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RESEARCH ARTICLE

Comparative Analysis of Tear Film Parameters in Patients With and Without Meibomian Gland Dysfunction: A Prospective Observational Study

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ABSTRACT

Background: Meibomian gland dysfunction (MGD) is recognized as the leading cause of evaporative dry eye disease and contributes significantly to tear film instability and ocular surface inflammation. Alterations in tear film parameters such as tear break-up time (TBUT), Schirmer's test values, Ocular Surface Disease Index (OSDI), lower tear meniscus height, and meibography findings are frequently observed in patients with MGD. Comparative assessment of these parameters in patients with and without MGD is essential for understanding disease severity and optimizing management strategies.

Aim: To compare tear film parameters between patients with and without meibomian gland dysfunction.

Materials and Methods: This prospective observational study was conducted in the Department of Ophthalmology, SCB Medical College and Hospital, Cuttack, Odisha, over a period of 1.5 years from September 2022 to May 2024. A total of 269 patients presenting with symptoms suggestive of dry eye disease were enrolled. Patients were divided into two groups according to meibomian gland status: MGD group (n=155) and Non-MGD group (n=114). Clinical evaluation included slit lamp examination, Schirmer's test, tear break-up time, fluorescein staining, OSDI scoring, blink rate, blink interval, lower tear meniscus height, Marx line score, and meibography. Statistical analysis was performed using R version 4.3.2. Continuous variables were expressed as mean ± standard deviation and compared using Student's t-test. Categorical variables were analyzed using Chi-square test. A p-value <0.05 was considered statistically significant.

Results: Patients with MGD demonstrated significantly lower TBUT values (8.12±2.11 s vs 11.89±1.84 s, p<0.001), lower Schirmer's test scores (12.41±3.84 mm vs 16.93±3.17 mm, p<0.001), and reduced lower tear meniscus height (0.24±0.08 mm vs 0.36±0.10 mm, p<0.001). OSDI scores and Marx line scores were significantly higher among MGD patients (58.61±11.27 vs 41.48±9.36; p<0.001 and 1.87±1.02 vs 0.71±0.74; p<0.001 respectively). Meibography grades and fluorescein staining severity were also significantly associated with MGD.

Conclusion: Meibomian gland dysfunction is associated with significant deterioration of tear film parameters and increased symptom severity. Early diagnosis and intervention are essential to prevent progression of ocular surface disease and improve quality of life.

Keywords: Meibomian gland dysfunction; Tear film; Dry eye disease; Tear break-up time; Schirmer's test; Ocular Surface Disease Index.

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Introduction

Dry eye disease (DED) is a multifactorial disorder of the ocular surface characterized by loss of tear film homeostasis accompanied by ocular symptoms, tear film instability, hyperosmolarity, inflammation, and neurosensory abnormalities. It represents one of the most common ophthalmic disorders encountered in clinical practice and significantly affects visual function and quality of life[1].

The tear film consists of lipid, aqueous, and mucin components that function synergistically to maintain ocular surface integrity, provide lubrication, and ensure optical clarity. Disruption of any of these layers results in tear film instability and ocular discomfort[2].

Meibomian glands are modified sebaceous glands located within the tarsal plates of the eyelids and are responsible for secretion of meibum, which forms the

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superficial lipid layer of the tear film. This lipid layer retards evaporation and maintains tear film stability[3].

Meibomian gland dysfunction (MGD) is defined as a chronic diffuse abnormality of the meibomian glands characterized by terminal duct obstruction and/or qualitative or quantitative changes in glandular secretion[4]. It is considered the major cause of evaporative dry eye disease and is responsible for nearly 70–90% of dry eye cases[5].

The pathophysiology of MGD involves hyperkeratinization of the ductal epithelium, stagnation of meibum, bacterial colonization, increased viscosity of glandular secretions, and progressive gland dropout. These changes ultimately result in tear film instability and ocular surface inflammation[6].

Several studies have demonstrated that MGD prevalence is higher among Asian populations, with reported prevalence ranging from 35% to 70%. Age, female gender, diabetes mellitus, prolonged digital device exposure, contact lens wear, and systemic diseases have been identified as important risk factors[7-8].

Patients with MGD commonly complain of burning sensation, foreign body sensation, redness, watering, photophobia, itching, fluctuating vision, and ocular fatigue. Symptoms often overlap with those of dry eye disease, making diagnosis challenging[9].

Assessment of tear film parameters including tear break-up time (TBUT), Schirmer's test, fluorescein staining, lower tear meniscus height, Ocular Surface Disease Index (OSDI), and meibography provides valuable information regarding disease severity and ocular surface health[10].

TBUT is one of the most widely used indicators of tear film stability and is frequently reduced in patients with MGD. Similarly, Schirmer's test evaluates aqueous tear production, whereas OSDI serves as a reliable measure of symptom severity[11].

Advances in infrared meibography have enabled direct visualization of gland morphology and assessment of gland dropout, facilitating early diagnosis and monitoring of disease progression[12].

Although the association between MGD and dry eye disease has been extensively documented, comparative evaluation of tear film parameters in patients with and without MGD remains limited in eastern India. Understanding these differences may facilitate earlier diagnosis and targeted therapeutic intervention.

Therefore, the present study was undertaken to compare tear film parameters among patients with and without meibomian gland dysfunction attending a tertiary care centre in Odisha.

Materials And Methods

Study Design

This was a hospital-based prospective observational study conducted to evaluate and compare tear film parameters among patients with and without meibomian gland dysfunction (MGD).

Study Setting

The study was carried out in the Department of Ophthalmology, Srirama Chandra Bhanja (SCB) Medical College and Hospital, Cuttack, Odisha, India.

Study Duration

The study was conducted over a period of 1.5 years from September 2022 to May 2024.

Study Population

Patients attending the ophthalmology outpatient department with symptoms suggestive of dry eye disease were screened and enrolled after obtaining written informed consent.

Sample Size

A total of 269 patients were included in the study.
Based on meibomian gland status, patients were divided into:

- **Group I (MGD group):** 155 patients (57.62%)
- **Group II (Non-MGD group):** 114 patients (42.38%)

Only one eye per patient was included in the analysis. The right eye was preferred; if the right eye failed to satisfy inclusion criteria, the left eye was considered.

Inclusion Criteria

- Age between 18 and 70 years.
- Presence of symptoms suggestive of dry eye disease including:
  - Ocular discomfort
  - Foreign body sensation
  - Burning sensation
  - Photophobia
  - Watering
  - Itching
  - Ocular fatigue

Exclusion Criteria

- Acute ocular infections.
- Keratoconjunctivitis and inflammatory ocular surface disorders unrelated to MGD.

- Previous ocular surgery.
- Alteration of lacrimal drainage pathways.
- Patients already receiving treatment for dry eye disease or MGD.
- Use of topical medications affecting ocular surface integrity.
- Contact lens wearers with active inflammatory disease.
- Patients unwilling to participate.

Clinical Evaluation

A detailed history regarding age, sex, occupation, duration of symptoms, and associated systemic illnesses was obtained. All subjects underwent complete ophthalmic examination.

Visual Acuity Assessment

Best corrected visual acuity (BCVA) was recorded using Snellen's chart.

Slit Lamp Biomicroscopy

Slit lamp examination was performed to assess:

- Lid margin abnormalities
- Meibomian gland orifices
- Capping
- Pouting
- Retroplacement
- Opaque secretions
- Tear film abnormalities
- Corneal changes

Schirmer's Test I

Schirmer's test was performed without topical anesthesia using Whatman filter paper No.41 measuring 5 × 35 mm.
Interpretation:

- 10 mm : Normal
- 6–10 mm : Mild-to-moderate deficiency
- ≤5 mm : Severe aqueous deficiency

Tear Break-Up Time (TBUT)

Following fluorescein instillation, the interval between complete blinking and appearance of the first dry spot was recorded.
Classification:

- 10 seconds : Normal
- 6–10 seconds : Borderline
- 2–5 seconds : Abnormal
- <2 seconds : Severe instability

Fluorescein Staining

Corneal staining was graded according to the National Eye Institute (NEI) Workshop grading system.
Grades:

- Grade 0 : No staining
- Grade 1 : Mild staining
- Grade 2 : Moderate staining
- Grade 3 : Severe staining

A score greater than 3 was considered abnormal.

Ocular Surface Disease Index (OSDI)

Symptoms were quantified using the 12-item Ocular Surface Disease Index questionnaire.
The score was calculated as:
OSDI=(Total Score)×25Number of Questions AnsweredOSDI=\frac{(Total\ Score)\times25}{Number\ of\ Questions\ Answered}OSDI=Number of Questions Answered(Total Score)×25
Interpretation:

- <12 : Normal
- 13–22 : Mild
- 23–32 : Moderate
- 33–100 : Severe

Meibography

Infrared meibography was performed to assess gland morphology.

Grading

Grade	Gland Loss
0	No loss
1	1–25%
2	26–50%
3	51–75%
4	>75%

Marx Line Scoring

The lower lid margin was stained with fluorescein dye and graded as:

Score	Description
0	Entirely conjunctival side
1	Touches meibomian orifices
2	Runs through all orifices
3	Marginal side involvement
4	Severe lid margin alteration

Blink Dynamics

The following parameters were recorded:

- Blink rate (blinks/minute)
- Blink interval (seconds)

Lower Tear Meniscus Height

Lower tear meniscus height (LTMH) was measured under slit lamp biomicroscopy and expressed in millimeters.

Outcome Measures

Primary Outcome Measures

Comparison between MGD and non-MGD groups regarding:

- Tear break-up time (TBUT)
- Schirmer's test values
- OSDI score
- Lower tear meniscus height
- Meibography grade

Secondary Outcome Measures

- Fluorescein staining score
- Marx line score
- Blink rate
- Blink interval
- Correlation between MGD severity and tear film parameters

Statistical Analysis

Data were analyzed using R software version 4.3.2. Continuous variables were expressed as mean ± standard deviation (SD), whereas categorical variables were presented as frequency (n) and percentage (%). Normality of data distribution was assessed using the Shapiro–Wilk test. Comparison of continuous variables between the MGD and non-MGD groups was performed using the independent Student's t-test, while the Mann–Whitney U test was applied when data were not normally distributed. Categorical variables were compared using the Chi-square test or Fisher's exact test, as appropriate. Correlation between meibomian gland dysfunction and various tear film parameters was evaluated using Pearson's correlation coefficient (r). A p-value less than 0.0**5** was considered statistically significant.

Ethical Considerations

Ethical approval was obtained from the Institutional Ethics Committee, SCB Medical College and Hospital, Cuttack.

Written informed consent was obtained from all participants before enrolment.

The study adhered to the principles outlined in the Declaration of Helsinki.

Results

A total of 269 patients with dry eye disease were included in the study. Based on meibomian gland status, 155 patients (57.62%) constituted the MGD group, whereas 114 patients (42.38%) comprised the non-MGD group. Comparative analysis revealed significant differences in tear film parameters and ocular surface characteristics between the two groups.

Demographic Characteristics

The mean age of the study population was 47.97 ± 11.64 years. The majority of participants belonged to the 41–50 years age group. Males constituted 51.3% of the study population, yielding a male-to-female ratio of approximately 1.06:1.

As shown in Table 1, patients aged 41–50 years represented the largest proportion of the study population (40.5%), followed by those aged 51–70 years (21.9%).

The gender distribution of the study population is presented in Table 2. Of the 269 patients, 138 (51.3%) were males and 131 (48.7%) were females.

The residential distribution of the patients is summarized in Table 3. Rural residents accounted for 54.6% of the study population.

Comparison of Tear Film Parameters Between MGD and Non-MGD Groups

The comparison of tear film parameters between the MGD and non-MGD groups is shown in Table 4. Patients with MGD had significantly lower Schirmer's test values, tear

Table 1: Age distribution of study participants (n=269)

Age group (years)	*Frequency*	*Percentage (%)*
17–30	46	17.1
31–40	55	20.4
41–50	109	40.5
51–70	59	21.9
Total	269	100

Table 2: Gender distribution of study participants

Gender	*Frequency*	*Percentage (%)*
Male	138	51.3
Female	131	48.7
Total	269	100

Table 3: Residential distribution of study population

Residence	*Frequency*	*Percentage (%)*
Urban	122	45.4
Rural	147	54.6
Total	269	100

Table 4: Comparison of tear film parameters between MGD and non-MGD groups

Parameter	*MGD (n=155) Mean ± SD*	*Non-MGD (n=114) Mean ± SD*	*t-value*	*p-value*
Schirmer's test (mm)	12.41 ± 3.84	16.93 ± 3.17	10.18	<0.001
TBUT (seconds)	8.12 ± 2.11	11.89 ± 1.84	15.28	<0.001
Blink rate (blinks/min)	16.18 ± 2.35	14.74 ± 2.06	5.12	<0.001
Blink interval (seconds)	4.79 ± 1.03	5.57 ± 1.02	6.01	<0.001
OSDI score	58.61 ± 11.27	41.48 ± 9.36	13.35	<0.001
Marx line score	1.87 ± 1.02	0.71 ± 0.74	10.12	<0.001
Lower tear meniscus height (mm)	0.24 ± 0.08	0.36 ± 0.10	11.14	<0.001

break-up time, blink interval, and lower tear meniscus height compared with patients without MGD. Conversely, OSDI scores, Marx line scores, and blink rate were significantly higher among subjects with MGD. These differences are graphically represented in Figure 1.

Visual Acuity Distribution

Visual acuity findings are summarized in Table 5. The most common visual acuity recorded was 20/20 (26.0%), followed by 20/40 (21.6%).

Meibomian Orifice Characteristics

The distribution of meibomian gland orifice abnormalities is shown in Table 6. Normal orifices were observed in 42.4% of subjects, while capping represented the most common abnormality (22.3%). Characteristic slit-lamp findings of MGD, including meibomian gland obstruction, matted eyelashes, seborrheic blepharitis, and corneal superficial vascularization are illustrated in Figure 2, whereas frothing over the lower lid margin suggestive of altered meibum secretion is demonstrated in Figure 3.

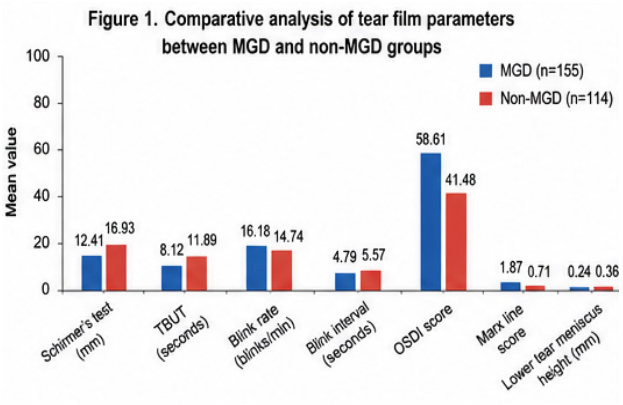

Figure 1: Comparative analysis of tear film parameters between MGD and non-MGD groups

Table 5: Distribution of visual acuity among study participants

Visual acuity	*Frequency*	*Percentage (%)*
20/20	70	26.0
20/30	49	18.2
20/40	58	21.6
20/50	46	17.1
20/60	46	17.1
Total	269	100

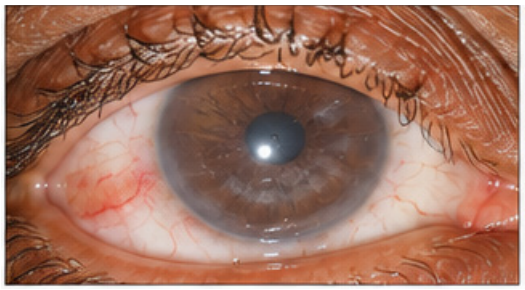

Figure 2: Slit-lamp photograph demonstrating upper eyelid meibomian gland obstruction with sago-grain appearance, matted eyelashes, seborrheic blepharitis, and corneal superficial vascularization suggestive of MGD-induced dry eye sequelae.

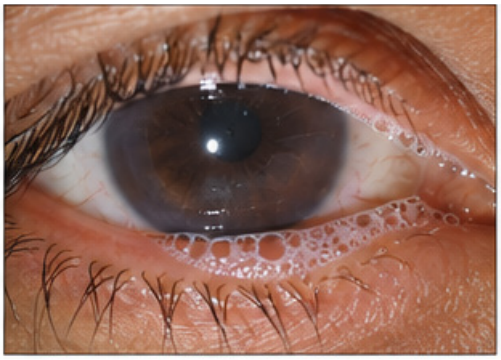

Figure 3: Frothing over the lower eyelid margin suggestive of meibomian gland dysfunction.

Table 6: Distribution of meibomian gland orifice characteristics

Meibomian orifice pattern	Frequency	Percentage (%)
Normal	114	42.4
Capping	60	22.3
Pouting	34	12.6
Retroplacement	27	10.0
Obliteration narrowing	18	6.7
Opaque orifices	16	5.9
Total	269	100

Fluorescein Staining Pattern

Corneal fluorescein staining findings are presented in Table 7. Mild staining was the most frequent finding (31.2%), followed by severe staining (26.4%). Representative fluorescein staining with punctate epithelial erosions and dry spots indicating tear film instability is depicted in Figure 6.

Symptom Severity According to OSDI Score

The mean OSDI score was 51.35 ± 12.97. As shown in Table 8, mild symptoms were the most commonly observed category (41.3%).

Meibography Findings

Meibography demonstrated varying degrees of gland dropout and atrophy. As shown in Table 9, Grade 1 was the most frequently encountered grade (30.9%). Infrared meibography demonstrating gland morphology and architecture is presented in Figure 4.

Marx Line Score

The mean Marx line score was 1.23 ± 1.03. Distribution of Marx line scores is shown in Table 10.

Schirmer's Test

The mean Schirmer's test value was 14.32 ± 4.04 mm. Normal tear secretion (>10 mm) was observed in 82.5% of subjects, as shown in Table 11. The Schirmer strip placement technique employed for tear secretion assessment is illustrated in Figure 5.

Tear Break-Up Time

The mean TBUT was 9.72 ± 2.42 seconds. Most patients had TBUT values between 6 and 10 seconds, as shown in Table 12. Fluorescein staining demonstrating tear film breakup and punctate epithelial erosions secondary to ocular surface dryness is shown in Figure 6.

Correlation Analysis

Pearson correlation analysis revealed significant associations between MGD and various ocular surface parameters (Table 13). Fluorescein staining demonstrated the strongest positive correlation with MGD (r = 0.62, p = 0.001), whereas meibomian orifice status showed a moderate negative correlation (r = –0.45, p = 0.002). OSDI score

Table 7: Distribution of fluorescein staining grades

Fluorescein staining	*Frequency*	*Percentage (%)*
Grade 0 (No staining)	53	19.7
Grade 1 (Mild)	84	31.2
Grade 2 (Moderate)	61	22.7
Grade 3 (Severe)	71	26.4
Total	269	100

Table 8: Distribution according to OSDI score

OSDI category	*Frequency*	*Percentage (%)*
Normal (<12)	62	23.0
Mild (13–22)	111	41.3
Moderate (23–32)	62	23.0
Severe (33–100)	34	12.6
Total	269	100

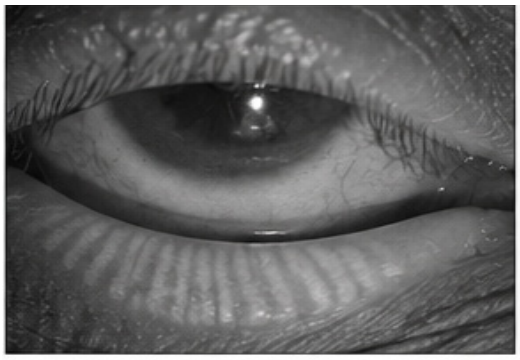

Figure 4: Infrared meibography demonstrating meibomian glands of the right eye.

Table 9: Distribution of meibography grades

Meibography grade	*Frequency*	*Percentage (%)*
Grade 0	44	16.4
Grade 1	83	30.9
Grade 2	45	16.7
Grade 3	53	19.7
Grade 4	44	16.4
Total	269	100

Table 10: Distribution of Marx line score

Marx line score	*Frequency*	*Percentage (%)*
0	73	27.1
1	54	20.1
2	42	15.6
3	50	18.6
4	50	18.6
Total	269	100

Table 11: Distribution according to Schirmer's test

Schirmer's score	*Frequency*	*Percentage (%)*
>10 mm	222	82.5
6–10 mm	35	13.0
≤5 mm	12	4.5
Total	269	100

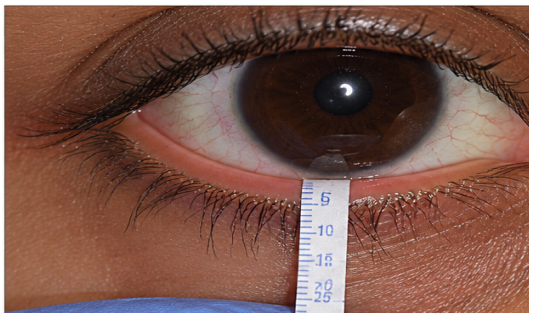

Figure 5: Schirmer strip inserted at the junction of the middle and outer third of the lower eyelid for assessment of aqueous tear secretion

Table 12: Distribution according to tear break-up time

TBUT	*Frequency*	*Percentage (%)*
>10 seconds	128	47.6
6–10 seconds	119	44.2
2–5 seconds	15	5.6
<2 seconds	8	3.0
Total	269	100

also exhibited a significant positive correlation with MGD ($r = 0.51$, $p = 0.001$).

Overall, the present study demonstrated that patients with meibomian gland dysfunction had significantly impaired tear film stability, reduced tear secretion, increased symptom severity, and greater ocular surface abnormalities compared with individuals without MGD, highlighting the critical role of meibomian gland dysfunction in the pathogenesis and progression of dry eye disease.

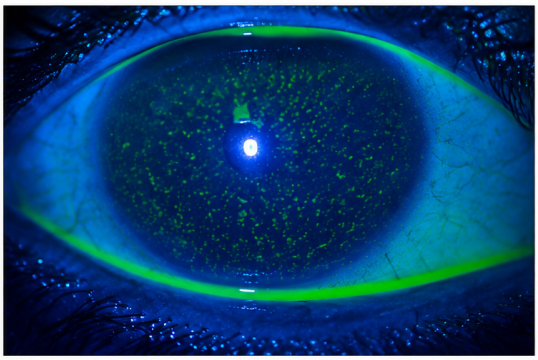

Figure 6: Fluorescein-stained ocular surface showing dry spots and punctate epithelial erosions suggestive of tear film instability

Table 13: Correlation between MGD and various tear film parameters

Parameter	*Correlation coefficient (r)*	*p-value*
Meibomian orifices	-0.45	0.002
Fluorescein staining	0.62	0.001
Meibography grade	-0.37	0.004
Schirmer's test (mm)	-0.28	0.022
TBUT (seconds)	-0.34	0.011
Blink rate (blinks/min)	0.15	0.247
Blink interval (seconds)	-0.18	0.189
OSDI score	0.51	0.001
Marx line score	0.29	0.039
Lower tear meniscus height	-0.26	0.058

The clinical and imaging findings further support the observed functional and structural changes associated with meibomian gland dysfunction.

Discussion

Meibomian gland dysfunction (MGD) is currently recognized as the leading cause of evaporative dry eye disease and represents one of the most important contributors to ocular surface instability. The present prospective observational study compared tear film parameters in patients with and without MGD and demonstrated significant differences in objective and subjective measures of ocular surface function. The findings emphasize the impact of meibomian gland abnormalities on tear film homeostasis and support the importance of early diagnosis and intervention.

The mean age of the study population was 47.97±11.64 years, with the highest proportion of patients belonging to the 41–50 years age group. Age-related changes in meibomian gland morphology and function have been extensively described. Non-contact meibography studies have shown progressive gland dropout and reduced meibum secretion with advancing age, resulting in increased tear evaporation and ocular surface damage. Age-related meibomian gland changes are considered one of the principal mechanisms underlying evaporative dry eye disease[13].[13]

A slight male predominance was observed in the present study. However, previous epidemiological investigations have reported variable gender distributions, suggesting that hormonal influences, environmental exposure, occupational factors, and geographic variations all contribute to disease occurrence. Large population-based studies have demonstrated that MGD affects both sexes and its prevalence increases with age[14].

The prevalence of MGD among patients with dry eye disease in the present study was 57.62%, which is comparable to reports from Asian populations. Studies conducted in Japan, Singapore, and other East Asian countries have consistently demonstrated a high prevalence of MGD ranging from 46% to 70%. Ethnic predisposition, environmental conditions, and climatic factors may account for these variations[15].

One of the most important findings of the present study was the significantly lower tear break-up time (TBUT) observed in patients with MGD compared with those without MGD (8.12±2.11 seconds versus 11.89±1.84 seconds; $p<0.001$). Tear film instability is considered the hallmark of MGD-induced evaporative dry eye. Obstruction of gland ducts and qualitative changes in meibum lead to lipid layer deficiency, accelerated tear evaporation, and early tear film breakup. The International Workshop on Meibomian Gland Dysfunction highlighted shortened TBUT as one of the characteristic features of MGD[16]. Similar findings were reported by Shimazaki et al., who demonstrated significantly reduced TBUT values in patients with obstructive meibomian gland disease[17].

Schirmer's test values were significantly lower among patients with MGD than in the non-MGD group. Although MGD primarily affects the lipid component of the tear film, chronic ocular surface inflammation and tear hyperosmolarity may eventually compromise aqueous secretion. Previous studies have shown that evaporative dry eye and aqueous-deficient dry eye frequently coexist, resulting in a vicious cycle of inflammation and tear film instability[18].

Patients with MGD in the present study exhibited significantly higher Ocular Surface Disease Index (OSDI) scores than subjects without MGD. Increased symptom severity among patients with MGD has been consistently demonstrated in previous studies. The OSDI questionnaire has been validated as a reliable and reproducible tool for assessing dry eye symptoms and their effect on visual function and quality of life[19]. A strong relationship between symptom severity and tear film abnormalities has also been described, supporting the clinical utility of OSDI in evaluating disease burden[20].

Lower tear meniscus height was significantly reduced among patients with MGD in the present study. Reduced tear meniscus height reflects diminished tear volume and impaired ocular surface lubrication. Imaging studies have shown that chronic evaporative loss and increased tear turnover eventually reduce tear reservoir capacity, thereby aggravating ocular surface symptoms[21].

Marx line scores were significantly higher among patients with MGD. The Marx line has been recognized as a useful marker of lid margin pathology and meibomian gland dysfunction. Displacement and thickening of the Marx line are associated with meibomian gland obstruction and chronic inflammation. Previous investigators demonstrated that abnormal Marx line scores correlate well with the severity of gland dysfunction and lid margin disease[22].

Meibography findings in the present study demonstrated varying degrees of gland dropout, with Grade 1 changes being the most common abnormality. Infrared meibography has revolutionized the assessment of meibomian gland morphology by allowing direct visualization of gland architecture. Structural loss of glands has been shown to correlate closely with disease severity and symptom burden. Studies using non-contact meibography have confirmed that gland dropout increases progressively with advancing age and chronic inflammation[23].

Corneal fluorescein staining exhibited the strongest positive correlation with MGD severity ($r=0.62$, $p=0.001$). Increased staining indicates epithelial damage resulting from tear film instability, hyperosmolar stress, and ocular surface inflammation. Experimental and clinical studies have demonstrated that meibomian gland dysfunction induces inflammatory changes that lead to epithelial disruption and punctate keratopathy[24].

Correlation analysis in the present study showed that worsening MGD was associated with lower Schirmer's test values, shorter TBUT, higher OSDI scores, increased Marx line scores, and reduced tear meniscus height. Similar associations have been reported in studies evaluating the

relationship between gland morphology and functional tear film parameters. Structural loss of meibomian glands has been shown to correlate significantly with tear film instability and symptom severity[25].

Blink dynamics represent an important component of ocular surface physiology. Although only weak correlations were observed between blink parameters and MGD severity in the present study, altered blinking patterns may represent compensatory responses to increased tear evaporation. Reduced blink interval and increased blink frequency have been reported in patients with ocular surface disease and are considered adaptive mechanisms aimed at maintaining tear film integrity[26].

More than half of the study population in the present study had diabetes mellitus. Diabetes has emerged as an important risk factor for ocular surface disorders because chronic hyperglycemia affects corneal innervation, lacrimal gland function, and meibomian gland secretion. Diabetic patients have been shown to exhibit higher frequencies of gland dropout and greater tear film instability compared with non-diabetic individuals[27].

The findings of the present study are in agreement with the Tear Film and Ocular Surface Society Dry Eye Workshop II (TFOS DEWS II), which emphasized that disruption of tear film homeostasis forms the central mechanism underlying dry eye disease. Hyperosmolarity, inflammation, and neurosensory abnormalities interact in a self-perpetuating cycle that ultimately leads to progressive ocular surface damage[28].

Overall, the present study demonstrates that patients with meibomian gland dysfunction exhibit significantly impaired tear film stability, reduced tear secretion, increased symptom burden, and more severe ocular surface abnormalities compared with individuals without MGD. These observations highlight the importance of comprehensive evaluation of tear film parameters and reinforce the need for early recognition and appropriate management of meibomian gland dysfunction to preserve ocular surface integrity and improve patients' quality of life.

Conclusion

The present study demonstrated that patients with meibomian gland dysfunction had significantly impaired tear film parameters compared with individuals without MGD. Reduced tear break-up time, Schirmer's test values, and lower tear meniscus height, along with higher OSDI and Marx line scores, indicated greater tear film instability and ocular surface involvement among MGD patients. These findings emphasize the importance of comprehensive evaluation and early diagnosis of MGD to prevent progression of dry eye disease and improve patients' quality of life.

Limitations

The study was conducted at a single center with a relatively small sample size and lacked long-term follow-up. Advanced investigations such as tear osmolarity and inflammatory biomarkers were not assessed.

Recommendations

Routine assessment of meibomian gland function should be incorporated in patients with dry eye symptoms. Larger multicentric prospective studies with advanced diagnostic modalities are recommended to further elucidate the relationship between MGD and tear film abnormalities.

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