• Clinical Research •

Ocular surface in patients with different degrees of myopia

Yan-Yun Lyu[1], Shuang Wang[2], Xiao-Niao Chen[3], Zhen-Yu Wang[2], Shan-Shan Huang[2], Yan Yuan[2], Hong-Shuang Lu[4], Wen-Li Yang[2], Li-Ya Qiao[2], Lei Tian[2], Ying Jie[2]

[1]Tongren Eye Care Center, Beijing Tongren Hospital, Capital Medical University, Beijing 100730, China
[2]Beijing Institute of Ophthalmology, Beijing Tongren Eye Center, Beijing Tongren Hospital, Capital Medical University and Beijing Ophthalmology and Visual Sciences Key Laboratory, Beijing 100730, China
[3]Department of Ophthalmology, the Third Medical Center of Chinese People's Liberation Army General Hospital, Beijing 100039, China
[4]Department of Ophthalmology and Visual Science, Tokyo Medical and Dental University, Tokyo 113-8510, Japan
Correspondence to: Lei Tian and Ying Jie. Beijing Institute of Ophthalmology, Beijing Tongren Eye Center, Beijing Tongren Hospital, Capital Medical University and Beijing Ophthalmology and Visual Sciences Key Laboratory, Beijing 100730, China. tianlei0131@163.com; jieyingcn@aliyun.com
Received: 2024-03-10 Accepted: 2024-05-29

Abstract
● **AIM:** To investigate the clinical features of the ocular surface in patients with different degrees of myopia.
● **METHODS:** A cross-sectional study was conducted involving 122 participants with myopia in Beijing Tongren Hospital from February to June, 2023. After completing the Ocular Surface Disease Index (OSDI) score scale, measurements were taken for refraction, biometric parameters and ocular surface parameters. The prevalence, severity and related parameters of the dry eye among different groups based on axial length (AL) were compared. Correlation analysis was performed between ocular surface parameters and refraction/biometric measurement parameters.
● **RESULTS:** Statistically significant differences were observed in refractive error, corneal thickness, anterior chamber depth, and subfoveal choroidal thickness among the groups (all $P<0.05$). With the increase in AL, the incidence and severity of dry eye increased significantly ($P<0.05$). Moreover, the tear film break-up time (BUT) shortened ($P<0.05$), and the corneal fluorescein staining (CFS) points increased significantly ($P<0.05$). OSDI scores were positively correlated with AL and spherical equivalent (SE; both $P<0.05$); BUT was negatively correlated with AL, SE, and corneal astigmatism (AST; all $P<0.05$); Schirmer I test (SIT) results were negatively correlated with AL and SE (both $P<0.05$).
● **CONCLUSION:** AL elongation is a risk factor for dry eye onset in myopic participants. The longer the AL, the more severe the dry eye is, with the increased CFS spots and tear film instability. Additionally, SE and AST exhibit negative correlations with dry eye symptom scores and ocular surface parameters.
● **KEYWORDS:** myopia; axial length; ocular surface; dry eye
DOI:10.18240/ijo.2024.07.17

Citation: Lyu YY, Wang S, Chen XN, Wang ZY, Huang SS, Yuan Y, Lu HS, Yang WL, Qiao LY, Tian L, Jie Y. Ocular surface in patients with different degrees of myopia. *Int J Ophthalmol* 2024;17(7):1313-1321

INTRODUCTION
Currently, changes in lifestyle habits have led to two prevalent ocular conditions, myopia and dry eye, becoming significant public health concerns worldwide[1]. The number of individuals with myopia in China has surpassed 600 million. And globally, approximately 2.6 billion people are affected. Projections indicate that by 2050, the global myopia prevalence rate will escalate to 49.8%, with the rate in East Asian populations soaring to 65.3%[2]. This trend poses substantial challenges to ocular health. Myopia not only impairs vision, impacts daily activities and academic pursuits, but also increases the risk of complications such as myopic retinal degeneration, retinal detachment, and macular diseases. These complications can lead to severe visual impairment and even blindness as myopia progresses and the eye's axial length (AL) increases[3-6]. Besides myopia, dry eye is the most frequently diagnosed ophthalmic condition[7]. It exhibits a higher prevalence in Asian populations, with rates varying from 52.4% in China to 85.6% among the older elderly in

Korea[8-9]. Recent epidemiological investigation has found that the myopia population has a higher prevalence rate of dry eye[10-11]. Increasing evidence suggests that dry eye may be associated with myopia[12-17]. However, no studies have been conducted on the aspect of the myopic degrees affecting the incidence of dry eye clinically. Therefore, this study carried out a comprehensive measurement of ocular surface parameters for the patients with different degrees of myopia, aiming to clarify the incidence of dry eye in patients with different ALs, and analyze the relationship between dry eye related parameters and refraction/biometric parameters, hoping to provide a reference for the early prevention and treatment of dry eye in people with myopia.

SUBJECTS AND METHODS

Ethical Approval This study was approved by the Ethics Committee of Beijing Tongren Hospital (No.TRECKY2021-230), Capital Medical University, and all participants and their families gave informed consent.

Participants The sample/power analysis shows that the minimum sample size that can produce positive statistics is 118. A total of 122 myopic participants who visited the Refractive Surgery Department at Beijing Tongren Hospital from February to June, 2023 were included as study subjects, with the right eyes selected for observation. Inclusion criteria: 1) aged 18-42y, able to actively cooperate with the examination; 2) a clear diagnosis of myopia, with manifest refraction spherical equivalent (MRSE) ≤0.5 diopters (D); Exclusion criteria: 1) history of ocular trauma or ocular surgery; 2) corneal limbal stem cell abnormalities or other ocular surface diseases (such as eyelid position abnormalities, trichiasis, pterygium, *etc*.); 3) active eye inflammation; 4) systemic immune diseases, connective tissue diseases, organic lesions, and mental disorders; 5) standard treatment for dry eye within the past six months.

Examinations A comprehensive medical history was taken from all participants to rule out ocular and systemic medical conditions proposed in the exclusion criteria and their dry eye symptoms were assessed using the Ocular Surface Disease Index (OSDI) questionnaire. The OSDI questionnaire used contains 12 questions related to dry eye from three categories: ocular symptoms, visual function, and environmental effects on the eyes. Each question is scored from 0-4 based on the frequency of symptoms over the past week, where 0 indicates no symptoms; 1, occasionally; 2, half the time; 3, most of the time; 4, always. The OSDI score=total score of answered questions×25/number of questions answered, ranging from 0 to 100[18].

All participants also underwent a comprehensive ophthalmic examination at the same location on the one day and was instructed to avoid eye usage habits that could affect measurement results 30min before measurement. The examinations included: 1) slit-lamp microscopy (to exclude other ocular diseases) and manifest refraction results measured by the same experienced optometrist; 2) ocular biometric parameters including AL, corneal thickness (CCT), anterior chamber depth (ACD), lens thickness (LT), and corneal astigmatism (AST) measured using the Lenstar optical biometer (Lenstar LS 900; Haag Streit AG, Koeniz, Switzerland); 3) subfoveal choroidal thickness (SFCT) measured with the Heidelberg posterior segment optical coherence tomography (OCT; Spectralis HRA+OCT; Heidelberg Engineering, Heidelberg, Germany) adjusted to star-scan and EDI mode; 4) tear film visual inspection and imaging using Lipiview II ocular surface interferometer (LipiView® II, Tearscience, North Carolina), based on the principle of white light interference from mirror reflections, measuring objective dry eye indicators including tear film lipid layer thickness (LLT), frequency of blink in 20s and incomplete blink ratio; 5) tear meniscus height (TMH), non-contact tear film first break-up time (NIKf-BUT), and non-contact tear film average break-up time (NIKav-BUT) measured using Keratograph 5M ocular surface analyzer (K5M, Oculus Optikgerate GmbH, Germany), which also produces high-definition multi-dimensional images of the meibomian glands through infrared light penetration of skin and tarsal plate, allowing photographic analysis of the glands. TMH was formed by the tear gathered at the upper and lower eyelid margin, representing the amount of tear secretion and lacrimal gland function[19]. In infrared light, the meibomian gland showed white lines, while the other parts showed dark gray background. The meibomian gland dropout rate (MGDR) was divided into four grades: Grade 0, no gland missing; Grade 1, missing area ≤1/3; Grade 2, missing area 1/3-2/3; Grade 3, missing area ≥2/3[20]; 6) corneal fluorescein staining (CFS) examination: after moistening, the fluorescein strip is touched to the conjunctiva under the lower tarsus and then removed, and the patient was instructed to blink several times to distribute the fluorescein evenly over the corneal surface. The patient was then asked to look straight ahead, and the BUT (*i.e.*, the time when the first dark spot appears on the tear film) was recorded, measured three times and averaged. Using cobalt blue light in the slit lamp, the presence of CFS was observed and recorded according to the American NEI scale[21]. The cornea was divided into five regions and graded based on dye distribution. The CFS score was between 0 and 15, ranging from 0 to 3 in each region as follows: 0, no staining; 1, 1-30 punctate staining; 2, punctate staining >30; 3, diffuse staining, filaments, and ulcer. The higher the score, the more severe the corneal epithelial defect is. The longer the BUT, the more stable the tear film; 7) Tear secretion measurement with the Schirmer I test (SIT): after the patient rested with

Table 1 Characteristics and comparison of refractive parameters among myopic groups with different ALs

Characteristic	Total (*n*=122)	23.20-24.93 mm (*n*=30)	24.94-26.13 mm (*n*=32)	26.14-27.13 mm (*n*=31)	27.14-33.20 mm (*n*=29)	*P*
Participants, *n* (%)						0.866
Men	33 (27.05)	8 (26.67)	7 (21.88)	9 (29.03)	9 (31.03)	
Women	89 (72.95)	22 (73.33)	25 (78.12)	22 (70.97)	20 (68.97)	
Age (y)	26.00 (24.00, 31.00)	25.50 (24.00, 30.00)	26.00 (24.00, 30.25)	26.00 (23.00, 31.00)	28.00 (25.00, 35.00)	0.244
CCT (μm)	534.87±30.78	539.47±34.18	522.44±29.61	534.39±29.49	544.34±26.26	0.032[a]
ACD (mm)	3.17±0.24	3.06±0.21	3.20±0.23	3.19±0.23	3.24±0.24	0.016[a]
LT (mm)	3.68±0.26	3.73±0.33	3.64±0.25	3.68±0.22	3.69±0.22	0.627
AST (D)	1.10 (0.75, 1.59)	1.08 (0.67, 1.33)	1.07 (0.83, 1.54)	1.02 (0.78, 1.57)	1.25 (0.92, 2.08)	0.411
SE (D)	-6.50 (-3.75, -9.19)	-2.75 (-2, -3.94)	-5.25 (-3.75, -6.5)	-7.5 (-6.25, -8.62)	-11.25 (-10.25, -14.25)	<0.001[a]
SFCT (μm)	201.00 (162.75, 253.75)	257.80 (205.20, 311.25)	217.40 (156.00, 251.75)	202.00 (187.90, 248.00)	139.60 (114.00, 180.00)	<0.001[a]

[a]$P<0.05$. AL: Axial length; CCT: Corneal thickness; ACD: Anterior chamber depth; LT: Lens thickness; AST: Astigmatism; SE: Spherical equivalent refraction; SFCT: Subfoveal choroidal thickness.

eyes closed for 10min, a folded Schirmer strip was placed at the temporal third of the lower conjunctival sac. The patient gently closed their eyes, and after 5min, the strip was read to determine the tear secretion rate per unit time. SIT was mainly used to measure the basal and reflex secretions amount of the main and accessory lacrimal glands[22]. The longer the wetted paper, the more the tear secretion is.

The diagnosis of dry eye disease (DED) was based on the Diagnostic Methodology Report published by the Tear Film and Ocular Surface Society (TFOS) Dry Eye Workshop (DEWS) in 2017[18]. The severity of dry eye was graded based on clinical signs[23]: mild, with no significant ocular surface damage and CFS<5 points, BUT≥2s; moderate, with corneal damage not exceeding two quadrants and CFS≥5 but <30 points, BUT≥2s; severe, with corneal damage over two quadrants and CFS≥30 points, BUT<2s, with CFS forming coarse dots, patches, or accompanied by filamentous material.

Statistical Analysis This study is a cross-sectional study, and statistical analysis was conducted using SPSS 26.0 statistical software. Only the right eye of each patient was included in the analysis to avoid bilateral correlation bias. Missing values were supplemented using Multiple Imputation (MI). The Kolmogorov-Smirnov test was employed to assess the normality of quantitative data. Quantitative data that followed a normal distribution or were close to normal distribution were expressed as mean±standard deviation, while those not conforming to a normal distribution were expressed as median (Q1, Q3). Qualitative data were presented as rates or proportions. The differences between different groups were evaluated using the χ^2 test, one-way analysis of variance (ANOVA), and Kruskal-Wallis *H* test. Subsequently, bivariate correlation analysis was conducted to compare the pairwise relationships between refractive error and ocular biometric parameters, as well as dry eye-related ocular surface parameters. A significance level of $P<0.05$ was considered statistically significant for differences.

RESULTS

General Information This study included 122 participants, with 33 males (27.05%) and 89 females (72.95%), aged 18-42y, with an average age of 27.63±5.405y. The observed eyes had a median AL of 26.13 (24.95, 27.1) mm. All participants were divided into 4 groups using the quartile method: 23.20-24.93 mm group (30 eyes), 24.94-26.13 mm group (32 eyes), 26.14-27.13 mm group (31 eyes), and 27.14-33.20 mm group (29 eyes). A comparison of general information and refractive parameters among different AL myopia groups is shown in Table 1. No statistically significant differences were found in gender, age, LT, and corneal AST between different AL groups ($P>0.05$). However, as the eye axis grows, CCT and ACD increase, SE increases, and SFCT decreases. The difference was statistically significant ($P<0.05$).

Comparison of Dry Eye Incidence Among Myopic Groups with Different Axial Lengths The total incidence of dry eye was 85.25% (104/122). As the AL of myopic participants increased, the incidence of dry eye disease in the four groups was 66.67% (20/30), 81.25% (26/32), 93.55% (29/31), and 100% (29/29), respectively. The overall difference was statistically significant (F=19.75, $P<0.05$; Table 2).

Comparison of Dry Eye Severity Among Myopic Groups with Different Axial Lengths According to the dry eye signs, the severity of dry eye was classified for four groups of myopic participants with different AL. There were 18 cases with no dry eye, 37 cases with mild dry eye, 42 cases with moderate dry eye, 25 cases with severe dry eye. The differences were statistically significant (F=41.64, $P<0.05$; Table 3).

Characteristics of Ocular Surface Parameters Among Myopic Groups with Different Axial Lengths This study conducted examinations of ocular surface parameters related to dry eye in four groups of participants with different AL. The results showed that for the four groups of participants, CFS score increased with the increase of AL, while BUT decreased with the increase of AL. These differences were statistically

Table 2 Comparison of dry eye prevalence among myopic groups with different ALs

Parameters	23.20-24.93 mm	24.94-26.13 mm	26.14-27.13 mm	27.14-33.20 mm	Total	*F*	*P*
Dry eye	20	26	29	29	104		
Non-dry eye	10	6	2	0	18		
Total	30	32	31	29	122		
Dry eye prevalence (%)	66.67	81.25	93.55	100.00	85.25	19.75	<0.05

AL: Axial length.

Table 3 Comparison of the severity of dry eye among myopic groups with different ALs

Parameters	23.20-24.93 mm	24.94-26.13 mm	26.14-27.13 mm	27.14-33.20 mm	Total	*F*	*P*
Normal	10	6	2	0	18		
Mild	13	11	8	5	37		
Moderate	3	13	14	12	42		
Severe	4	2	7	12	25		
Total	30	32	31	29	122	41.64	<0.05

AL: Axial length.

Table 4 Comparison of ocular surface related parameters of dry eye among myopic groups with different ALs

Parameters	23.20-24.93 mm	24.94-26.13 mm	26.14-27.13 mm	27.14-33.20 mm	*K/F*	*P*
TMH (mm)	0.25 (0.22, 0.28)	0.22 (0.2, 0.26)	0.2 (0.16, 0.22)	0.23 (0.18, 0.26)	2.482	0.101
NIKf-BUT (s)	4.78 (4.4, 6.5)	5.54 (3.87, 9.04)	5.54 (3.86, 7.84)	4.5 (3.54, 5.93)	0.749	0.422
NIKav-BUT (s)	7.81±2.34	8.52±3.32	8.01±2.87	8.12±2.55	0.291	0.469
MGDR	2 (2, 2)	2 (2, 3)	2 (2, 2)	2 (2, 2)	2.164	0.068
LLT (nm)	50 (45, 61)	59.5 (45, 78)	52 (42, 80)	44 (35.25, 61.5)	1.469	0.361
Frequency of blink (times)	30 (25.5, 31.5)	22.5 (17.25, 33.75)	18 (15, 27)	21 (17.25, 30)	1.000	0.332
Incomplete blink ratio	1 (1, 1)	0.83 (0.59, 1)	1 (0.5, 1)	0.79 (0.19, 1)	1.838	0.475
BUT (s)	4.59 (3.65, 5.46)	3.08 (2.61, 4.33)	2.43 (2.16, 3.01)	2.38 (2.22, 2.58)	5.686	<0.001[a]
CFS (points)	0 (0, 1)	0 (0, 1)	1 (0, 2)	2.5 (1, 5)	8.489	0.002[a]
SIT (mm)	10 (8.5, 17.5)	13.5 (6.75, 15.75)	9 (5, 15)	9.5 (4, 15)	5.201	0.071

[a]$P<0.05$. AL: Axial length; TMH: Tear meniscus height; NIKf-BUT: Non-contact tear film first break-up time; NIKav-BUT: Non-contact tear film average break-up time; MGDR: Meibomian gland dropout rate; LLT: Lipid layer thickness; BUT: Tear film break-up time; CFS: Corneal fluorescein staining spots; SIT: Schirmer I test.

Table 5 Results of correlation analysis between AL and ocular surface parameters

Values	OSDI	TMH	NIKf-BUT	NIKav-BUT	LLT	Frequency of blink	Incomplete blink ratio	BUT	CFS	SIT
Pearson correlation	0.209	-0.105	-0.137	-0.067	-0.177	-0.145	-0.092	-0.335	0.383	-0.222
P	0.021[a]	0.249	0.134	0.463	0.051	0.112	0.315	0.000[a]	0.115	0.014[a]

[a]$P<0.05$. OSDI: Ocular Surface Disease Index; TMH: Tear meniscus height; NIKf-BUT: Non-contact tear film first break-up time; NIKav-BUT: Non-contact tear film average break-up time; LLT: Lipid layer thickness; BUT: Tear film break-up time; CFS: Corneal fluorescein staining spots; SIT: Schirmer I test.

significant (CFS K/F=8.489, P=0.002; BUT K/F=5.686, P<0.001). There were no significant differences in TMH, NIKf-BUT, NIKav-BUT, MGDR, LLT, frequency of blink, incomplete blink ratio, and SIT among different AL groups (P>0.05; Table 4).

Correlation Analysis Between Myopia Parameters and Dry Eye Ocular Surface Parameters In this study, it was found that AL was positively correlated with OSDI score (r=0.209, P=0.021), and negatively correlated with BUT (r=-0.335, P<0.001) and SIT (r=-0.222, P=0.014) (Figure 1, Table 5). SE was positively correlated with OSDI score (r=0.223, P=0.014), and negatively correlated with BUT (r=-0.363, P<0.001) and SIT value (r=-0.279, P=0.002; Figure 2, Table 6). AST was negatively correlated with BUT (r=-0.245, P=0.006; Figure 3, Table 7).

DISCUSSION

Both myopia and dry eye can lead to a decrease in visual quality for participants. Although both conditions are currently hot topics in ophthalmology, there is still limited research on the relationship between myopia and dry eye both domestically and internationally. Fahmy and Aldarwesh[17] conducted a cross-sectional study and found that NIK-BUT was lower in both myopic and hyperopic groups compared to emmetropic eyes. The TMH was lower in myopic eyes and higher in

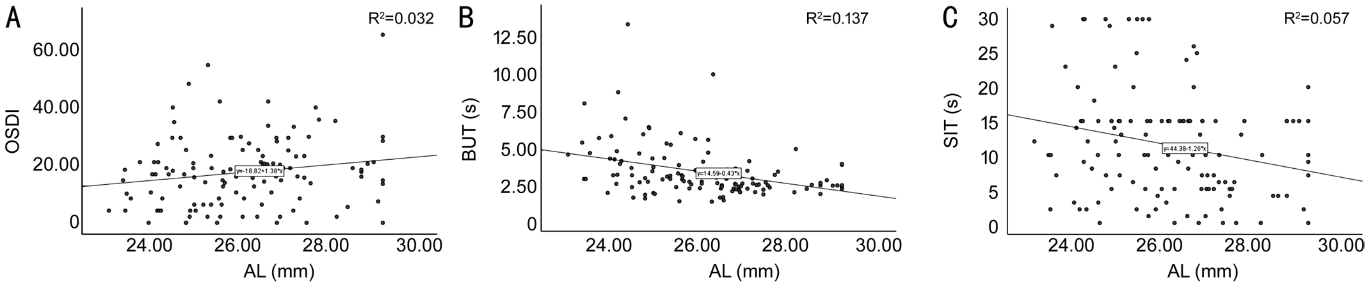

Figure 1 Correlation analysis between AL and OSDI, BUT and SIT A: AL is positively correlated with OSDI; B: AL is negatively correlated with BUT; C: AL is negatively correlated with SIT. AL: Axial length; OSDI: Ocular Surface Disease Index; BUT: Tear film break-up time; SIT: Schirmer I test.

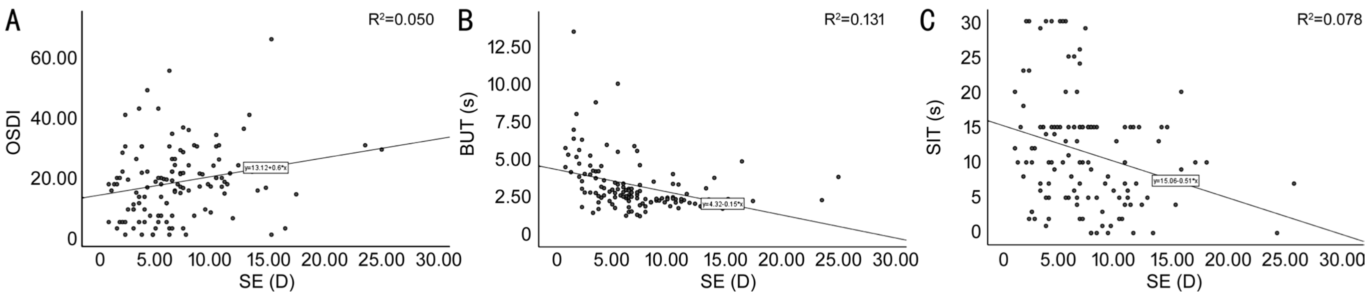

Figure 2 Correlation analysis between SE, OSDI, BUT, and SIT A: SE is positively correlated with OSDI; B: SE is negatively correlated with BUT; C: SE is negatively correlated with SIT. SE: Spherical equivalent refraction; OSDI: Ocular Surface Disease Index; BUT: Tear film break-up time; SIT: Schirmer I test.

Table 6 Results of correlation analysis between SE and ocular surface parameters

Values	OSDI	TMH	NIKf-BUT	NIKav-BUT	LLT	Frequency of blink	Incomplete blink ratio	BUT	CFS	SIT
Pearson correlation	0.223	-0.142	-0.071	-0.015	-0.139	-0.113	-0.121	-0.363	0.405	-0.279
P	0.014[a]	0.119	0.437	0.869	0.125	0.216	0.185	0.000[a]	0.085	0.002[a]

[a]*P*<0.05. OSDI: Ocular Surface Disease Index; TMH: Tear meniscus height; NIKf-BUT: Non-contact tear film first break-up time; NIKav-BUT: Non-contact tear film average break-up time; LLT: Lipid layer thickness; BUT: Tear film break-up time; CFS: Corneal fluorescein staining spots; SIT: Schirmer I test; SE: Spherical equivalent refraction.

Table 7 Results of correlation analysis between AST and ocular surface parameters

Values	OSDI	TMH	NIKf-BUT	NIKav-BUT	LLT	Frequency of blink	Incomplete blink ratio	BUT	CFS	SIT
Pearson correlation	0.019	0.160	-0.074	-0.013	-0.089	-0.079	-0.029	-0.245	0.068	0.042
P	0.840	0.079	0.419	0.089	0.328	0.386	0.749	0.006[a]	0.459	0.645

[a]*P*<0.05. OSDI: Ocular Surface Disease Index; TMH: Tear meniscus height; NIKf-BUT: Non-contact tear film first break-up time; NIKav-BUT: Non-contact tear film average break-up time; LLT: Lipid layer thickness; BUT: Tear film break-up time; CFS: Corneal fluorescein staining spots; SIT: Schirmer I test; AST: Astigmatism.

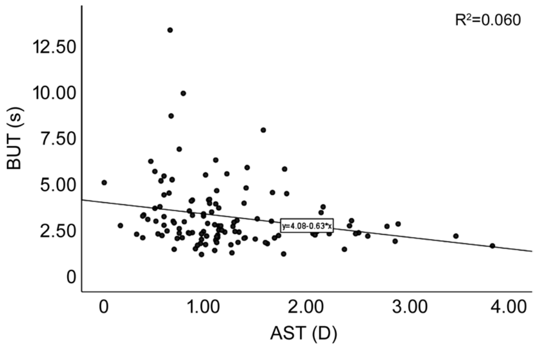

Figure 3 Correlation analysis between AST and BUT AST is negatively correlated with BUT. AST: Astigmatism; BUT: Tear film break-up time.

hyperopic eyes compared to emmetropic eyes. Additionally, it was observed that emmetropic eyes were more common in the group without dry eye, while myopic eyes were more common in the group with mild to moderate dry eye, and hyperopic eyes were more common in the group with severe dry eye. This suggests a certain association between refractive errors and dry eye. Dhungel and Shrestha[24] assessed 242 artists to determine the relationship between refractive errors and visual symptoms. They found that an increase in myopic refractive error and astigmatism was often associated with worsening symptoms of dry eye on the ocular surface. AST was more strongly correlated with dry eye symptoms than myopia. Li[11] found that the prevalence of dry eye was significantly higher in highly myopic individuals compared to non-highly myopic individuals. The OSDI score and CFS score were higher, while the BUT was shorter, and meibomian gland completeness was lower in highly myopic individuals. Furthermore, when investigating changes in ocular surface function among participants with different degrees of myopia, it was found that as the degree of myopia increased, ocular surface function damage also increased. This was mainly manifested in tear film instability, thinning of the lipid layer, meibomian gland loss, and ocular surface inflammation. Ilhan *et al*[16] found that pathological myopic participants had shorter BUT and higher OSDI scores compared to healthy individuals. Yotsukura *et al*[12] conducted research to explore the relationship between myopia and dry eye in Japanese schoolchildren. They investigated 1478 elementary and junior high school students and found that AL, SE, and AL-corneal curvature radius were all correlated with the occurrence of dry eye. As the severity of dry eye symptoms increased, the degree of myopia in elementary school students and the AL in junior high school students also increased. Furthermore, Hazra *et al*[13] explored the relationship between myopia and dry eye by evaluating high-order aberrations (HOAs) and choroidal thickness in 72 myopic children with dry eye. They found that as the BUT decreased, AL increased, and choroidal thickness decreased. The study concluded that dry eye was a confounding factor in the association between myopia and HOAs, but the relationship between myopia and dry eye was unrelated to HOAs. Our study further investigated the impact of the degree of myopia on dry eye by categorizing subjects based on ALs. By analyzing dry eye symptoms and ocular surface dry eye parameters of different groups, we provided additional conclusive evidence regarding the correlation between myopia and dry eye.

Li[11] discovered that with the increase in refractive error, the incidence of dry eye gradually rises among participants with different degrees of myopia. However, no one has investigated the impact of AL on the incidence and severity of dry eye so far. To address this gap, our team categorized myopic participants into groups based on AL and found that with the increase in AL, both the incidence and severity of dry eye increased. This may be attributed to the possibility that with the growth of the AL, there is an increased likelihood of inadequate eyelid coverage of the cornea, raising the risk of exposure-related corneal diseases—a phenomenon frequently mentioned in reports on thyroid eye disease[25-26]. Inflammation and corneal damage are crucial pathogenic mechanisms for dry eye[27-28]. Furthermore, axial elongation is often indicative of worsening myopia, and participants with higher degrees of myopia often exhibit more unfavorable eye habits, such as prolonged use of electronic devices at close distances and wearing contact lenses[29]. These factors are well-known contributors to dry eye. Additionally, the myopic population tends to adjust their near point to a farther distance, experiencing a decrease in accommodative amplitude, leading to visual fatigue and consequently contributing to the onset and progression of dry eye[30].

In comparing ocular surface parameters among different groups of myopia with varying ALs, we observed significant intergroup differences in BUT and CFS. As the AL increased, BUT significantly shortened, while CFS markedly increased. Further correlation analyses confirmed these findings, revealing a negative correlation between BUT and AL/SE, and a positive correlation between CFS and AL/SE. The rationale behind these observations may be associated with the concurrent increase in refractive error and AL in myopic participants. The AL, representing the distance from the anterior corneal surface to the retina, signifies the length of the eyeball. An increase in AL results in eyeball protrusion, enlarging the exposed ocular surface area, leading to a thinner tear film and a shorter BUT. Additionally, changes in corneal morphology accompany AL growth. A cross-sectional study from Korea suggests that, despite a compensatory flattening of corneal curvature with increasing AL, AST tends to increase[31]. AST primarily depends on corneal AST, which arises from disparate refractive powers along the two meridians of the cornea, indicating inconsistent curvature in different directions. This irregularity results in an uneven distribution of tears on the ocular surface, leading to an unstable tear film and faster BUT. This explanation aligns well with the negative correlation observed between AST and BUT in our correlation analysis. Regarding the increase in CFS with AL and its positive correlation with AL/SE, it may be attributed to corneal staining, often caused by mechanical or chemical irritants or physiological factors, being a common complication of contact lens wear[32]. With higher degrees of myopia and longer ALs, the likelihood of wearing tight-fitting contact lenses and lens adhesion increases, potentially causing corneal epithelial damage and resulting in corneal staining. Additionally, the larger exposed ocular surface area due to increased AL may lead to uneven tear film distribution, causing damage or detachment of epithelial cells on the corneal surface not uniformly covered by the tear film, consequently increasing CFS points.

However, we did not observe significant differences in OSDI among different groups, indicating that AL is not a key factor influencing the subjective symptoms of dry eye. The reason for this may lie in the clinical inconsistency between symptoms and signs in dry eye participants. The strong subjectivity of symptoms, influenced by physiological, psychological, and neural factors, may not accurately reflect the severity of pathological changes in dry eye. Therefore, there is a considerable deviation in OSDI scores among different study participants. It is also possible that the human body has compensatory mechanisms that alleviate the subjective symptoms of dry eye, a topic that warrants further investigation and discussion in the future. Additionally, we did not find significant differences in blink frequency, incomplete blink ratio, LLT, and meibomian gland integrity between different groups. Blinking is a crucial physiological movement for distributing tears on the ocular surface, forming the meibomian gland lipid layer with each blink. Blink rate is influenced by mental state, attention, activity, ocular surface exposure, and environmental conditions[33]. Incomplete blinking, when the orbicularis oculi muscle provides relatively weak contraction during an incomplete blink, results in insufficient compression of the meibomian glands. Some meibum cannot be expelled through the gland orifice, leading to accumulation, solidification, and blockage, ultimately causing meibomian gland atrophy and loss[34]. Moreover, due to the lack of contact between the upper and lower eyelids, the tear film cannot replenish enough lipid from the lower lid margin lipid pool, resulting in a decrease in the thickness of the tear film lipid layer[35]. In this study, we measured blink frequency and incomplete blink ratio within 20s in participants with different ALs, and no significant differences were found between groups. This suggests that AL is not a factor influencing blink frequency and incomplete blink ratio. This observation may be related to variations in the mental state and attention of the participants during the examination. Consequently, AL also does not appear to have an impact on the thickness of the tear film lipid layer and the integrity of the meibomian glands.

It is worth noting that, currently, there have been no reports on the association between myopia and OSDI scores related to dry eye symptoms. Our team is the first to establish a positive correlation between OSDI and SE/AL, albeit with a relatively weak correlation. This may be attributed to the elongation of the eyeball in myopic participants, resulting in a larger exposed ocular surface area. Combined with potential changes in corneal curvature, lubrication of the ocular surface is affected, making the eyes more susceptible to environmental stimuli and triggering a range of dry eye discomfort symptoms, such as dryness, foreign body sensation, and visual fatigue. The higher the degree of myopia, the longer the AL, and the more pronounced the symptoms. In our correlation analysis, we also found a negative correlation between SIT and AL/SE. This may be due to the increased protrusion of the eyes after axial elongation, leading to easier evaporation of tears and reduced retention time of tears on the ocular surface, resulting in a decreased SIT. The assessment results of the SIT to some extent reflect the basal tear secretion of the eyes[36]. This conclusion further validates the hypothesis that there may be a common upstream pathway between myopia and dry eye, regulating the secretion of tears by the lacrimal gland and affecting choroidal blood flow, possibly under the control of the parasympathetic nervous system[13,37]. However, unlike this relationship, SFCT and BUT did not exhibit theoretically expected negative correlation results in our study. This discrepancy could be due to the prevalence of lifestyle-related dry eye in young participants compared to children, where prolonged use of video terminals, insufficient outdoor activities, sleep disturbances, smoking, alcohol consumption, and the use of cosmetics significantly shorten the tear film BUT, resulting in an absence of correlation between SFCT and BUT. We also didn't observed significant difference in the prevalence and severity of dry eye between males and females. In the comparison of ocular surface parameters of dry eye, it was found that the NIKf-BUT of females was longer, and the thickness of tear film LLT was thicker than that of males. No statistical differences exist in the comparison of the other parameters. There is no theoretical basis to support this conclusion, which is related to our insufficient sample size and sampling error.

In this study, there are also some limitations. When conducting comprehensive dry eye related examinations, we did not further examine the signs of the lid margin and the secretion of meibum. We also did not pay attention to the morphology of the meibomian glands or conduct an analysis of conjunctival redness levels, resulting in an incomplete assessment of the dry eye ocular surface. Moreover, we only conducted measurements and statistical analysis based on clinical data and did not explore in depth from the perspective of molecular mechanisms. We will further quantitatively analyze inflammatory factors in the tears of myopic participants with different AL and try to discover strong evidence supporting the conclusion that AL is an important indicator affecting dry eye.

In summary, the AL of the eye in myopic participants can influence the occurrence and development of dry eye. The longer the AL, the more severe the dry eye, accompanied by an increase in CFS and instability of the tear film. In addition, the degree of refractive error and corneal AST also have some influence on dry eye ocular surface parameters. Therefore, measuring ocular biometric parameters in myopic participants in clinical practice can help identify dry eye symptoms early and assess the severity of dry eye, leading to targeted interventions and treatments. Additionally, further efforts could be made to determine the physiological and genetic mechanisms linking these two conditions. This could have significant implications for improving the quality of life of individuals with these conditions and reducing the socio-economic burden associated with them.

ACKNOWLEDGEMENTS

Authors' contributions: Lyu YY: conception and design, data interpretation, manuscript preparation; Wang S: research execution, data analysis, manuscript preparation; Chen XN: data acquisition, data analysis, manuscript preparation; Wang ZY: data acquisition, data analysis, manuscript preparation; Huang SS: data analysis and interpretation, manuscript preparation; Yuan Y: research execution; Lu HS: research execution; Yang WL: data analysis and inter preparation; Qiao LY: conception and design, data analysis; Tian L: conception and design, funding acquisition; Jie Y: conception and design, funding acquisition.

Foundation: Supported by the Capital Health Development Scientific Research.

Conflicts of Interest: Lyu YY, None; **Wang S,** None; **Chen XN,** None; **Wang ZY,** None; **Huang SS,** None; **Yuan Y,** None; **Lu HS,** None; **Yang WL,** None; **Qiao LY,** None; **Tian L,** None; **Jie Y,** None.

REFERENCES

1 Harb EN, Wildsoet CF. Origins of refractive errors: environmental and genetic factors. *Annu Rev Vis Sci* 2019;5:47-72.

2 Holden BA, Fricke TR, Wilson DA, Jong M, Naidoo KS, Sankaridurg P, Wong TY, Naduvilath TJ, Resnikoff S. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. *Ophthalmology* 2016;123(5):1036-1042.

3 Song ML, Shen MX, Zhou YP, Zheng KR, Zhai YQ, Xiao MC, Wang XH, Wang FH, Sun XD. Observation of vitreous features using enhanced vitreous imaging optical coherence tomography in highly myopic retinoschisis. *Retina* 2019;39(9):1732-1741.

4 Zhao XJ, Ding XY, Lyu CC, Li SS, Liu BQ, Li T, Sun LM, Zhang AY, Lu JG, Liang XL, Jin CJ, Lu L. Morphological characteristics and visual acuity of highly myopic eyes with different severities of myopic maculopathy. *Retina* 2020;40(3):461-467.

5 Voide N, Kaeser PF. Outbreak of myopia in pediatrics: management, prevention and treatment. *Rev Med Suisse* 2023;19(855):2407-2411.

6 Ohno-Matsui K, Wu PC, Yamashiro K, Vutipongsatorn K, Fang Y, Cheung CMG, Lai TYY, Ikuno Y, Cohen SY, Gaudric A, Jonas JB. IMI pathologic myopia. *Invest Ophthalmol Vis Sci* 2021;62(5):5.

7 Stapleton F, Alves M, Bunya VY, Jalbert I, Lekhanont K, Malet F, Na KS, Schaumberg D, Uchino M, Vehof J, Viso E, Vitale S, Jones L. TFOS DEWS II epidemiology report. *Ocul Surf* 2017;15(3):334-365.

8 Li XL, Wang Z, Mu JY, Puerkaiti H, Nulahou A, Zhang J, Zhao Y, Sun Q, Li YY, Wang Y, Gao YX. Prevalence and associated risk factors of dry eye disease in Hotan, Xinjiang: a cross-sectional study. *BMC Ophthalmol* 2023;23(1):214.

9 Lim MN, Lee JY, Hyon JY, Han SB. Association of self-reported psychiatric and systemic risk factors in dry eye disease in adult Korean population. *Eye (Lond)* 2024;38(5):917-922.

10 He GY, Li QX. Keratograph assessment of ocular surface function in patients with high myopia. *Shaanxi Medical Journal* 2017;46(10):1444-1446.

11 Li Q. Clinical observation of the ocular surface condition of patients with different degrees of myopia. *Hunan Normal University* 2018:62.

12 Yotsukura E, Torii H, Inokuchi M, *et al*. Current prevalence of myopia and association of myopia with environmental factors among schoolchildren in Japan. *JAMA Ophthalmol* 2019;137(11):1233-1239.

13 Hazra D, Yotsukura E, Torii H, Mori K, Maruyama T, Ogawa M, Hanyuda A, Tsubota K, Kurihara T, Negishi K. Relation between dry eye and myopia based on tear film breakup time, higher order aberration, choroidal thickness, and axial length. *Sci Rep* 2022;12(1):10891.

14 Fagehi R, El-Hiti GA, Alsubaie MH, Abusharha A, Alanazi MA, Masmali AM, Almubrad T. Measurements of tear evaporation rate in subjects with refractive errors using a portable evaporimeter. *Healthcare* 2022;10(2):405.

15 Alanazi MA, El-Hiti GA, Al-Madani A, Fagehi R. Analysis of tear ferning patterns in young female subjects with refractive errors. *J Ophthalmol* 2021;2021:9524143.

16 Ilhan N, Ilhan O, Ayhan Tuzcu E, Daglioglu MC, Coskun M, Parlakfikirer N, Keskin U. Is there a relationship between pathologic myopia and dry eye syndrome? *Cornea* 2014;33(2):169-171.

17 Fahmy RM, Aldarwesh A. Correlation between dry eye and refractive error in Saudi young adults using noninvasive Keratograph 4. *Indian J Ophthalmol* 2018;66(5):653-656.

18 Wolffsohn JS, Arita R, Chalmers R, *et al*. TFOS DEWS II diagnostic methodology report. *Ocul Surf* 2017;15(3):539-574.

19 Tung CI, Perin AF, Gumus K, Pflugfelder SC. Tear meniscus dimensions in tear dysfunction and their correlation with clinical parameters. *Am J Ophthalmol* 2014;157(2):301-310.e1.

20 Mounika V, Kamath SJ, Tejaswi P, Kamath AR, Rodrigues GR, Mendonca TM. A simple technique of meibography for morphological and functional evaluation of meibomian glands in dry eye conditions. *Indian J Ophthalmol* 2023;71(4):1420-1425.

21 Amparo F, Wang HB, Yin J, Marmalidou A, Dana R. Evaluating corneal fluorescein staining using a novel automated method. *Invest Ophthalmol Vis Sci* 2017;58(6):BIO168-BIO173.

22 Brott NR, Ronquillo Y. Schirmer test. In: *Statpearls*. StatPearls Publishing; 2023.

23 Asia Dry Eye Society China Branch, Cross-Strait Medical and Health Exchange Association Ophthalmology Professional Committee Cornea and Tear Disease Group, and Chinese Medical Association Ophthalmologist Branch Cornea and Dry Eye Group. Chinese Expert Consensus on Dry Eye: Definition and Classification (2020). *Chinese Journal of Ophthalmology* 2020;56(6):418-422.

24 Dhungel D, Shrestha GS. Visual symptoms associated with refractive errors among Thangka artists of Kathmandu valley. *BMC Ophthalmol* 2017;17(1):258.

25 Rana HS, Akella SS, Clabeaux CE, Skurski ZP, Aakalu VK. Ocular

surface disease in thyroid eye disease: a narrative review. *Ocul Surf* 2022;24:67-73.

26 Abusharaha A, Alturki AA, Alanazi SA, Fagehi R, Al-Johani N, El-Hiti GA, Masmali AM. Assessment of tear-evaporation rate in thyroid-gland patients. *Clin Ophthalmol* 2019;13:131-135.

27 Kado Abdalkader R, Chaleckis R, Fujita T, Kamei KI. Modeling dry eye with an air-liquid interface in corneal epithelium-on-a-chip. *Sci Rep* 2024;14(1):4185.

28 Lee KE, Oh S, Bhujel B, Kim CM, Lee H, Park JH, Kim JY. Effect of topical programmed death-Ligand1 on corneal epithelium in dry eye mouse. *Biomolecules* 2024;14(1):68.

29 Biswas S, El Kareh A, Qureshi M, Lee DMX, Sun CH, Lam JSH, Saw SM, Najjar RP. The influence of the environment and lifestyle on myopia. *J Physiol Anthropol* 2024;43(1):7.

30 Mahmood M, Day M, Seidel D, Cameron LA. The effect of multifocal contact lenses on the dynamic accommodation step response. *Ophthalmic Physiol Opt* 2024;44(2):321-333.

31 Lee MH, Kim HK, Kim SS. Interocular difference of axial length, anterior chamber depth, keratometry, corneal astigmatism according to axial length. *J Korean Ophthalmol Soc* 2022;63(1):83-88.

32 Gagliano C, Zeppieri M, Longo A, *et al*. Efficacy and safety of artificial tears containing lipidure and hypromellose for the treatment of moderate dry eye disease in contact lens wearers. *Medicina (Kaunas)* 2024;60(2):287.

33 Wang MTM, Tien L, Han A, Lee JM, Kim D, Markoulli M, Craig JP. Impact of blinking on ocular surface and tear film parameters. *Ocul Surf* 2018;16(4):424-429.

34 Wan T, Jin XM, Lin L, Xu YF, Zhao YY. Incomplete blinking may attribute to the development of meibomian gland dysfunction. *Curr Eye Res* 2016;41(2):179-185.

35 Jie Y, Sella R, Feng J, Gomez ML, Afshari NA. Evaluation of incomplete blinking as a measurement of dry eye disease. *Ocul Surf* 2019;17(3):440-446.

36 Chidi-Egboka NC, Briggs NE, Jalbert I, Golebiowski B. The ocular surface in children: a review of current knowledge and meta-analysis of tear film stability and tear secretion in children. *Ocul Surf* 2019;17(1):28-39.

37 Jin K, Imada T, Hisamura R, Ito M, Toriumi H, Tanaka KF, Nakamura S, Tsubota K. Identification of lacrimal gland postganglionic innervation and its regulation of tear secretion. *Am J Pathol* 2020;190(5):1068-1079.