VISION SCIENCE AND EYE HEALTH JOURNAL

RESEARCH

A Cross-Sectional Study of the Prevalence of Keratoconus in Patients with Astigmatism More than Two Diopters

Authors:
Zinatus Sama[1]
Tamanna Afroz[2]
Salman Ahmed T. Hamid[3]
Saeema M. Abdulmajeed[3]
Imtiaj Hossain Chowdhury[4]
Md Mahmudul Hasan[4]*

Affiliations:
[1]Cornea and Phaco Surgeon, Al-Noor Eye Hospital, Dhaka, Bangladesh.
[2]Cornea and Anterior Segment, Makka Eye Hospital, Dhaka, Bangladesh.
[3]Ophthalmology Department, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh.
[4]Research, Education and Training Department, Al-Noor Eye Hospital, Dhaka, Bangladesh.

Corresponding author:
Md Mahmudul Hasan
mahmud.albasar@gmail.com

Dates:
Received: 08 December 2024
Revised: 05 February 2025
Accepted: 16 February 2025
Published: 04 March 2025

DOI:
https://doi.org/10.20473/vsehj.v4i2.2025.34-41

Abstract

Introduction: Patients with astigmatism, especially those with more than two diopters, appear to have keratoconus as a co-morbidity. Understanding the coexistence of these two diseases may aid in these patients' early detection and management. **Purpose:** The purpose of the present study was to establish the rate of keratoconus among the patients with >2D astigmatism in Bangladesh. **Methods:** 80 astigmatic patients >2D among the age group 10-45 years old participated in this cross-sectional study between May and August 2024 at Noor Makka and Makka Eye Hospitals, Dhaka, Bangladesh. Keratoconus and subclinical cases were identified by using corneal topography, slit lamp, and corneal asymmetry, along with general visual evaluation by an ophthalmology consultant. Statistical package for the social sciences (SPSS) software was used as the data analysis tool. **Results:** This study analyzed the socio-demographic information and the eye characteristics of people with astigmatism. Out of 80 studied participants, keratoconus appeared in 65%, mainly from the age group 17-30 (56.25%). Among the study participants, males and females were 47.50% and 52.50%, respectively. The average astigmatism level was recorded at 4.697 diopters. The research established a significant statistical correlation between Keratoconus diagnosis and corneal biomicroscopy ($p = .001$) and corneal topography ($p = .000$), where most of the keratoconus patients showed thinning patterns in their stromal structure. The research also established a connection between age and gender to keratoconus. **Conclusions:** This cross-sectional study revealed a high prevalence of diagnosed keratoconus among astigmatic patients, particularly affecting younger individuals.

Keywords: astigmatism; corneal biomicroscopy; corneal topography; keratoconus

Introduction

Astigmatism creates vision problems when the eye takes a football shape instead of maintaining its circular basketball shape.[1] Vision becomes unclear for distances both close and far when light refracts inconsistently because of unusual cornea or lens structures. The two main astigmatism categories involve horizontal eye alignment, where width exceeds height, and vertical alignment, where height exceeds width. The disease mechanisms for astigmatism remain uncertain, however, heredity is a common factor in possible eye illnesses, injuries, and surgeries of the optical system.[1] Eye specialists use a combination of an eye chart, a phoropter, an autorefractor, and a keratometer during comprehensive exams to diagnose astigmatism by measuring vision clarity and the cornea's curvature. People worldwide experience astigmatism, yet its occurrence shows substantial differences between different geographic areas. A systematic review conducted by Zhang et al.[2] found that astigmatism prevalence varies between 27% in Northern Western Europe, up to 62% in China along with multiple other regions such as South Korea (31-58%), Germany (32%), Spain (54%), Japan (54%) and the United States with rates ranging from 11 to 46%.

In addition to understanding astigmatism's causes, diagnosis, and prevalence, it is crucial to examine its severity-wise prevalence across different populations globally. The severity of astigmatism is categorized in diopters, ranging from

mild (<1.00 diopters), moderate (1.00-2.00), high (2.00-4.00), and extreme (>4.00 diopters).[3] Evidence suggests that populations with less than 2D astigmatism are more prevalent in different countries.[2] However, subjects with high or extreme astigmatism are not rare. Research by Heidary et al.[4] established that astigmatism exceeding 2.5 D existed in 22% of the population, but more recent data from Han et al.[5] study identified this condition in 34% of participants. Prospective observational research at a tertiary eye hospital in Bangladesh found that 5.2% of patients exhibited astigmatism more significantly than 2D.[6] The figure matched the results of Miyake et al.[7], who discovered 5.6% astigmatism above 2D in their research population.

Astigmatism population may show several types of coexistence ocular morbidities such as blurred vision, eye strain, headaches, poor night vision, keratoconus, and amblyopia ('lazy eye').[8] Research indicates that keratoconus constitutes a leading vision condition because of astigmatism.[9] The eye condition called keratoconus makes the front window of the eye, known as the cornea, progressively thin and bulge outward into a cone shape, producing improper light refocusing that causes vision distortion and blurriness.[10] High astigmatism leads to increased Keratoconus development, according to the studies[11],[12], however, mainly when astigmatism occurs irregularly or progresses too fast.[11] The risk of developing keratoconus exists in patients from families with this condition or receiving an early diagnosis.[12]

In 1736, experts first recognized keratoconus.[13] Its prevalence varies depending on the group, with less frequent cases in Caucasians showing below 1,000 in every 100,000 populations.[14] Nevertheless, it is more prevalent in Asian and Middle Eastern regions, hitting 1,500 to 5,000 per 100,000 individuals.[14] The yearly incidence of keratoconus is pretty steep in these areas, too, with about 25 cases out of 100,000 getting it.[15] This number is way smaller for Caucasians, with just two to four peeps per 100,000 catching it yearly.[15] Research suggests ethnicity plays a more prominent role than geographic location in these differences, as seen in higher prevalence among Asians and Maori Islanders.[14],[16] The etiology of keratoconus is multifactorial, involving genetic and environmental factors like eye rubbing, atopy, and UV exposure.[17],[18] Genetic predisposition has been noted, with some studies suggesting autosomal dominant inheritance, though autosomal recessive patterns have also been observed.[18] Keratoconus significantly affects quality of life, with increased severity leading to more pronounced difficulties in daily activities and emotional well-being.[19] Studies[20] have shown that patients with keratoconus report lower scores on vision-related quality-of-life measures, particularly in areas like general vision, near vision, and peripheral vision. The disease's severity, history of surgery, and specific corneal measurements further exacerbate its impact on quality of life.[21]

Astigmatism is usually characterized by distortion of the vision since the cornea or lens is not shaped correctly. Many studies[9],[11] have also revealed a directly proportional correlation between astigmatism higher than 2D and keratoconus – an uncommon, however, progressive form of eye ailment that can severely inhibit vision. Although a vast amount of information relating to astigmatism is available globally, a research void is apparent regarding the prevalence of keratoconus in Bangladesh among those with high astigmatism. Because of these significant vision-related co-morbidities in patients with astigmatism and this potential increased susceptibility to the condition in this population, there was an evident need for an early detection study. Thus, the purpose of the present study was to establish the rate of keratoconus among patients with >2D astigmatism in Bangladesh to get an idea about demographic and clinical predictors for keratoconus and make some practical recommendations for early identification and management of these patients.

Methods

This cross-sectional study was conducted at Noor Makka Eye Hospital and Makka Eye Hospital in Dhaka, Bangladesh, between May and August 2024. A total of 80 patients, aged between 10 and 45 years, with astigmatism more significant than two diopters (D), were selected as the study sample. These two hospitals, managed by the Al-Basar International Foundation, were chosen as the study sites. The study chose participants using specific rules for who could join and who could not. People between 10 and 45 years old with astigmatism above 2D were allowed to participate. The study excluded those under 10, over 45, or with astigmatism of 2D or less. Every patient went through a thorough eye check-up. This check-up looked at their vision using a Snellen chart, examined their eyes with a special microscope, and mapped their corneas with a pentacam (4 Map) device. The diagnosis of keratoconus was confirmed by analyzing clinical findings and topographic features. The thickness and elevation maps from the Galilei System were employed to verify keratoconus cases. This comprehensive diagnostic process ensured an accurate assessment of the corneal condition in patients with significant astigmatism.

The patient's eye was categorically diagnosed with keratoconus when the slit lamp showed corneal topography along with paracentral steeping. Other features, such as stromal thinning, Vogt's striae, anterior corneal bulging, or Fleischer ring being present, helped

Table 1. The patients' socio-demographic status and their ocular characteristics (N= 80)

	Frequency	Percentage (%)
Keratoconus		
Yes	52	65.00
No	28	35.00
Age		
10-16 (child)	30	37.50
17-30 (young adult)	45	56.25
31-43 (middle-aged adults)	05	6.25
Mean ± Standard Deviation	20.0125 ± 7.19	
Median	19	
Gender		
Male	38	47.50
Female	42	52.50

aid the diagnosis. While examining the counterpart eye of a patient suffering from keratoconus, if under slit lamp biomicroscopy, keratometry, and ophthalmoscopy, showed normal parameters such as asymmetry below average, bow tie pattern, and skewed radial axes with tangential maps, then subclinical keratoconus was established. Patients without these parameters were diagnosed with normal astigmatism. The data and their findings were further processed through descriptive statistics, and the results showcased mean values and percentages. Furthermore, inferential statistics were utilized to analyze the patients' demographic parameters with keratoconus and its prevalence. Analyzing was performed using SPSS Software version 26.0 (IBM Corp., Armonk, NY, USA), yielding a statistical significance at a p-value of 0.05 or less.

Before conducting the study, ethical approval was obtained from the Ethics Committee of the Al-Basar International Foundation to ensure the research adhered to ethical standards and guidelines. In addition, each research participant received a complete understanding of the study's purpose and intended objectives. The research team outlined the nature of the study together with data usage information and explained why participant involvement was essential. The research team obtained spoken and written consent from participants who voluntarily participated before they began their data collection processes. The participants could ask questions and withdraw without receiving any adverse consequences. The researchers emphasized that all registered information would remain confidential and serve only research functions while stored under strict privacy protocols. The research team stressed that they would anonymize the data yet use secure methods to protect participant privacy during its handling. By implementing this approach, the participants fully understood their rights, combined with ethical protections, strengthening research transparency and participant trust.

Results

This section reveals study outcomes that provide a breakdown of the patient's demographic features and eye characteristics alongside astigmatism measures, eye examination reports, and connections between patient demographics and eye features to Keratoconus development.

A group of patients exhibits socio-demographic traits and eye conditions according to the breakdown in Table 1. Keratoconus diagnosis exists in 65% of the subjects, however, the remaining 35% did not have this condition. Most patients with keratoconus belong to the young adult group aged 17-30 (56.25%), children aged 10-16 occupied 37.50% of all patients, and middle-aged adults between 31-43 years made up only 6.25% of the population. The mean age was 20.01 years, with a median of 19 years, indicating that most patients were young adults. The standard deviation of 7.19 shows a relatively wide variation in ages, ranging from 10 to 43 years. Gender distribution is nearly balanced, with 52.50% female and 47.50% male. These statistics suggest a predominance of younger individuals with keratoconus and a relatively equal gender distribution in this population.

In terms of astigmatism, Figure 1 shows the average level is 4.697 diopters, with a median of 4.625, suggesting moderate levels of astigmatism in this group. The standard deviation of 2.022 indicates some variation in astigmatism levels, ranging from a minimum of 2.25 to a maximum of 9.5 diopters. These statistics highlight a diverse age range but a somewhat concentrated range of astigmatism.

The ophthalmic examination report can be observed in Table 2, which reveals key insights into the patient's eye conditions. A majority of patients (63.75%) have issues affecting both eyes, while 21.25% have problems in the right eye (OD) and 15% in the left eye (OS). Corneal biomicroscopy results show that 6.25% of patients have a Fleischer ring, 65% exhibit stromal thinning, 12.50% present with Vogt's striae, and 16.25% have normal findings. Corneal topography patterns vary, with asymmetric bowtie with inferior steeping being the most

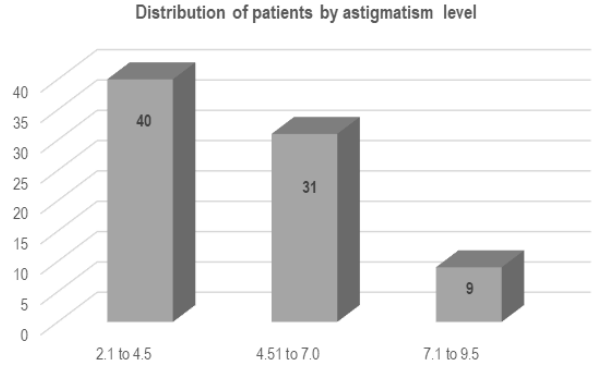

Figure 1. Distribution of patients according to their astigmatism level (N= 80).

Table 2. Patient ophthalmic examination report

	Frequency	Percentage (%)
Eye		
Oculus dexter (OD)	17	21.25
Oculus sinister (OS)	12	15.00
Both	51	63.75
Corneal biomicroscopy		
Normal	13	16.25
Fleischer ring	5	6.25
Stromal thinning	52	65.00
Vogt's striae	10	12.50
Corneal topography patterns		
Asymmetric bowtie	02	2.50
Asymmetric bowtie inferior steeping	25	31.25
Asymmetric bowtie with skewed steepest radial axis	10	12.50
Asymmetric bowtie superior steeping	11	13.75
Oval	02	2.50
Round	06	7.50
Symmetric bowtie	24	30.00

common pattern (31.25%), followed by symmetric bowtie (30%). Less frequent patterns include asymmetric bowtie with skewed steepest radial axis (12.50%) and superior steeping (13.75%). The least common patterns are oval and asymmetric bowtie, each accounting for only 2.50%. This data highlights a range of corneal irregularities, with many patients showing advanced signs of keratoconus.

Table 3 presents the relationship between socio-demographic variables and keratoconus occurrence. A significant association is found between age and keratoconus (p = .023), with younger individuals (10-16 and 17-30 years) likelier to have keratoconus than middle-aged adults. The Phi and Cramer's V value of .308 suggests a moderate relationship between age and Keratoconus occurrence. Gender is also significantly associated with keratoconus (p = .044), with males being more affected (29 cases) than females (23 cases). The Phi and Cramer's V value of .226 indicates a weak to moderate relationship. This data suggests that age and gender play a role in keratoconus prevalence.

Table 4 illustrates the relationship between ocular characteristics and keratoconus occurrence, showing strong statistical associations. Corneal biomicroscopy findings reveal a significant link with keratoconus (p = .001), where the presence of a Fleischer ring (one case), stromal thinning (49 cases), and Vogt's striae (two cases) are strongly associated with keratoconus. In contrast, most patients with normal corneal findings (13 cases) do not have keratoconus. The Phi and Cramer's V value of .632 suggests a strong relationship between corneal biomicroscopy characteristics and Keratoconus occurrence.

Corneal topography patterns also have a highly significant association with keratoconus (p = .000), with asymmetric bowtie patterns—particularly inferior steeping (24 cases) and skewed steepest radial axis (11 cases); being prevalent in keratoconus patients. Symmetric bowties (19 cases) and round patterns (5 cases) are common in those without keratoconus. The Phi and Cramer's V value of .797 indicates a robust relationship between corneal topography and keratoconus. This data underscores that specific ocular characteristics are highly predictive of Keratoconus occurrence.

Discussion

Our study aimed to assess the prevalence of keratoconus in patients with astigmatism more significant than two diopters and found that 52 (65%) of the participants had been diagnosed with keratoconus. This finding reveals that the prevalence was higher than those prior studies conducted in different countries.[9],[11] The difference between studies regarding their sample size and investigative methods has been referred to as the reason for this difference.[9]

On the other hand, most respondents were young adults, with an average age of 20.01 years, and the age range was from 10 to 43 years. It is similar to other studies of this nature. For instance, Serdarogullari et al.[22] studied 65 patients aged 29.9 years, ranging from 15 to 45 years. Similarly, in the study conducted by Shehadeh et al.[23], the participants' age range was found to be from 17 to 27 years old, with a mean age of 21.1 years, while Hashemi et al.[11] chose patients aged 20-34 years. All these studies[11],[22][23] emphasize this age bracket, which agrees with several findings that keratoconus is an age-related factor in its development. It usually starts after the teenage years and advances into a mature life. Therefore, selecting a similar age group in our investigation aligns with previous research that found this population highly relevant to understanding keratoconus onset and progression issues.

Table 3. The relationship between the socio-demographic variables and keratoconus occurrence

	Keratoconus		P Value	Phi and Cramer's V; (approximate significance)
	Yes	No		
Age				
10-16 (child)	17	13	.023	.308 & .308; (.023)
17-30 (young adult)	34	11		
31-43 (middle-aged adults)	01	04		
Gender				
Male	29	09	.044	.226 & .226; (.044)
Female	23	19		

Table 4. The relationship between the ocular characteristics and keratoconus occurrence

	Keratoconus		P Value	Phi & Cramer's V; (Approximate significance)
	Yes	No		
Corneal biomicroscopy				
Normal	00	13	.001	.632 & .632; (.001)
Fleischer ring	01	04		
Stromal thinning	49	03		
Vogt's striae	02	08		
Corneal topography patterns				
Asymmetric bowtie	02	00	.000	.797 & .797; (.000)
Asymmetric bowtie inferior steeping	24	01		
Asymmetric bowtie with skewed steepest radial axis	11	00		
Asymmetric bowtie superior steeping	09	01		
Oval	00	02		
Round	01	05		
Symmetric bowtie	05	19		

The degree of astigmatism among this study subjects ranged between 2.25 and 9.5 diopters, with a significant mean of 4.697 diopters. Our investigation involved higher grades of astigmatism compared to that by Zhang et al.[2], who discussed, in a broad sense, the prevalence of astigmatism as ranging between 8% and 62%. Zhang's et al.[2] results also showed a high prevalence of with-the-rule (WTR) astigmatism in younger patients and against-the-rule (ATR) astigmatism in older patients, consistent with our young patient population. Heidary et al.[4] also found lower astigmatism ranges (1.0–2.5 D), where WTR astigmatism was most frequent among young patients, which agreed with our findings.

Han et al.[5] reported lower astigmatism levels (average 2.09 D) in patients with congenital cataracts and found a correlation between astigmatism and aberrations, which may influence future research on patients with higher astigmatism levels. Islam et al.[6] observed ATR astigmatism more frequently in older populations, while our younger cohort displayed a higher rate of WTR astigmatism. Miyake et al.[7] also confirmed the prevalence of WTR astigmatism in younger individuals, further supporting the age-related trends seen in our study. Our study highlights significant differences in astigmatism severity, age distribution, and type, contributing to understanding keratoconus and high astigmatism in younger patients.

Our corneal biomicroscopy study findings show that 6.25% of patients have a Fleischer ring, 65% exhibit stromal thinning, 12.25% present with Vogt's striae, and 16.25% have normal results. The presence of stromal thinning in 65% of patients was a decisive factor in diagnosing keratoconus. These findings align with those of Shakir et al.[9], where stromal thinning was observed in 21 eyes, all diagnosed as Keratoconus cases. Similarly, Reinstein et al.[24] found that normal eyes had a stromal thickness progression of 29.9 ± 5.4 µm, compared to 60.6 ± 25.6 µm in keratoconus eyes, confirming that stromal thinning is more pronounced and worsens with the progression of keratoconus. Zhou and Stojanovic[25] also emphasized stromal thinning as a critical indicator of keratoconus.

Additionally, our study observed Vogt's striae in ten cases. Of these eyes, only two were diagnosed with keratoconus. Therefore, the others may be at high risk for developing subclinical keratoconus. Grieve et al.[26] identified Vogt's striae as a key indicator of keratoconus, suggesting that further examinations are necessary for these patients. Similarly, Shi[27] highlighted the Fleischer ring, observed in five cases in our study, along with Vogt's striae, as markers of subclinical keratoconus that warrant additional diagnostic evaluations.

In our study, corneal topography patterns showed significant variation, the most common being asymmetric bowtie with inferior steeping (AB/IS), observed in 31.25% of cases, followed by symmetric bowtie in 30%. It aligns with previous research[9], though some variations in pattern prevalence are evident. For instance, an author found symmetric bowtie to be the most frequent pattern in their study, observed in 49% of patients.[9] This discrepancy could be attributed to differences in study populations and diagnostic criteria. Similarly, a group of scholars reported symmetric bowtie as the most frequent pattern (29%) in their study conducted in Iran[11], and another study also identified symmetric bowtie as the most prevalent pattern in 36% of their keratoconus patients.[28] In contrast, our study identified AB/IS as the second most frequent pattern, observed in 15 eyes (31.25%). This finding is consistent with a prior report, which reported AB/IS in 16.7% of their patients.[11] The prominence of AB/IS in our study may reflect regional differences or patient demographics, as studies have shown variability in topography patterns across different populations.

Less frequent patterns in our study included asymmetric bowtie with skewed steepest radial axis (AB/SRAX) in 12.5% of cases and superior steeping (AB/SS) in 13.75%. These patterns have also been documented in previous studies[9],[11],[28], albeit at varying frequencies. For instance, a group of researchers found AB/SRAX in 12% of cases[11], aligning closely with our findings. Additionally, asymmetric bowtie and oval patterns were the least common, each accounting for 2.5% of cases in our study, which is similar to the findings of prior research[9],[28], who reported low frequencies of these patterns.

The variations in corneal topography patterns observed in our study, when compared with previous

research, underscore the importance of regional and demographic factors in the presentation of keratoconus. Our findings add to the growing body of literature by providing additional insights into the distribution of topography patterns in patients with astigmatism greater than two diopters. Understanding these patterns is crucial for early diagnosis and effective management of keratoconus, particularly in populations at higher risk for this condition. Further research is warranted to explore the potential underlying factors contributing to the differences in pattern distribution across different studies and regions.

Our study observed a significant association between age and keratoconus, with younger individuals (10-16 and 17-30 years) more likely to have keratoconus than middle-aged adults (p = .023). The Phi and Cramer's V value of .308 suggests a moderate relationship between age and Keratoconus occurrence. These findings are consistent with previous research[11],[23], which has identified younger age as a critical factor in the development of keratoconus. However, some studies did not find a significant relationship between age and keratoconus (p= .1)[9],[29] and also reported no significant association between age and keratoconus in both genders. Despite these differences, our results support the broader understanding that keratoconus often manifests in younger individuals, particularly during adolescence and early adulthood, which has been documented as a crucial developmental period for the disorder.

In terms of gender, our study revealed a significant association with keratoconus (p = .044), with males being more frequently affected (29 cases) compared to females (23 cases). The Phi and Cramer's V value of .226 indicates a weak to moderate relationship between gender and keratoconus occurrence. Past research[11],[30] supports this discovery that keratoconus affects males more often than females, however, the studies show varying degrees of association between gender and disease prevalence. Our study, along with others, shows male predominance in keratoconus probably because of genetic, hormonal, and environmental factors that lead to gender disparities in incidence rates.

This study showed a significant association between findings from corneal biomicroscopy: Fleischer rings, stromal thinning, Vogt's striae, and keratoconus development, where the p-value was .001. Besides this, the value of Phi and Cramer's V was .632, proving a strong positive relationship between keratoconus and corneal biomicroscopy features. This agrees with other studies that were conducted previously.[31],[32],[33] Corneal biomicroscopy can hence be concluded to be a good predictor of the incidence of keratoconus. Our study further confirmed a strong relationship between corneal topography patterns and the occurrence of keratoconus at p = .000 because Phi and Cramer's V value was .797, indicating a robust relationship between these two variables. This agrees with the conclusions of some previous researchs[11],[28], who included the patterns of corneal topography among the reliable predictors of the development of keratoconus.

Nothing is beyond the limitations, and neither is this study. Our sample size is not significant; thus, the generalization to the population has certain limitations. Larger-sized studies conducted across various regions will most aptly meet the purpose of understanding the prevalence of keratoconus among high-astigmatism patients. Moreover, our study had a single geographical focus and thus is not fully representative of the variability of keratoconus regarding different populations, ethnicities, and environmental conditions. Further research should be extended to larger areas for regional variation to be confirmed as influencing the prevalence and characteristics of keratoconus.

Another limitation is that it was a cross-sectional study. Cross-sectional studies obtain information simultaneously and do not reveal how keratoconus progresses in subjects with high astigmatism. Longitudinal studies could reveal much about progression over several years, particularly in youth, where progression occurs rapidly. In addition, although corneal topography and biomicroscopic examination played a significant role in diagnosing, employing newer technology such as corneal tomography or biomechanical testing could reveal a lot about subclinical keratoconus and allow early detection.

Finally, even though our study detected significant correlations between age, gender, and specific corneal traits concerning keratoconus, several confounding factors, such as genetic factors, environmental factors (e.g., UV radiation), and individual patient factors (e.g., eye-rubbing habits), could not be addressed in our study. Accounting for such factors in future studies can contribute to a deeper understanding of the complex interrelationships between several factors and the development of keratoconus.

Conclusions

This cross-sectional study observed Keratoconus rates among patients with astigmatic diopter measurements exceeding two. Results indicated that many such patients had keratoconus, which exceeded the previous study's findings. Eye examination with corneal topography needs to be done thoroughly. Early detection of the condition proves essential because the population most affected by keratoconus consists of young adults between 10 and 30. Men among the subjects showed higher rates of keratoconus development compared to women. These findings highlight the importance of age and gender specific early examinations followed by interventions to control eye diseases.

Acknowledgement

The authors would like to thank the authorities of Al-Basar International Foundation, Bangladesh, for their sincere support during the study.

References

[1] Boyd K. Astigmatism. American Academy of Ophthalmology 2024. https://www.aao.org/eye-health/diseases/what-is-astigmatism (accessed October 20, 2024).

[2] Zhang J, Wu Y, Sharma B, Gupta R, Jawla S, Bullimore MA. Epidemiology and burden of astigmatism: A systematic literature review. Optomet Vis Sci 2023. https://doi.org/10.1097/OPX.0000000000001998.

[3] Cornea Associates of Texas. Refractive Errors and Vision Correction Surgery Dallas Fort Worth. Cornea Associates of Texas 2024. https://www.corneatexas.com/refractive-errors/ (accessed October 20, 2024).

[4] Heidary G, Ying G-S, Maguire MG, Young TL. The association of astigmatism and spherical refractive error in a high myopia cohort. Optomet Vis Sci 2005;82:244–247. https://doi.org/10.1097/01.OPX.0000159361.17876.96.

[5] Han X, Fan Q, Hua Z, Qiu X, Qian D, Yang J. Analysis of corneal astigmatism and aberration in chinese congenital cataract and developmental cataract patients before cataract surgery. BMC Ophthalmol 2021;21:34. https://doi.org/10.1186/s12886-020-01794-2.

[6] Islam MA, Rana MM, Azam AAH, Alam AE, Hasanuzzaman M, Rasel SSB. Prevalence of corneal astigmatism in age related cataract patient in a Tertiary Eye Hospital. Cent Med Coll J 2023;6:67–70. https://doi.org/10.3329/cemecj.v6i2.67069.

[7] Miyake T, Kamiya K, Amano R, Shimizu K. Corneal astigmatism before cataract surgery. Nippon Ganka Gakkai Zasshi 2011;115:447–453.

[8] ABC Children's Eye Specialists. 6 Problems That Are Linked to Astigmatism. ABC Children's Eye Specialists 2024. https://www.abckidseyes.com/blog/6-problems-that-are-linked-to-astigmatism (accessed October 24, 2024).

[9] Shakir AN, Alwan EH. Prevalence of keratoconus in patients with astigmatism more than two diopters: A cross-sectional study. J Emerg Heal Care 2019;8.

[10] Boyd K. What is Keratoconus? American Academy of Ophthalmology 2024. https://www.aao.org/eye-health/diseases/what-is-keratoconus (accessed November 2, 2024).

[11] Hashemi H, Khabazkhoob M, Fotouhi A. Topographic keratoconus is not rare in an Iranian population: The Tehran eye study. Ophthalmic Epidemiol 2013;20:385–391. https://doi.org/10.3109/09286586.2013.848458.

[12] Wang Y, Rabinowitz YS, Rotter JI, Yang H. Genetic epidemiological study of keratoconus: Evidence for major gene determination. Am J Med Genet 2000;93:403–409. https://doi.org/https://doi.org/10.1002/1096-8628(20000828)93:5%3C403::AID-AJMG11%3E3.0.CO;2-A.

[13] Wyman AL. Benedict Duddell: Pioneer oculist of the 18th century. J R Soc Med 1992;85:412–415.

[14] Pearson AR, Soneji B, Sarvananthan N, Sandford-Smith JH. Does ethnic origin influence the incidence or severity of keratoconus? Eye 2000;14:625–628. https://doi.org/10.1038/eye.2000.154.

[15] Georgiou T, Funnell CL, Cassels-Brown A, O'Conor R. Influence of ethnic origin on the incidence of keratoconus and associated atopic disease in Asians and white patients. Eye 2004;18:379–383. https://doi.org/10.1038/sj.eye.6700652.

[16] Papali'i-Curtin AT, Cox R, Ma T, Woods L, Covello A, Hall RC. Keratoconus prevalence among high school students in New Zealand. Cornea 2019;38:1382–1389. https://doi.org/10.1097/ICO.0000000000002054.

[17] Santodomingo-Rubido J, Carracedo G, Suzaki A, Villa-Collar C, Vincent SJ, Wolffsohn JS. Keratoconus: An updated review. Cont Lens Anter Ey 2022;45:101559. https://doi.org/10.1016/j.clae.2021.101559.

[18] Rong SS, Ma STU, Yu XT, Ma L, Chu WK, Chan TCY, et al. Genetic associations for keratoconus: A systematic review and meta-analysis. Sci Rep 2017;7:4620. https://doi.org/10.1038/s41598-017-04393-2.

[19] Kymes SM, Walline JJ, Zadnik K, Sterling J, Gordon MO. Changes in the quality-of-life of people with keratoconus. Am J Ophthalmol 2008;145:611-617.e1. https://doi.org/10.1016/j.ajo.2007.11.017.

[20] Al-Dairi W, Al Dehailan AM, Alhammadi Y, Aljohar HI, Alhadi FA, Alhaboob ZA, et al. Vision-related quality of life in patients with keratoconus: A nationwide study in Saudi Arabia. Cureus 2023. https://doi.org/10.7759/cureus.35178.

[21] Saunier V, Mercier A-E, Gaboriau T, Malet F, Colin J, Fournié P, et al. Vision-related quality of life and dependency in French keratoconus patients: Impact study. J Cataract Refract Surg 2017;43:1582–1590. https://doi.org/10.1016/j.jcrs.2017.08.024.

[22] Serdarogullari H, Tetikoglu M, Karahan H, Altin F, Elcioglu M. Prevalence of keratoconus and subclinical keratoconus in subjects with astigmatism using pentacam derived parameters. J Ophthalmic Vis Res 2013;8:213–219.

[23] Shehadeh MM, Diakonis VF, Jalil SA, Younis R, Qadoumi J, Al-Labadi L. Prevalence of keratoconus among a Palestinian Tertiary student population. Open Ophthalmol J 2015;9:172–176. https://doi.org/10.2174/1874364101509010172.

[24] Reinstein DZ, Gobbe M, Archer TJ, Silverman RH, Coleman DJ. Epithelial, stromal, and total corneal thickness in keratoconus: Three-dimensional display with artemis very-high frequency digital ultrasound. J Refract Surg 2010;26:259–271. https://doi.org/10.3928/1081597X-20100218-01.

[25] Zhou W, Stojanovic A. Comparison of corneal epithelial and stromal thickness distributions between eyes with keratoconus and healthy eyes with corneal astigmatism ≥2.0 D. PLoS One 2014;9:e85994. https://doi.org/10.1371/journal.pone.0085994.

[26] Grieve K, Ghoubay D, Georgeon C, Latour G, Nahas A, Plamann K, et al. Stromal striae: A new insight into corneal

physiology and mechanics. Sci Rep 2017;7:13584. https://doi.org/10.1038/s41598-017-13194-6.

[27] Shi Y. Strategies for improving the early diagnosis of keratoconus. Clin Optom (Auckl) 2016:13. https://doi.org/10.2147/OPTO.S63486.

[28] Munsamy AJ, Moodley VR, Naidoo P, Mangwarara TR, Abdullah R, Govender D, et al. A frequency analysis of cone characteristics for the different stages of keratoconus. Afr Vis Eye Heal 2015;74. https://doi.org/10.4102/aveh.v74i1.302.

[29] Abdu M, Binnawi K, Elmadina AE, Hassan R. Clinical profile of keratoconus patients in Sudan. Sudanese J Ophthalmol 2016;8:20. https://doi.org/10.4103/1858-540X.184235.

[30] Millodot M, Shneor E, Albou S, Atlani E, Gordon-Shaag A. Prevalence and associated factors of keratoconus in Jerusalem: A cross-sectional study. Ophthalmic Epidemiol 2011;18:91–97. https://doi.org/10.3109/09286586.2011.560747.

[31] Güngör I. Bilateral horizontal Vogt's striae in keratoconus. Clini Ophthalmol 2008:653. https://doi.org/10.2147/OPTH.S2573.

[32] Khaled ML, Helwa I, Drewry M, Seremwe M, Estes A, Liu Y. Molecular and histopathological changes associated with keratoconus. Biomed Res Int 2017;2017:1–16. https://doi.org/10.1155/2017/7803029.

[33] Song P, Wang S, Zhang P, Sui W, Zhang Y, Liu T, et al. The superficial stromal scar formation mechanism in keratoconus: A study using laser scanning in vivo confocal microscopy. Biomed Res Int 2016;2016:1–10. https://doi.org/10.1155/2016/7092938.