% of cases and 22.5% of controls (OR, 4.91; 95% CI, 2.47–9.76). Mean tear-film break-up time was lower in the astigmatism group by 3.80 seconds (95% CI, −4.54 to −3.06). Conclusion: Ocular surface abnormalities, eye rubbing, and tear-film instability were associated with pediatric astigmatism, although causation and temporality cannot be inferred. Keywords: Pediatric astigmatism; ocular surface disease; allergic conjunctivitis; dry eye disease; eye rubbing; tear-film instability.

INTRODUCTION

Astigmatism is a common refractive error in children and occurs when the optical power of the eye varies across different meridians, most commonly because of variation in corneal curvature. Clinically significant astigmatism may reduce uncorrected visual acuity, impair contrast sensitivity, and produce blurred or distorted vision. During childhood, persistent uncorrected astigmatism may interfere with normal visual development and increase the risk of meridional amblyopia, particularly when the refractive error is substantial or asymmetrical. Its prevalence varies across populations and has been associated with age, ethnicity, genetic susceptibility, family history, prematurity, and developmental characteristics of the cornea and eyelids (1–3). Studies conducted among school-aged children in Pakistan have also documented a considerable burden of astigmatism and uncorrected refractive error, supporting the need for timely pediatric refractive assessment in local clinical and school-health settings (4,5).

The ocular surface comprises the cornea, conjunctiva, tear film, eyelids, and meibomian glands, which function collectively to maintain a smooth, stable, and optically regular anterior eye surface. Ocular surface disease encompasses a heterogeneous group of disorders, including dry eye disease, allergic conjunctivitis, vernal keratoconjunctivitis, meibomian gland dysfunction, blepharitis, and blepharokeratoconjunctivitis. Dry eye disease is characterized by loss of tear-film homeostasis accompanied by tear-film instability, hyperosmolarity, ocular surface inflammation, neurosensory abnormalities, and variable epithelial damage (6–10). Although ocular surface disease is more extensively investigated in adults, emerging evidence indicates that dry eye, tear-film instability, and meibomian gland abnormalities also occur in children and may produce irritation, fluctuating vision, photophobia, redness, watering, burning, and foreign-body sensation (11,12).

An unstable tear film can transiently disturb the regularity of the anterior optical surface and reduce the repeatability of refractive measurements. This optical disturbance should, however, be distinguished from persistent structural astigmatism caused by stable differences in corneal or lenticular curvature. Ocular surface disease may not directly cause regular refractive astigmatism, but chronic inflammation, severe ocular allergy, and associated behavioral responses may plausibly influence corneal surface quality or contribute to variability in measured refraction. Allergic conjunctivitis has previously been associated with astigmatism among school-aged children, while young children with ocular allergy have also demonstrated a high frequency of tear-film abnormalities and dry-eye findings (13,14).

Eye rubbing represents a potentially important link between ocular surface irritation and corneal mechanical stress. Children with allergic conjunctivitis, dryness, or recurrent itching may rub their eyes repeatedly to obtain temporary symptomatic relief. Persistent and vigorous rubbing has been associated with alterations in corneal biomechanics and morphology, particularly in susceptible individuals and in conditions such as vernal keratoconjunctivitis and keratoconus (15–18). Evidence derived from keratoconus should not be interpreted as direct proof that eye rubbing causes ordinary pediatric astigmatism; nevertheless, it provides biological plausibility for investigating whether habitual rubbing and chronic ocular irritation are more frequent among children with clinically significant astigmatism.

Pediatric dry eye and tear-film dysfunction have received increasing attention because of changing environmental and behavioral exposures. Prolonged use of mobile phones, tablets, computers, and other digital displays can reduce blink frequency and blink completeness, thereby increasing tear evaporation and ocular discomfort. Studies among school-aged children have reported associations between digital-display exposure and dry-eye symptoms (19). Similar findings have been reported in Pakistan, particularly during periods of increased online education and prolonged screen exposure (20–22). Screen use is therefore more plausibly considered a contributor to ocular surface symptoms than a direct cause of astigmatism, although it may coexist with refractive complaints and influence visual comfort.

Despite increasing recognition of pediatric ocular surface disease, limited local evidence has examined its relationship with clinically significant astigmatism in Pakistani children. Children presenting with blurred vision are commonly assessed primarily for refractive correction, while accompanying allergy, tear-film instability, meibomian gland dysfunction, and rubbing behavior may receive less systematic attention. Determining whether these ocular surface findings are disproportionately present among children with astigmatism could support a more comprehensive clinical examination without implying that ocular surface disease necessarily initiates or causes the refractive error.

This study therefore aimed to determine whether ocular surface disease, allergic conjunctivitis, dry eye disease, meibomian gland dysfunction, reduced tear-film break-up time, frequent eye rubbing, and prolonged screen exposure were associated with clinically significant astigmatism among children aged 5–14 years attending ophthalmology services in Peshawar, Pakistan. The study hypothesized that ocular surface abnormalities and frequent eye rubbing would be more prevalent among children with clinically significant astigmatism than among children without significant astigmatism.

MATERIALS AND METHODS

A case-control study was conducted over six months in the outpatient ophthalmology department of a tertiary-care eye unit and selected ophthalmology clinics in Peshawar, Pakistan. Children attending these facilities for routine eye examination, blurred vision, refractive assessment, itching, redness, watering, dryness, or frequent eye rubbing were consecutively screened for eligibility. The study population comprised children aged 5–14 years who were able to undergo visual-acuity assessment, refraction, and ocular-surface examination with parental or guardian assistance where necessary.

A non-probability consecutive sampling technique was used to enroll 160 participants, including 80 children with clinically significant astigmatism and 80 children without significant astigmatism. The case group comprised children with cylindrical refractive error of at least 1.00 diopter in either eye. The control group comprised children from the same clinical source population and age range with cylindrical refractive error below 0.50 diopter. Children with cylindrical refractive error between 0.50 and 0.99 diopter were not included in either group. Participants with previous ocular surgery, corneal trauma, congenital corneal opacity, active ocular infection, contact-lens use, diabetes mellitus, systemic autoimmune disease, neurological disease, prolonged topical ocular medication use, or inability to complete refraction or slit-lamp examination were excluded.

Parents or legal guardians received an explanation of the study objectives and examination procedures before enrollment. Written informed consent was obtained from a parent or guardian, and verbal assent was obtained from participating children when appropriate for their age and level of understanding. Participation was voluntary, and refusal to participate did not affect the clinical care provided to the child.

Data were collected using a structured study proforma. Recorded variables included age, sex, residence, school grade, family history of refractive error, previous spectacle use, duration of visual complaints, average daily screen exposure, itching, redness, watering, dryness, burning, foreign-body sensation, seasonal allergy, and eye-rubbing behavior. Screen exposure included time spent using mobile phones, tablets, computers, television, or comparable digital displays and was recorded in hours per day. Screen exposure exceeding three hours per day was categorized as prolonged screen use. Eye rubbing was recorded from the history provided by the child and parent or guardian and was categorized according to whether recurrent habitual rubbing was reported.

Monocular visual acuity was assessed under appropriate illumination using a standard Snellen chart or an age-appropriate visual-acuity chart at the recommended testing distance. Uncorrected and best-corrected visual acuity were recorded separately for each eye. Objective refraction was performed using an autorefractometer, and cycloplegic refraction was undertaken in younger children or when accommodative interference was clinically suspected. Subjective refinement was subsequently performed in children who were able to provide reliable responses. Astigmatism was expressed as cylindrical power in diopters and classified as mild at 1.00–1.99 D, moderate at 2.00–2.99 D, and high at 3.00 D or greater. Cylinder axis was classified as with-the-rule, against-the-rule, or oblique. Both eyes were examined; for participant-level analyses, the eye with the greater absolute cylindrical power was designated as the index eye.

The ocular surface was examined using slit-lamp biomicroscopy. Examination included the eyelid margins, meibomian gland orifices, bulbar and tarsal conjunctiva, corneal epithelium, tear meniscus, and precorneal tear film. Recorded findings included conjunctival hyperemia, papillary or follicular reaction, lid-margin thickening, crusting, obstruction of meibomian gland openings, superficial punctate epithelial staining, and clinical evidence of tear-film instability. Allergic conjunctivitis was identified through a compatible history of itching, redness, watering, or seasonal recurrence accompanied by conjunctival inflammatory findings. Meibomian gland dysfunction was identified by obstruction or abnormal appearance of the meibomian gland openings with associated lid-margin or

tear-film abnormalities. Blepharokeratoconjunctivitis was recorded when inflammatory lid-margin changes occurred with conjunctival or corneal involvement.

Tear-film stability was assessed using fluorescein tear-film break-up time. A fluorescein strip moistened with sterile normal saline was gently applied to the lower conjunctival fornix. After several natural blinks, the child was instructed to keep the eye open, and the interval between the final blink and appearance of the first corneal dry spot was measured in seconds using slit-lamp cobalt-blue illumination. Lower tear-film break-up time values were interpreted as indicating greater tear-film instability. Schirmer testing was additionally performed in children with prominent symptoms suggestive of aqueous tear deficiency. The strip was placed at the junction of the middle and lateral thirds of the lower eyelid, and the length of wetting was measured after five minutes.

Ocular surface disease was defined as the presence of chronic ocular-surface symptoms, including itching, redness, watering, dryness, burning, foreign-body sensation, or recurrent eye rubbing, together with at least one compatible clinical finding on slit-lamp examination, including conjunctival inflammatory changes, tear-film instability, lid-margin disease, meibomian gland abnormality, or corneal epithelial staining. Allergic conjunctivitis, dry eye disease, meibomian gland dysfunction, and blepharokeratoconjunctivitis were recorded separately to distinguish the principal clinical phenotypes within the composite ocular-surface disease variable.

Data were entered and analyzed using IBM SPSS Statistics version 26. Continuous variables, including age, cylindrical power, daily screen exposure, and tear-film break-up time, were summarized using mean and standard deviation. Categorical variables, including sex, family history of refractive error, prolonged screen exposure, ocular surface disease, allergic conjunctivitis, dry eye disease, meibomian gland dysfunction, blepharokeratoconjunctivitis, and frequent eye rubbing, were summarized using frequencies and percentages. The astigmatism and control groups were compared using the independent-samples t-test for continuous variables and the chi-square test for categorical variables. Fisher's exact test was used where expected cell frequencies were insufficient for valid chi-square approximation. All statistical tests were two-sided, and a p-value below 0.05 was considered statistically significant.

The study was undertaken after approval from the relevant institutional ethical review committee. Participant confidentiality was maintained by using study identifiers rather than names in the analytical dataset and final report. Examination findings were used only for research and clinical-care purposes. Children diagnosed with refractive error or ocular surface disease were advised appropriate clinical management, including spectacle correction, lubricating eye drops, antiallergic treatment, lid hygiene, behavioral advice regarding eye rubbing, and ophthalmological follow-up according to individual clinical requirements.

RESULTS

A total of 160 children were included in the analysis, comprising 80 children with clinically significant astigmatism and 80 controls without significant astigmatism. The participants were aged 5–14 years. The mean age was 9.31 ± 2.45 years in the astigmatism group and 9.08 ± 2.31 years in the control group. Age and sex distributions were comparable between the groups.

Table 1. Demographic and Baseline Characteristics of the Study Participants

Characteristic	Astigmatism Group, n = 80	Control Group, n = 80	Effect Estimate	95% CI	p-value
Age, years, mean ± SD	9.31 ± 2.45	9.08 ± 2.31	0.23[1]	−0.51 to 0.97	0.542
Male sex, n (%)	46 (57.5)	44 (55.0)	1.11[2]	0.59 to 2.07	0.752
Female sex, n (%)	34 (42.5)	36 (45.0)	—	—	—
Family history of refractive error, n (%)	31 (38.8)	20 (25.0)	1.90[2]	0.96 to 3.74	0.062
Screen exposure >3 hours/day, n (%)	43 (53.8)	28 (35.0)	2.16[2]	1.14 to 4.08	0.017

Characteristic	Astigmatism Group, n = 80	Control Group, n = 80	Effect Estimate	95% CI	p-value
Previous spectacle use, n (%)	29 (36.3)	11 (13.8)	3.57[2]	1.63 to 7.80	0.001

[1] Mean difference. [2] Crude odds ratio. CI, confidence interval; SD, standard deviation. Continuous variables were compared using the independent-samples t-test, and categorical variables were compared using the Pearson chi-square test.

The mean age differed by 0.23 years between the groups, with a 95% confidence interval spanning zero (95% CI, −0.51 to 0.97; p = 0.542). Male participants constituted 57.5% of the astigmatism group and 55.0% of the control group, indicating no meaningful difference in sex distribution. A family history of refractive error was more frequent among children with astigmatism, although the corresponding estimate did not reach the prespecified significance threshold (OR, 1.90; 95% CI, 0.96–3.74; p = 0.062). Children with astigmatism had greater odds of reporting screen exposure exceeding three hours per day than controls (OR, 2.16; 95% CI, 1.14–4.08; p = 0.017). Previous spectacle use was also more frequent in the astigmatism group (36.3% versus 13.8%; OR, 3.57; 95% CI, 1.63–7.80; p = 0.001).

Table 2. Distribution of Astigmatism Severity and Axis Among Cases

Astigmatism Characteristic	n (%)
Severity	
Mild, 1.00–1.99 D	39 (48.8)
Moderate, 2.00–2.99 D	27 (33.8)
High, ≥3.00 D	14 (17.5)
Axis classification	
With-the-rule	52 (65.0)
Against-the-rule	17 (21.3)
Oblique	11 (13.8)

D, diopter. Among the 80 children with astigmatism, 39 (48.8%) had mild astigmatism, 27 (33.8%) had moderate astigmatism, and 14 (17.5%) had high astigmatism. With-the-rule astigmatism was the predominant axis pattern, occurring in 52 children (65.0%), followed by against-the-rule astigmatism in 17 (21.3%) and oblique astigmatism in 11 (13.8%).

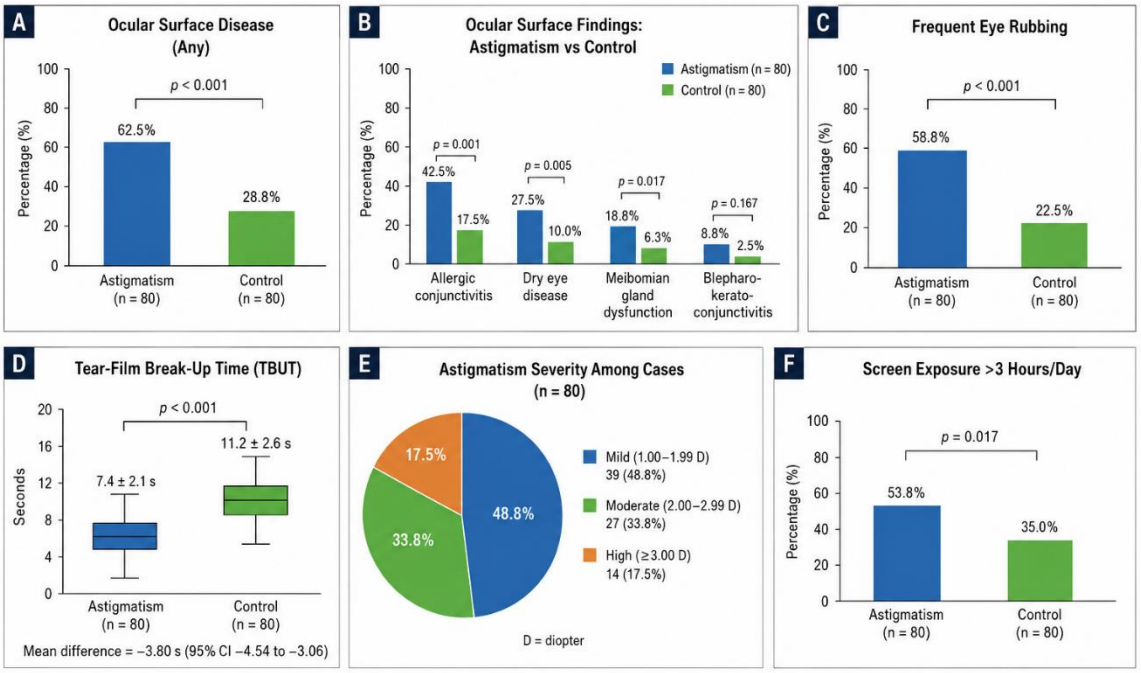
Table 3. Ocular Surface Findings in Children With and Without Astigmatism

Ocular Surface Finding	Astigmatism Group, n = 80	Control Group, n = 80	Crude OR	95% CI	p-value
Any ocular surface disease, n (%)	50 (62.5)	23 (28.8)	4.13	2.13 to 8.01	<0.001
Allergic conjunctivitis, n (%)	34 (42.5)	14 (17.5)	3.48	1.68 to 7.21	0.001
Dry eye disease, n (%)	22 (27.5)	8 (10.0)	3.41	1.42 to 8.23	0.005
Meibomian gland dysfunction, n (%)	15 (18.8)	5 (6.3)	3.46	1.19 to 10.04	0.017
Blepharokeratoconjunctivitis, n (%)	7 (8.8)	2 (2.5)	3.74	0.75 to 18.59	0.167[1]
Frequent eye rubbing, n (%)	47 (58.8)	18 (22.5)	4.91	2.47 to 9.76	<0.001
TBUT, seconds, mean ± SD	7.4 ± 2.1	11.2 ± 2.6	−3.80[2]	−4.54 to −3.06	<0.001

[1] Fisher's exact test. [2] Mean difference. CI, confidence interval; OR, odds ratio; SD, standard deviation; TBUT, tear-film break-up time. Pearson chi-square tests were used for categorical comparisons except where Fisher's exact test was required because of sparse cell counts. TBUT was compared using the independent-samples t-test. Ocular surface disease was identified in 62.5% of children with astigmatism compared with 28.8% of controls. Children with astigmatism had approximately fourfold greater crude odds of ocular surface disease than children in the control group (OR, 4.13; 95% CI, 2.13–8.01; p < 0.001). Allergic conjunctivitis was present in 42.5% of cases and 17.5% of controls and was associated with greater odds of astigmatism (OR, 3.48; 95% CI, 1.68–7.21; p = 0.001).

Dry eye disease was observed in 22 children with astigmatism and eight controls, corresponding to a crude odds ratio of 3.41 (95% CI, 1.42–8.23; p = 0.005). Meibomian gland dysfunction was also more frequent in the astigmatism group (18.8% versus 6.3%; OR, 3.46; 95% CI, 1.19–10.04; p = 0.017). Blepharokeratoconjunctivitis occurred in seven cases and two controls; however, the confidence interval was wide and included the null value (OR, 3.74; 95% CI, 0.75–18.59; Fisher's exact p = 0.167).

Frequent eye rubbing was reported in 58.8% of children with astigmatism compared with 22.5% of controls. The crude odds of frequent eye rubbing were approximately five times greater in the astigmatism group (OR, 4.91; 95% CI, 2.47–9.76; p < 0.001). Mean TBUT was 7.4 ± 2.1 seconds in children with astigmatism and 11.2 ± 2.6 seconds in controls, representing a mean between-group difference of −3.80 seconds (95% CI, −4.54 to −3.06; p < 0.001). Overall, clinically significant astigmatism was associated with a greater frequency of ocular surface disease, allergic conjunctivitis, dry eye disease, meibomian gland dysfunction, frequent eye rubbing, prolonged screen exposure, and reduced tear-film stability in the unadjusted analyses. Because these exposures may be interrelated and the available aggregate data did not permit multivariable modelling, the reported odds ratios should be interpreted as crude associations rather than independent effects.



The figure shows that participants with astigmatism had a significantly higher prevalence of ocular surface disease, frequent eye rubbing, allergic conjunctivitis, dry eye disease, meibomian gland dysfunction, and prolonged screen exposure than controls, while tear-film break-up time was significantly lower in the astigmatism group. Among astigmatism cases, mild astigmatism was most common, followed by moderate and high severity.

DISCUSSION

This case-control study found that ocular surface abnormalities were more frequently identified among children with clinically significant astigmatism than among controls without significant astigmatism. Any ocular surface disease was present in 62.5% of children with astigmatism and 28.8% of controls, corresponding to approximately fourfold greater crude odds of ocular surface disease in the astigmatism group. Allergic conjunctivitis, dry eye disease, meibomian gland dysfunction, frequent eye rubbing, prolonged screen exposure, and reduced tear-film break-up time were also more common among children with astigmatism. These findings indicate clinically relevant associations but do not establish that ocular surface disease preceded, initiated, or caused the refractive error.

Allergic conjunctivitis was the most frequently identified ocular surface disorder, affecting 42.5% of children with astigmatism compared with 17.5% of controls. This pattern is consistent with previous evidence showing an association between allergic conjunctivitis and astigmatism in school-aged children (13). Allergic inflammation may produce itching, watering, conjunctival hyperemia, and recurrent ocular irritation, while pediatric allergy has also been associated with tear-film abnormalities, dry-eye findings, and meibomian gland changes (14,23,24). The present results therefore support the clinical relevance of evaluating allergic ocular disease among children presenting with astigmatism, particularly when itching and recurrent redness are reported.

Frequent eye rubbing demonstrated one of the largest crude associations in the study, occurring in 58.8% of children with astigmatism and 22.5% of controls. Recurrent rubbing may represent a behavioral response to itching, allergy, dryness, or ocular discomfort rather than an independent disorder. Persistent mechanical stress from vigorous rubbing has been associated with corneal biomechanical and topographic abnormalities, especially among susceptible individuals with vernal keratoconjunctivitis or keratoconus (15–18). However, evidence derived from keratoconus should not be interpreted as direct proof that habitual rubbing causes ordinary regular astigmatism. In the present study, corneal topography, corneal biomechanics, rubbing intensity, and duration of rubbing were not assessed. Eye rubbing should therefore be interpreted as an associated behavioral factor and a plausible mechanistic hypothesis requiring prospective investigation.

Dry eye disease was identified in 27.5% of children with astigmatism and 10.0% of controls. This finding is consistent with growing evidence that dry eye and tear-film dysfunction are clinically relevant in pediatric populations rather than conditions confined to adults (11,12). The tear film contributes substantially to the regularity and optical quality of the anterior ocular surface. Instability of this layer may produce fluctuating vision, ocular discomfort, and variation in refractive measurements, although it does not necessarily indicate a persistent structural change in corneal curvature. The mean tear-film break-up time was 3.80 seconds lower in the astigmatism group than in controls, supporting greater tear-film instability among cases. The clinical interpretation should therefore focus on accompanying optical and symptomatic disturbance rather than inferring that dry eye directly produced astigmatism.

Meibomian gland dysfunction was also more common among children with astigmatism. Meibomian gland abnormalities can compromise the lipid component of the tear film, increase evaporation, and contribute to ocular discomfort and tear-film instability. Previous pediatric studies have demonstrated meibomian gland atrophy or dysfunction among children with allergic conjunctivitis and among adolescents with refractive disorders (23,25). Blepharokeratoconjunctivitis was numerically more frequent among cases, but the estimate was imprecise and the confidence interval included no association. This finding should therefore be regarded as inconclusive. Pediatric blepharokeratoconjunctivitis can involve the corneal surface and, in more severe cases, has been associated with topographic corneal abnormalities (26,27). Larger studies using standardized diagnostic criteria would be required to determine whether this disorder is independently related to astigmatism.

Screen exposure exceeding three hours per day was more frequent among children with astigmatism. Prolonged digital-device use can reduce blink frequency and completeness, increase tear evaporation, and aggravate ocular surface symptoms (19–22). Nevertheless, the current findings do not establish that screen exposure caused astigmatism. Children with refractive complaints may use screens differently, may notice visual symptoms more readily, or may be brought for ophthalmic examination more frequently. Screen exposure may also be associated with educational demands, indoor activity, socioeconomic circumstances, and reduced outdoor time. These unmeasured factors could partly explain the observed association.

A family history of refractive error was more frequent among children with astigmatism, although the crude confidence interval included the null value. This pattern remains clinically relevant because genetic and developmental factors are established contributors to pediatric astigmatism (1–3). Previous spectacle use was also more common among cases, as expected, because children with clinically significant refractive errors are more likely to have received correction before enrollment. Previous spectacle use should consequently be interpreted as a marker of prior refractive diagnosis rather than a causal risk factor.

The observed associations may be influenced by several interrelated pathways. Ocular allergy may lead to itching and rubbing; dry eye and meibomian gland dysfunction may coexist with allergy; and screen exposure may exacerbate tear-film instability. Entering all of these variables into a single regression model without considering collinearity or mediation could produce unstable or misleading estimates. A

future participant-level analysis should distinguish potential confounders, mediators, and overlapping components of the composite ocular surface disease variable. Multivariable logistic regression should report adjusted odds ratios with 95% confidence intervals and should include clinically justified covariates such as age, sex, family history of refractive error, screen exposure, and selected ocular surface factors.

The study has several limitations. First, the case-control design and cross-sectional measurement of exposures and outcomes did not establish temporality. Ocular surface disease may have preceded astigmatism, developed after the refractive error, or arisen from shared underlying factors. Second, participants were recruited from clinical settings using consecutive non-probability sampling, which may limit generalizability and introduce selection bias. Children attending ophthalmology services may have a greater burden of symptoms than children in the general population. Third, eye rubbing, screen exposure, and symptoms were based on histories provided by children and parents and were therefore susceptible to recall and reporting bias.

Fourth, ocular surface disease was represented by a composite clinical definition that included several heterogeneous conditions. Although individual disorders were reported separately, standardized pediatric diagnostic instruments and validated symptom scales were not described. Schirmer testing was undertaken only in selected symptomatic children, creating the possibility of differential diagnostic verification. Fifth, the study did not report corneal topography, keratometry, pachymetry, corneal biomechanics, or longitudinal refractive measurements. It was therefore not possible to distinguish stable regular astigmatism from transient tear-film-related refractive variability or to identify subtle ectatic changes. Sixth, the participant-level index-eye rule, cycloplegic protocol, and objective refraction procedures require fuller standardization to ensure reproducibility.

Seventh, only crude comparisons were available. Residual confounding by genetic susceptibility, severity of allergy, environmental exposure, prematurity, socioeconomic status, medication use, outdoor activity, and other developmental factors cannot be excluded. Multiple ocular surface comparisons were also conducted without adjustment for multiplicity, increasing the possibility of chance findings. Finally, the relatively small number of participants with blepharokeratoconjunctivitis resulted in an imprecise estimate with a wide confidence interval. Despite these limitations, the study highlights the clinical value of examining the ocular surface in children undergoing refractive assessment. Refraction remains essential for diagnosing and correcting astigmatism, but accompanying allergy, tear-film instability, lid-margin disease, and habitual eye rubbing may contribute to persistent discomfort, fluctuating visual quality, and reduced tolerance of spectacle correction. Future community-based prospective studies should use standardized pediatric ocular surface criteria, uniform cycloplegic refraction, corneal topography, quantified eye-rubbing exposure, and longitudinal follow-up to determine whether ocular surface abnormalities precede or predict changes in astigmatism.

CONCLUSION

Ocular surface disease, allergic conjunctivitis, dry eye disease, meibomian gland dysfunction, frequent eye rubbing, prolonged screen exposure, and reduced tear-film break-up time were more frequently observed among children with clinically significant astigmatism than among controls. These findings demonstrate unadjusted associations but do not establish that ocular surface disease causes or contributes to the development or progression of astigmatism. Pediatric refractive assessment may nevertheless benefit from concurrent evaluation of ocular allergy, tear-film stability, lid-margin abnormalities, and eye-rubbing behavior, particularly in children reporting irritation or fluctuating vision. Prospective studies incorporating standardized ocular surface criteria, adjusted statistical models, corneal topography, and longitudinal refractive measurements are required to clarify temporality and determine whether these factors independently predict changes in pediatric astigmatism.

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