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Comparison of Tear Film Instability in Dry Eye Patients in Summer and Winter

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Abstract
Dry eye disease (DED) is a multifactorial ocular surface disorder characterized by tear film loss, often overlapped by ocular allergy (OA). Both conditions can have a major effect on people's standard of living. Topical treatments are advised for OA, but eye drop formulations may contain additional substances contributing to DED. Dry eyes as a result of decreased tear production, patients frequently suffer dryness, irritation, and a grainy feeling. To compare tear film instability in patients with dry eye disease during the summer and winter seasons. A comparative cross-sectional study was conducted on 128 dry eye patients (64 in winter, 64 in summer) at the Ophthalmology Department, District Headquarter Hospital, Okara. Tear film stability and tear production were assessed using TBUT and Schirmer I tests and symptoms were evaluated with the OSDI questionnaire. Ambient temperature and humidity were recorded, and data were analysed using non-parametric tests (Mann Whitney U, Chi square) with $p \leq 0.005$ considered significant. Tear film instability and dry eye symptoms were worse in winter than in summer, with lower TBUT (mean rank: 34.43 vs 94.57), lower Schirmer values (right eye: 94.84 vs 34.16), and higher OSDI scores ($p<0.000$). Winter conditions exacerbate dry eye, highlighting the impact of seasonal environmental factors.

Key Words: Dry Eye, Tear Film, Tear Break Up Test, Schirmer Test, Winter Season, Summer Season

Introduction

Dry eye disease (DED) is a multifactorial disorder of the ocular surface characterized by loss of tear film homeostasis, accompanied by ocular symptoms such as dryness, irritation, burning sensation, and visual disturbance. It is frequently associated with tear film instability, hyperosmolarity, inflammation, and neurosensory abnormalities, making it a complex and heterogeneous condition (1,2). DED often overlaps with ocular allergy (OA), further complicating diagnosis and management, as topical medications used in OA may contain preservatives or additives that exacerbate dry eye symptoms (1). DED is broadly classified into two major subtypes: aqueous-deficient dry eye and evaporative dry eye. Aqueous deficiency results from reduced tear secretion by the lacrimal glands, whereas evaporative dry eye is primarily due to increased tear evaporation, often linked to meibomian gland dysfunction (3). Patients typically present with symptoms such as foreign body sensation, redness, photophobia, blurred vision, and difficulty wearing contact lenses, all of which significantly impair quality of life (3,4). The tear film plays a critical role in maintaining ocular surface integrity and visual clarity. Despite its minimal thickness of approximately 3 μm, it has a highly complex composition consisting of lipids, aqueous components, and mucins (5). The outer lipid layer reduces tear evaporation, the middle aqueous layer provides nutrients and antimicrobial proteins, and the inner mucin layer ensures tear film stability by promoting adhesion to the corneal epithelium (6). The tear film is continuously produced at a rate of 1–2 μL/min, with a total volume of 3–10 μL, and maintains a slightly alkaline pH that can vary with environmental and physiological factors (7,8). One of the hallmark features of DED is tear film instability, which is significantly influenced by environmental conditions. Seasonal and climatic variations play a crucial role in modulating tear dynamics. High temperatures and low humidity during summer increase tear evaporation, while cold weather, wind exposure, and indoor heating during winter reduce ambient humidity and destabilize the tear film (9,10). These environmental stressors can exacerbate symptoms, particularly in individuals predisposed to dry eye or with underlying systemic or ocular conditions such as autoimmune diseases or ocular rosacea (10).

DED is one of the most prevalent ocular disorders worldwide, affecting millions of individuals, with higher prevalence observed in females and increasing incidence with age (11). Environmental pollutants, smoke, air conditioning, prolonged screen exposure, and reduced blink rate further contribute to disease progression. Both indoor and outdoor environmental factors, including dry air and wind, are recognized as significant contributors to tear film disruption and ocular discomfort (10,12). Accurate diagnosis of DED requires a combination of clinical evaluation and diagnostic testing. Commonly used methods include the Schirmer test for tear production and tear break-up time (TBUT) for assessing tear film stability (13,14). Ocular surface staining with fluorescein, lissamine green, or rose bengal helps identify epithelial damage. Advanced diagnostic techniques such as tear osmolarity measurement, meibography, and inflammatory marker analysis (e.g., MMP-9) provide quantitative assessment but are often limited by cost and accessibility (13). The Schirmer test remains a widely used clinical tool to evaluate tear secretion, although it may stimulate reflex tearing and has variability in interpretation (14,15). TBUT, on the other hand, assesses tear film stability by measuring the time interval between a blink and the first appearance of a dry spot on the cornea, with shorter times indicating instability (16,17). These diagnostic approaches are essential for identifying the severity and subtype of DED, thereby guiding appropriate management strategies.

Given the strong influence of environmental and seasonal factors on tear film dynamics, understanding their role in the pathophysiology of DED is essential. Seasonal variations not only affect tear evaporation and stability but also influence symptom severity and disease progression.

Therefore, evaluating these variations is crucial for improving diagnosis, management, and patient outcomes in individuals with dry eye disease.

Material and Methods:

Ethical approval was given by the Research Committee of Superior University Lahore, Ref: IRB/FAHS/REHAB/10/25/MS/RS-3791. This comparative cross-sectional study was conducted at the Department of Ophthalmology, District Headquarter Hospital, Okara, over a period of six months. A total of 128 participants diagnosed with mild-to-moderate dry eye disease (DED) were enrolled using a non-probability purposive sampling technique, with 64 participants assessed during the winter season and 64 during the summer season. Adults aged 18–70 years of both genders with clinically diagnosed DED were included. Patients with recent ocular surgery (within the past 6 months), contact lens use, active ocular infection, or systemic autoimmune diseases were excluded. Data collection was performed during routine clinical visits after obtaining informed consent. Environmental conditions, including room temperature and relative humidity, were recorded using a digital hygrometer (model no. HTC-1 Medical) at the time of examination. Dry eye symptoms were assessed using the Ocular Surface Disease Index (OSDI) questionnaire. Tear film stability was evaluated using Tear Break-Up Time (TBUT) following fluorescein instillation, with values <10 seconds indicating instability. Tear production was measured using Schirmer's Test I (without anesthesia), with <10 mm wetting in 5 minutes considered abnormal. Data were analyzed using SPSS (IBM version 25). Descriptive statistics were calculated for all variables. The Shapiro–Wilk test indicated non-normal distribution; therefore, the Mann–Whitney U test was used to compare continuous variables between groups, and the Chi-square test was applied for categorical data. A p-value of ≤0.05 was considered statistically significant.

Results:

A total of 128 participants with dry eye disease were evaluated, with 64 individuals assessed during the winter season and 64 during the summer season. Descriptive statistics indicated a mean age of 30.96 ± 7.60 years and a mean OSDI score of 50.06 ± 14.39, reflecting moderate to severe dry eye symptoms. Seasonal variations in ocular symptoms, tear film parameters, and environmental conditions were further explored to determine the impact of weather on dry eye severity.

Table No. 1: Descriptive Profile of Study Participants

	N	Minimum	Maximum	Mean	Std. Deviation
Age	128	18	45	30.96	7.598
OSDI-total score	128	17.86	82.14	50.055	14.39
TBUT-Right- sec	128	4.00	11.00	7.117	1.889
TBUT-Left-sec	128	4.00	12.00	7.343	1.99778
Shimmer-Right without anesthesia	128	6.00	16.00	10.639	2.5773
Shimmer-Left without anesthesia	128	6.00	17.00	10.687	2.7314
Temperature-C	128	10.0	40.0	25.25	11.0001
Humidity %	128	30	75	50.27	13.859

Table 1 presents the descriptive statistics of the study participants (N=128). The mean age of participants was 30.96 ± 7.59 years, ranging from 18 to 45 years.

The mean OSDI total score was 50.05 ± 14.39, indicating a moderate to severe level of dry eye symptoms among participants. Tear film breakup time (TBUT) showed mean values of 7.11 ± 1.88 seconds in the right eye and 7.34 ± 1.99 seconds in the left eye, suggesting reduced tear film stability. Schirmer test values without anesthesia demonstrated mean tear production of 10.63 ± 2.57mm in the right eye and 10.68 ± 2.73 mm in the left eye, indicating borderline to mildly reduced tear secretion. Environmental conditions varied, with a mean temperature of 25.25 ± 11.00 °C (range: 10-40 °C) and a mean humidity of 50.27 ± 13.85% (range: 30-75%).

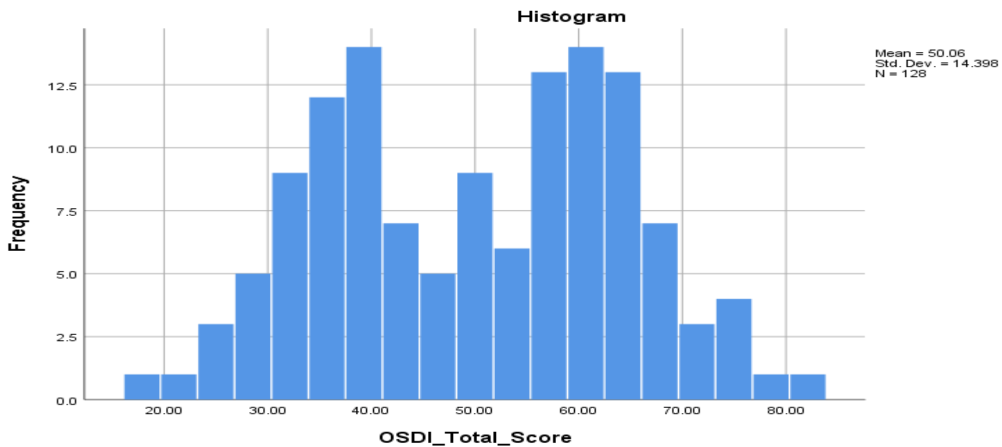

Figure 1: Distribution of Total OSDI scores

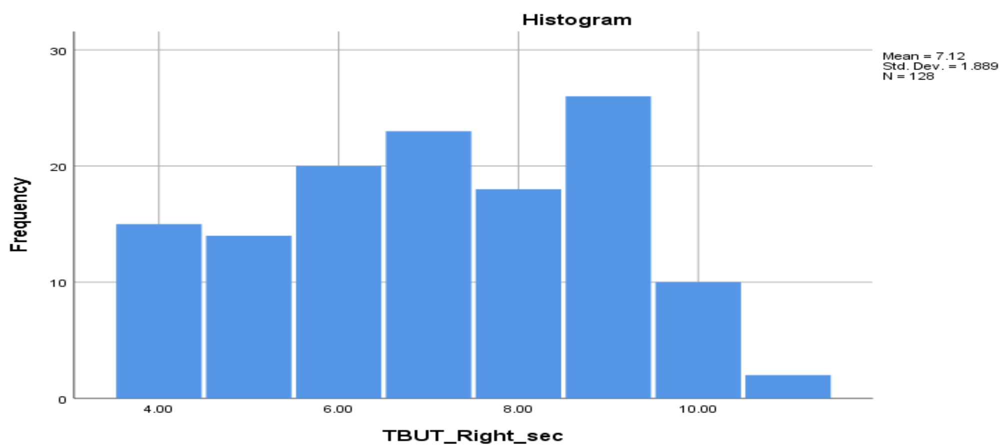

Figure 2: Tear breakup time (TBUT) in the right eye in seconds

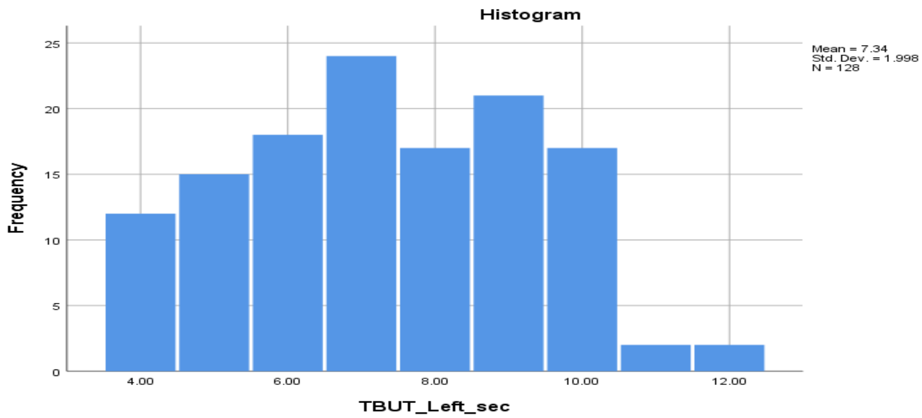

Figure 3: Tear breakup time (TBUT) in the left eye in seconds

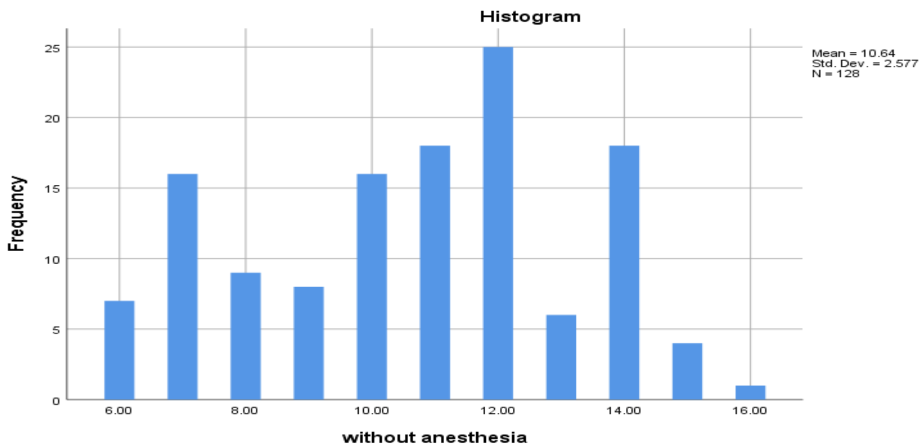

Figure 4: Schirmer test without anesthesia in the Right eye

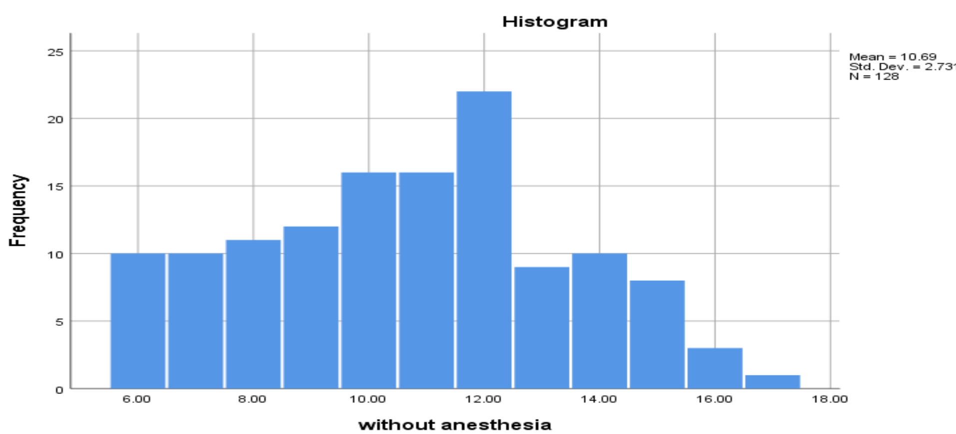

Figure 5: Schirmer test without anaesthesia in the Left eye

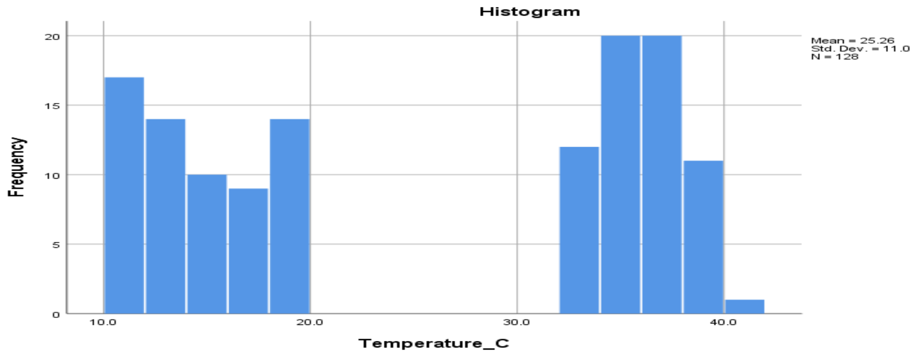

Figure 6: Distribution of Temperature according to weather conditions

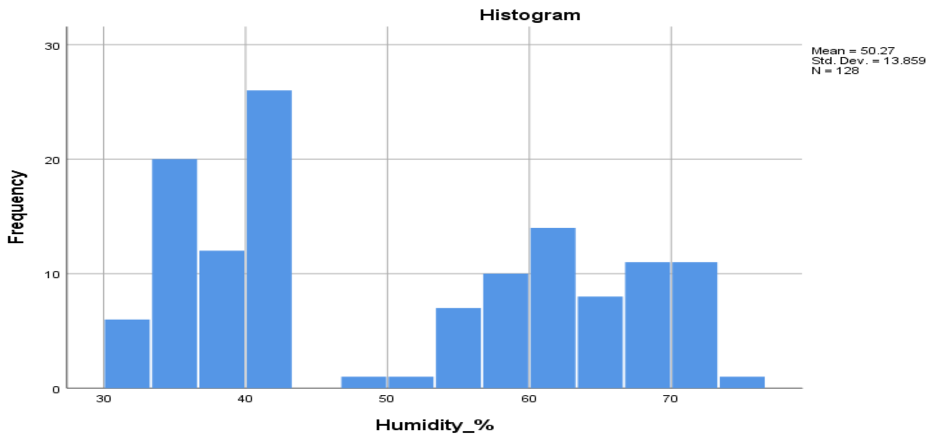

Figure 7: Distribution of Humidity according to the weather conditions

Table No. 2: Ocular Symptoms According to Winter Weather

Symptoms	Never	Rarely	Sometimes	Often	Always	P-value
Eyes Sensitive to light	0	13	22	23	6	<0.000
Gritty/Sandy Sensation	0	6	31	20	7	<0.000
Painful or Sore Eyes	0	11	19	25	9	<0.000
Blurred Vision	0	12	21	23	8	<0.000
Discomfort in Windy Conditions	0	10	23	22	9	<0.000
Discomfort in Low Humidity	0	6	20	21	17	<0.000
Discomfort in air-conditioned environments	0	10	23	23	8	<0.000

Table 2 shows that all participants experienced ocular symptoms during winter, with no reports of "never" for any symptom. Most symptoms, including light sensitivity, gritty sensation, painful eyes, and blurred vision, were commonly reported as "sometimes" or "often". Environmental factors such as wind, low humidity, and air conditioning also contributed notably to discomfort, with low humidity showing a higher frequency of "always" responses. All findings were statistically highly significant (p<0.000), indicating a strong association between winter conditions and increased ocular symptoms.

Table No. 3: Ocular Symptoms According to Summer Weather

Symptoms	Never	Rarely	Sometimes	Often	Always	P-value
Eyes Sensitive to light	12	19	28	5	60	<0.000
Gritty/Sandy Sensation	11	21	23	9	0	<0.000
Painful or Sore Eyes	8	23	19	14	0	<0.000
Blurred Vision	5	19	33	7	0	<0.000
Discomfort in Windy Conditions	12	20	24	8	0	<0.000
Discomfort in Low Humidity	9	18	29	8	0	<0.000
Discomfort in air-conditioned environments	8	25	22	9	0	<0.000

Table 3 shows that ocular symptoms during summer were generally less frequent, with some participants reporting no symptoms. Most complaints, including gritty sensation, pain, blurred vision, and environmental discomfort, were mainly reported as "rarely" or "sometimes". Only light sensitivity showed a higher frequency in the "always" category. Overall, symptoms were mild to moderate, and all associations were statistically significant (p<0.000).

Table No. 4: Comparison of tear film parameters and environmental conditions across seasons using the Mann-Whitney U test

Weather Conditions	N	TBUT-right Mean Rank	TBUT-left Mean Rank	Schirmer-right Mean Rank	Schirmer-left Mean Rank	Tempera ture -C	Humidity %	p-value
Winter	64	34.43	34.53	94.84	94.32	32.5	32.5	0
Summer	64	94.57	94.47	34.16	34.68	96.5	96.5	0
Total	128							0

This table compares tear film parameters between winter and summer seasons for a total of 128 observations (64 in each group). In winter, the mean ranks for tear breakup time (TBUT) are low (34.43) for the right eye and 34.53 for the left eye, while Schirmer test values are high (94.84 for the right eye and 94.32 for the left eye). In contrast, during summer, TBUT mean ranks are lower (34.16 right, 34.68 left). Environmental conditions also differ substantially between seasons, with winter showing lower temperature and humidity values (32.50 C and 32.50%) compared to summer (96.50 C and 96.50%).

Discussion

This study, conducted on 128 participants (64 in winter and 64 in summer), demonstrates a significant seasonal impact on dry eye disease. The mean OSDI score (50.05 ± 14.39) indicated moderate to severe symptoms, supported by reduced TBUT (<7 seconds) and borderline Schimer values (<10mm), reflecting compromised tear film stability and secretion. A clear seasonal variation was observed, with winter showing more severe symptoms. Most participants reported symptoms as "sometimes" or "often", particularly under humidity, windy conditions, and air-conditioned environments, whereas summer symptoms were generally milder, with higher frequencies of "rarely" and "sometimes". However, light sensitivity remained relatively prominent in summer. Objective parameters also varied significantly between seasons. TBUT was lower in winter, indicating reduced tear film stability, while Schirmer values were higher, possibly due to reflex tearing. Environmental factors, particularly lower temperature and humidity in winter, appear to play a key role in worsening dry eye. All comparisons showed high statistical significance ($P<0.000$), confirming a strong association between seasonal changes and both subjective and objective dry eye parameters. Overall, the findings suggest that dry eye disease is more severe in winter, emphasizing the importance of environmental factors and the need for season-specific management strategies. The findings of the present study are consistent with previous literature demonstrating a strong association between environmental factors and dry eye disease. Miami's DE visit prevalence was about four times more variable during the year than the US, although being around 10% lower than the national average (22.5% vs. 33.7%). The Miami cohort's peak DE symptom levels corresponded with the retrospective sample's peak DE prevalence, which happened in the spring and fall. With DE indications, a similar but less patterned was observed. Monthly variations were observed in DE symptoms and, to a lesser extent, signs. The most severe symptoms were seen in spring and fall, which coincided with the peak allergy season and weather variations, respectively. (18)

The result of present study coincides with a Japanese study by Ayaki Masahiko et al. that found considerable seasonal fluctuation in tear film characteristics. According to their research, tear meniscus values and tear break-up time were lowest in the winter, which was correlated with lower temperatures and humidity. Similarly, our research supported the idea that environmental factors exacerbate dry eye illness by demonstrating decreased TBUT and increased symptom intensity during the winter. (19) Additionally, their idea demonstrated a substantial association between TBUT, Schirmer test results, and tear meniscus values, which is in line with our finding that tear production and tear film stability vary significantly between seasons ($p<0.000$). Our results are in line with Song Jae-Ho et al.'s study, which showed that low humidity and temperature considerably exacerbate dry eye symptoms and signs, with higher symptom scores ($p=0.004$) and increased tear osmolarity ($p<0.001$). in a similar vein, our study showed a highly significant seasonal fluctuation ($p<0.000$) in symptom severity and TBUT throughout the winter. They also found the temperature had a greater impact than humidity, which is consistent with our findings. All things considered, these findings support the important role that environmental factors play in dry eye illness (20). Our findings are consistent with a study by Fiona Buckmaster et al., which showed that environmental humidity affects Schirmer test results, with lower relative humidity resulting in shorter wetting times ($p<0.05$). Additionally, they discovered that while individuals with moderate tear production can receive a misleading diagnosis under low humidity fluctuations. In a comparable direction, our investigation revealed substantial seasonal variations in Schirmer values ($p<0.000$), indicating that environmental factors, particularly low humidity in the winter, can affect assessments of tear production and diagnosis of dry eye. (21)

The dreams study, which comprised 535 participants from five different climates, showed that environmental factors have a substantial impact on dry eye symptoms. While decreased humidity was linked to worse corneal staining ($p<0.0038$), participants in Mediterranean climates had superior TBUT, higher Schirmer scores, and lower corneal staining ($p<0.0001$). Temperature, humidity, and dewpoint all showed positive correlations with TBUT, but NO_2 levels showed an inverse correlation ($p<0.0038$). these results support our findings which demonstrates decreased TBUT and tear production during the colder, drier winter months ($p<0.000$), underscoring the important role that humidity and environment play in the severity of dry eye. (22) According to the Norwegian study by Eidet et al., some objective indicators, such Schirmer I and tear meniscus height, exhibited seasonal change ($p<0.01$), but overall dry eye severity and OSDI ratings did not alter substantially across seasons. On the other hand, our investigation revealed stronger seasonal

impacts, with both subjective symptoms and objective tear film, characteristics (TBUT and Schirmer) being significantly worse in winter ($p<0.000$) climate variations may be the cause of these discrepancies, as Norway experiences more noticeable temperature and humidity shifts. However, both studies highlight how environmental factors might affect several clinical assessments of dry eye, highlighting the significance of taking seasonality into account when evaluating patients. (23) Humayun et al.'s investigation confirmed that subjective symptoms reflect objective tear film stability and decreased tear production by showing an inverse correlation between OSDI ratings and TBUT and Schirmer values ($p<0.000$) and higher OSDI scores in the winter, suggesting worse dry eye severity in colder, drier weather. The usefulness of integrating OSDI with TBUT and Schirmer testing for a thorough evaluation of dry eye is supported by both studies; however our results go beyond this by demonstrating that seasonal variation and environmental factors can also affect these parameters. (24)
According to Chang et al.'s multicenter study in Taiwan, corneal staining and the Schirmer test were less sensitive in identifying dry eye than short TBUT (≤5 sec) and elevated OSDI scores. Ina same vein, our research revealed considerably lower TBUT and higher OSDI scores in the winter ($p<0.000$), which suggests worse tear film stability and more severe symptoms. While both studies stress the value of TBUT and OSDI as trustworthy diagnostic instruments, our results also show that seasonal and environmental factors might worsen signs and symptoms of dry eye, emphasizing the necessity of taking climate into account when interpreting tear film data. (25)

Conclusion

According to this study's findings, tear film instability and dry eye symptoms were significantly worse in winter than in summer, with lower TBUT, reduced Schirmer values, and higher OSDI scores. Seasonal temperature and humidity clearly affect dry eye severity, highlighting the need to consider environmental conditions when assessing and managing patients.

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