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ORIGINAL ARTICLE

Evaluation of dry eye disease and meibomian gland dysfunction with meibography in type 2 diabetes

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Abstract

Purpose: To identify the relationship between dry eye disease (DED) and type 2 diabetes mellitus (DM) and also to explore whether meibomian gland dysfunction was a significant predictor for the development of DED.

Methods: This prospective cross-sectional study involved patients with type 2 DM and age- and sex-matched healthy controls. All of the participants underwent dry eye tests, including meibomian gland function. Based on the DEW II diagnostic method, which included both symptom and objective tests, diabetic patients were grouped as DED+ and DED-. All findings were compared, and predictive factors for DED were identified.

Results: Of the 76 patients with type 2 DM, 47 (61.8%) were diagnosed as DED. In patients with type 2 DM, there was a significant increase in the ocular surface disease index, corneal surface staining, eyelid margin abnormality, and meibomian gland dysfunction, and a significant decrease in tear break-up time and Schirmer I test ($p<0.05$). Measurements of dry eye tests were more severe with the presence of DED ($p<0.05$). Duration of DM and HbA1c level were significantly correlated with ocular surface and meibomian gland dysfunction parameters ($p<0.05$). Duration of DM ($p=0.001$), HbA1c level ($p=0.005$), and presence of diabetic peripheral neuropathy ($p<0.001$) were found to be independent and significant predictors of DED.

Conclusion: Type 2 DM was found to be significantly associated with ocular surface abnormalities, including meibomian gland dysfunction. Furthermore, duration of DM, HbA1c level, and diabetic peripheral neuropathy were predictive factors of DED in type 2 DM.

Keywords: Diabetes mellitus, diabetic peripheral neuropathy, dry eye, meibomian gland, ocular surface.

Dmellitus (DM) is a chronic multisystem disorder, and glaucoma, retinopathy, keratopathy, and cataract are common ocular complications arising from DM.[1] In recent years, it has been suggested that DM affects every structure of the ocular surface, particularly the cornea.[2] The main pathophysiology of DM consists of chronic hyperglycemia, impaired insulin secretion, and corneal nerve damage, which lead to alterations in the tear film and ocular surface of patients.[1] Furthermore, tear film dysfunction, diabetic neuropathy, abnormal tear dynamics, and lacrimal functional unit dysfunction have also been considered additive factors in the development of DED in patients with DM.[1-8]

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Meibomian glands are large sebaceous glands embedded in the upper and lower eyelids that form a superficial lipid layer, preventing the evaporation of tears. Meibomian gland dysfunction results in evaporative dry eye by causing lipid layer breakdown.[4] A significant complication of DM is meibomian gland dysfunction and its associated evaporative DED. Insulin deficiency and high glucose exposure cause morphologic alterations and a progressive loss of human meibomian gland epithelial cells. However, the association between DED and meibomian gland dysfunction in type 2 DM remains unclear.

We hypothesized that meibomian gland dysfunction is one of the missing links between type 2 DM and DED and that meibomian gland dysfunction might be critical in the pathogenesis of DED in type 2 DM. Non-contact meibography is a non-invasive technique that allows for the analysis of the morphologic characteristics of meibomian glands and the correlation between the clinical quantification of meibomian gland dysfunction grade and area loss in the upper and lower eyelids.

Therefore, the aim of this study was to identify the relationship between DED and type 2 DM and to explore whether meibomian gland dysfunction is a significant predictor for the development of DED.

Materials and Methods

This prospective cross-sectional observational study included patients with type 2 DM in the Department of Ophthalmology of Izmir Atatürk Training and Research Hospital between January 2023 and March 2024. Patients with previous intraocular surgery, systemic diseases, history of corneal disease, retinopathy, eyelid abnormalities such as entropion, ectropion, or retraction, contact lens wear, glaucoma, smoking, and current use of medications other than insulin and topical PAs were excluded from the study. Age- and sex-matched healthy controls were also recruited with the same exclusion criteria. Informed consent was obtained from all patients. The study followed the principles of the Declaration of Helsinki and was approved by the İzmir Katip Celebi University Non-Interventional Clinical Studies Ethics Committee (162/2022). The prevalence of DED among the type 2 diabetic population in Türkiye was previously reported to be between 25% and 34%, as determined by the Schirmer test (<5 mm).[14,15] Power analysis calculated that a sample size of at least 36 per group was needed to achieve a power of 80% (α=0.05) for the given situation. Thus, our sample size (76 per group) provides more than 90% power at α=0.05.

Demographic and clinical characteristics of the patients were recorded, including age, duration of DM, gender, body mass index, and HbA1c level. Patients with type 2 DM and control subjects completed an OSDI questionnaire and underwent a detailed ophthalmic examination by a single observer in the following order: Schirmer I test, TBUT, corneal surface staining, eyelid margin abnormality score, meibomian expression, and meibography score. All measurements were performed during the same visit without a waiting period between tests. The right eye of each participant was used for analyses.

The OSDI questionnaire is a 12-item tool that assesses the frequency at which patients experience dry eye symptoms.[8] The 12 items are graded on a scale of 0–4, where 0 denotes none; 1, some; 2, half; 3, most; and 4, all of the time. The total OSDI score was calculated using the following formula:

Total OSDI score=(Sum of scores for all questions answered×100Total number of questions answered×4)\text{Total OSDI score} = \left(\frac{\text{Sum of scores for all questions answered} \times 100}{\text{Total number of questions answered} \times 4} \right)Total OSDI score=(Total number of questions answered×4Sum of scores for all questions answered×100)

The Schirmer I test was performed without anesthesia by placing standardized Schirmer strips on the lateral one-third of the lower lid for 5 minutes and then measuring the amount of tears that wetted the paper (in millimeters). TBUT was measured by introducing fluorescein strips moistened with a drop of normal saline into the conjunctival sac. Subjects were instructed to blink several times, and the interval between the last complete blink and the appearance of the first corneal black spot in the stained tear film was recorded. The mean of three measurements was used.

Corneal surface staining was performed to evaluate and grade superficial punctate keratopathy.[9] Corneal fluorescein staining was carried out by placing a drop of sterile saline on a sterile fluorescein strip. Cobalt blue light was then used to detect any corneal epithelial defects. Corneal fluorescein staining was graded on a scale of 0 to 3: Grade 0 (none), Grade 1 (<1/3), Grade 2 (1/3–2/3), and Grade 3 (>2/3). The density was graded as 0 (none), 1 (sparse density), 2 (moderate density), and 3 (high density and overlapped lesions).

The eyelid margin abnormality score ranged from 0 to 4 based on the presence of the following parameters: irregular lid margin, plugging of meibomian gland orifices, vascular engorgement, and a shift in the mucocutaneous junction.[10]

Meibomian gland expression was assessed by applying firm digital pressure over the middle and nasal one-third of the upper and lower eyelids to express the glands and release their oils.[11] Expression was graded as follows: Grade 0, clear meibum easily expressed; Grade 1, cloudy meibum expressed with mild pressure; Grade 2, cloudy meibum expressed with more than moderate pressure; and Grade 3, meibum not expressed even with hard pressure.

The morphology of meibomian glands was evaluated using non-contact meibography (Sirius; Costruzione Strumenti Oftalmici, Florence, Italy) by everting each eyelid.[12] Meibomian gland loss was calculated as the proportion of the area of gland dropout relative to the total area of the tarsal plate. The meiboscore was classified on a four-grade scale: Grade 0 (no loss), Grade 1 (loss <25%), Grade 2 (loss between 25%–50%), Grade 3 (loss between 50%–75%), and Grade 4 (loss >75%) (Fig. 1). The total meiboscore was calculated by summing the values for the upper and lower eyelids.

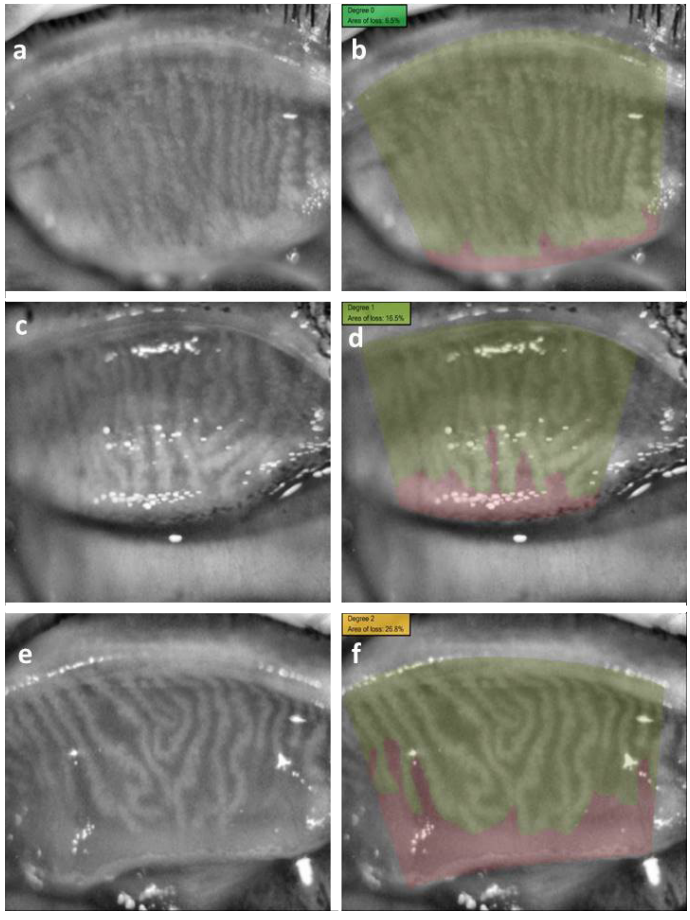

Fig. 1. Meibography of a normal eye in control group **(a, b)** and meibography of eyes affected by dry eye disease in type 2 diabetic group showing meibomian gland loss of eyelids: Grade 1 (meibomian gland area loss <25%) **(c, d)**, Grade 2 (meibomian gland area loss between 25% - 50%) **(e, f)**.

The diagnosis of DED was confirmed based on the DEW II methodology, which requires an OSDI score ≥13 and a positive result in one of the following tests: Schirmer I test ≤5 mm, positive corneal surface staining, or TBUT <10 seconds.[13] The diagnosis of DPN was based on neurologic examination for the presence of symptoms and signs of diabetic polyneuropathy and abnormal nerve conduction velocity test using an electromyography instrument (Nihon Cohden, Inc., Tokyo, Japan).

Statistical Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences version 25 (IBM SPSS Inc., Chicago, IL, USA). Categorical variables were presented as frequencies and percentages, while continuous variables were expressed as mean±standard deviation. ANOVA followed by post-hoc Tukey's test was used to determine significant differences in means. Comparisons of categorical data were assessed using the chi-square test.

The correlations between age, duration of diabetes, HbA1c level, body mass index, and ocular surface measurements in the diabetic group were analyzed using Pearson's correlation coefficient. Multivariate regression analysis was conducted to identify predictive factors for dry eye disease in diabetic patients. Associations were expressed as odds ratios (OR) with corresponding confidence intervals (CI) to describe the precision of the estimates.

The 95% CI was constructed to indicate a 95% probability that the population parameter lies between the evaluated lower and upper CI values. A p-value <0.05 was considered statistically significant.

Results

Seventy-six type 2 diabetic patients and 76 control subjects were recruited into the study. DED was diagnosed in 47 (61.8%) diabetic patients. Clinical characteristics and ocular findings of the groups are shown in Table 1. Clinical characteristics, including gender and body mass index, were not significantly different among the study groups ($p>0.05$). The age of the patients ($p=0.025$), HbA1c level ($p=0.001$), duration of DM ($p=0.001$), and presence of diabetic peripheral neuropathy ($p<0.001$) were significantly higher in the diabetic DED+ group compared to the control and diabetic DED- groups (Table 1).

Compared to the control and diabetic DED- groups, TBUT ($p<0.001$ and $p<0.001$ for control and DED- groups, respectively) and Schirmer I test ($p<0.001$ and $p<0.001$ for control and DED- groups, respectively) were significantly

Table 1. Clinical characteristics and ocular findings in control subjects and in patients with type 2 DM according to the presence (DED+) or absence (DED-) of DED

	Control (n=76)	Type 2 DM (n=76)		p*
		DED+ (n=47)	DED- (n=29)	
Age (years), mean±SD (range)	48.1±14.4 (29-67)	51.6±13.8 (33-67)	46.3±11.6 (29-65)	0.025
Gender (Male/Female)	42/34 (1.23)	26/21 (1.24)	16/13 (1.23)	0.937
HbA1c (%), mean±SD (range)		7.65±0.42 (6.91-8.23)	7.01±0.38 (6.58-7.79)	0.001
BMI (kg/m^2), mean±SD (range)	24.4±4.1 (18.7-29.5)	25.8±4.5 (19.1-31.8)	25.2±4.2 (19.6-30.7)	0.313
Duration of DM (years), mean±SD (range)		14.9±5.4 (5-24)	9.3±4.8 (4-22)	0.001
Diabetic peripheral neuropathy (n, %)		27 (57.4)	5 (17.2)	<0.001
OSDI score, mean±SD (range)	18.4±13.6 (4.7-39.7)	45.9±18.1 (17.8-76.1)	20.2±15.7 (4.9-64.3)	<0.001
Tear break-up time (s), mean±SD (range)	9.8±4.8 (3.8-18.6)	4.5±2.3 (2.1-12.7)	9.3±4.4 (3.6-15.3)	<0.001
Schirmer's I test (mm), mean±SD (range)	14.3±8.4 (4.7-26.7)	6.6±3.8 (2.4-13.2)	13.3±7.4 (4.8-25.3)	<0.001
Cornea surface staining score				
Area (range), mean±SD (range)	0.36±0.4 (0-3)	0.82±0.8 (0-3)	0.38±0.5 (0-3)	0.034
Density (range), mean±SD (range)	0.33±0.4 (0-3)	0.72±0.7 (0-3)	0.37±0.5 (0-3)	0.029
Eyelid margin abnormality score, mean±SD (range)	0.68±0.6 (0-4)	2.6±1.3 (0-4)	0.9±0.8 (0-4)	<0.001
Irregular eyelid margin	7 (9.2)	20 (42.6)	4 (13.8)	<0.001
Vascular engorgement	9 (11.8)	17 (36.2)	4 (13.8)	<0.001
Plugged meibomian gland orifices	7 (9.2)	19 (40.4)	3 (10.3)	<0.001
Shift in the mucocutaneous junction	10 (13.2)	21 (44.7)	5 (17.2)	<0.001
Meibomian expression				
Upper eyelid, mean±SD (range)	1.14±1.0 (0-3)	1.94±1.3 (0-3)	1.18±1.1 (0-3)	<0.001
Lower eyelid, mean±SD (range)	1.12±1.0 (0-3)	1.90±1.3 (0-3)	1.17±1.1 (0-3)	<0.001
Meibography score				
Upper eyelid, mean±SD (range)	1.13±1.1 (0-3)	1.92±1.0 (0-4)	1.19±1.0 (0-3)	<0.001
Lower eyelid, mean±SD (range)	1.10±0.9 (0-3)	1.91±1.0 (0-4)	1.16±0.9 (0-4)	<0.001
Total, mean±SD (range)	2.23±1.8 (0-6)	3.84±2.2 (0-8)	2.35±1.8 (0-7)	<0.001
Area of meibomian gland loss				
Upper eyelid, mean±SD (range)	22.57±11.4 (0-71)	47.4±25.1 (0-95)	26.1±14.8 (0-81)	<0.001
Lower eyelid, mean±SD (range)	25.65±12.1 (0-68)	46.9±22.7 (0-98)	29.4±15.2 (0-84)	<0.001
Total, mean±SD (range)	49.3±25.8 (0-139)	94.4±29.3 (0-193)	55.5±28.3 (0-165)	<0.001

*p-value obtained by ANOVA test. BMI: body mass index; DED: dry eye disease; DM: diabetes mellitus; OSDI: ocular surface disease index.

lower, while OSDI score (p<0.001 and p<0.001 for control and DED- groups, respectively), corneal staining area (p<0.001 and p<0.001 for control and DED- groups, respectively), and corneal staining density (p<0.001 and p<0.001 for control and DED- groups, respectively) were significantly higher in the diabetic DED+ group (Table 2). No significant differences were observed between the control and diabetic DED- groups in terms of OSDI score (p=0.233), TBUT (p=0.704), Schirmer I test (p=0.439), corneal staining area (p=0.208), and corneal staining density (p=0.348) (Table 2).

The eyelid margin abnormality score was higher in the diabetic DED+ group compared to the control and diabetic DED- groups (p<0.001 and p<0.001 for control and DED- groups, respectively) (Table 2). Irregular eyelid margin (p<0.001), vascular engorgement (p<0.001), plugged meibomian gland orifices (p<0.001), and a shift in the mucocutaneous junction (p<0.001) observed in the diabetic DED+ group were significantly higher than in the control and diabetic DED- groups (Table 1).

When meibomian gland function was compared in the diabetic DED+ group versus the control and diabetic DED- groups, significantly higher values were observed for upper (p<0.001 and p<0.001 for control and DED- groups, respectively) and lower meibomian expression (p<0.001 and p<0.001 for control and DED- groups, respectively); upper (p<0.001 and p<0.001 for control and DED- groups, respectively), lower (p<0.001 and p=0.001 for control

Table 2. Comparison of ocular surface measurements and meibomian gland changes according to study groups.

	Control vs DED+ p-value	Control vs DED- p-value	DED+ vs DED- p-value
OSDI score	<0.001	0.233	<0.001
Tear break-up time (s)	<0.001	0.704	<0.001
Schirmer's I test (mm)	<0.001	0.439	<0.001
Cornea surface staining score			
Area (range)	<0.001	0.208	<0.001
Density (range)	<0.001	0.348	<0.001
Eyelid margin abnormality score	<0.001	0.107	<0.001
Meibomian expression			
Upper eyelid	<0.001	0.369	<0.001
Lower eyelid	<0.001	0.255	<0.001
Meibography score			
Upper eyelid	<0.001	0.148	<0.001
Lower eyelid	<0.001	0.163	0.001
Total	<0.001	0.204	<0.001
Area of meibomian gland loss			
Upper eyelid	<0.001	0.314	<0.001
Lower eyelid	<0.001	0.258	<0.001
Total	<0.001	0.183	<0.001

*p-value obtained by Tukey's post hoc test. DPN, diabetic peripheral neuropathy; OSDI: ocular surface disease index.

and DED- groups, respectively), and total meibography scores (p<0.001 and p<0.001 for control and DED- groups, respectively); and upper (p<0.001 and p<0.001 for control and DED- groups, respectively), lower (p<0.001 and p<0.001 for control and DED- groups, respectively), and total area of meibomian gland loss (p<0.001 and p<0.001 for control and DED- groups, respectively) (Table 2). No significant differences in meibomian gland function were noted between the control and diabetic DED- groups (p>0.05) (Table 2).

In our study, Pearson's correlation analysis showed that the duration of type 2 DM and HbA1c level were positively and significantly correlated with OSDI score, corneal surface staining, eyelid margin abnormality score, meibography score, and area of meibomian gland loss (p<0.05) (Table 3). TBUT and Schirmer I test measurements showed significant negative correlations with the duration of DM and HbA1c level (p<0.05) (Table 3).

To determine factors associated with the occurrence of DED in type 2 DM, we compared diabetic patients with and without confirmed DED. The results demonstrated that the duration of DM (p=0.001), HbA1c level (p=0.001), and presence of DPN (p<0.001) were significantly associated with DED (Table 4). Multivariate logistic regression analysis revealed that the duration of DM (OR: 1.36, 95% CI: 0.53–3.52, p=0.001), HbA1c level (OR: 1.24, 95% CI: 1.10–1.38, p=0.001), and presence of diabetic peripheral neuropathy (OR: 2.03, 95% CI: 1.47–5.02, p<0.001) were independent and significant predictors of DED in type 2 DM (Table 4).

Discussion

Our study demonstrated that type 2 DM has significant adverse effects on ocular surface health compared to age- and sex-matched healthy control subjects. We also found that patients with poor glycemic control, longer duration of DM, and peripheral neuropathy were at increased risk for severe DED.

In this study, we observed that patients with type 2 DM exhibited decreased Schirmer I test scores and TBUT, along with increased OSDI scores, corneal surface staining, meibography scores, lid margin abnormality scores, and meibomian expression. Previous studies have reported that diabetic patients are at significant risk of developing ocular surface changes.[5-8,16] Naik et al. observed significantly lower TBUT measurements in patients with DM compared to those without DM.[17] In the study by Naik et al., more than half (55%) of diabetic patients exhibited varying degrees of DED severity.[17] In a study by Wu et al., the average Schirmer I test, TBUT, and tear lipid layer thickness values in diabetic groups were significantly lower (p<0.001) than those in the control group.[4] Koca et al. reported higher mean OSDI and Oxford staining scores in diabetic patients compared to

Table 3. The correlation between ocular surface and meibography measurements with age, DM duration, serum HbA1c level and body mass index.

	Age		Duration of DM		HbA1c level		Body mass index	
	r	p	r	p	r	p	r	p
OSDI score	0.355	0.104	0.404	0.026	0.355	0.001	0.167	0.312
TBUT	-0.122	0.235	-0.374	<0.001	-0.545	<0.001	-0.218	0.106
Schirmer's I Test	-0.451	0.073	-0.641	<0.001	-0.603	<0.001	-0.227	0.365
Corneal surface staining score								
Area (range)	0.109	0.524	0.485	0.001	0.339	0.001	0.369	0.408
Density (range)	0.214	0.447	0.549	<0.001	0.194	0.019	0.401	0.086
Eyelid margin abnormality score	0.301	0.116	0.717	<0.001	0.471	<0.001	0.194	0.688
Meibomian expression								
Upper eyelid	0.357	0.163	0.475	0.044	0.606	<0.001	0.185	0.547
Lower eyelid	0.289	0.219	0.458	0.001	0.511	<0.001	0.167	0.324
Meibography score								
Upper eyelid	0.317	0.081	0.687	<0.001	0.615	<0.001	0.209	0.144
Lower eyelid	0.282	0.178	0.573	<0.001	0.401	0.005	0.175	0.097
Total	0.281	0.163	0.471	0.001	0.613	<0.001	0.163	0.269
Area of meibomian gland loss								
Upper eyelid	0.313	0.266	0.576	<0.001	0.583	<0.001	0.158	0.154
Lower eyelid	0.282	0.357	0.508	<0.001	0.565	<0.001	0.236	0.231
Total	0.339	0.152	0.470	0.001	0.674	<0.001	0.249	0.394

DM: diabetes mellitus; OSDI: ocular surface disease index; TBUT: tear break up time.

Table 4. Univariate and multivariate regression analysis of the factors associated with the occurrence of DED in Type 2 DM.

Factors	OR (95% CI)*	p*	OR (95% CI)**	p**
Age	1.39 (1.09-4.23)	0.016	1.24 (0.96 - 3.18)	0.132
Duration of DM	1.49 (1.09-3.94)	0.001	1.36 (1.13-3.52)	0.001
Gender (Male)	1.18 (0.84-2.71)	0.875	1.14 (0.61 - 2.82)	0.784
HbA1c	1.22 (1.05-1.46)	0.001	1.24 (1.10 - 1.38)	0.005
Diabetic peripheral neuropathy	1.83 (1.34-4.73)	<0.001	2.03 (1.47 - 5.02)	<0.001

*Univariate analysis; **multivariate analysis; CI, confidence interval; DED, dry eye disease; DM, diabetes mellitus; OR, odds ratio.

controls, but the differences were not statistically significant.[18] Furthermore, Cousen et al. demonstrated significantly lower Schirmer test results and reduced corneal sensitivity in diabetic patients compared with control subjects.[8] Collectively, these findings suggest that type 2 DM causes ocular surface irregularities that lead to DED.

The main proposed mechanism for the development of DED in type 2 diabetic patients is blood glucose level dysregulation. Fluctuations in blood glucose levels may alter corneal hydration control, reducing corneal sensitivity and lacrimal gland secretory function.[1,2] Various functional, metabolic, and structural abnormalities in the cornea and conjunctiva of diabetic patients are also considered important in the pathophysiology of DED.[19] Enlargement of the epithelial basement membrane, deterioration of basal cell adhesion, and a reduction in goblet cell numbers may contribute to tear film instability and a shortened TBUT.[20]

Our study found that the duration of type 2 DM was significantly associated with ocular surface parameters. There was a gradual tendency for DED development as the duration of DM increased. In the study by Naik et al., DED was observed in 68% of patients with a diabetes duration of >10 years.[17] We also found that the incidence of DED was higher among patients with poor glycemic control. A significant correlation was observed between HbA1c levels and abnormalities in ocular surface parameters, including meibomian gland dysfunction. Similarly, Naik et al. reported DED in 67% of patients with HbA1c levels >8%, compared to only 7% of patients with HbA1c levels <6.5%.[17]

Another significant and independent predictor of DED in type 2 diabetic patients was the presence of peripheral neuropathy. Our study revealed that the severity of dry eye symptoms and findings increased with the presence of diabetic peripheral neuropathy. A type 2 diabetic patient with peripheral neuropathy is two times more likely to develop DED than a patient without neuropathy.

Diabetic peripheral neuropathy is the most common complication of DM, estimated to affect about one-third of diabetic patients.[3] While ocular surface disorders have been extensively studied in diabetic patients, the association between DED and diabetic peripheral neuropathy has only recently gained attention.[5,6,16] Several studies have established a correlation between DED and diabetic peripheral neuropathy.[5,6,16] In a study by Achtsidis et al., Schirmer I test, TBUT, and corneal sensitivity values were worse in patients with diabetic peripheral neuropathy compared to those without neuropathy and control subjects.[16] DeMill et al. demonstrated increased tear osmolarity in diabetic patients with peripheral neuropathy, although no statistically significant differences were observed between groups (with and without diabetic peripheral neuropathy) in Schirmer test, OSDI, TBUT, and corneal sensitivity values.[5] In contrast, Najafi et al. did not find a significant correlation between DED and diabetic peripheral neuropathy.[21]

A unique aspect of our study was the evaluation of meibomian gland dysfunction. Davidson et al. investigated early changes in corneal sensitivity and innervation in a rat model of type 1 diabetes.[22] They reported pathological changes in corneal innervation, including irregular nerve beading distribution, axonal degeneration, and alterations in Schwann cell basal lamina thickness.[22] These findings may provide a basis for the meibomian gland dysfunction observed in patients with diabetic peripheral neuropathy.

Although the connection between type 2 DM and DED has been proposed, methods for predicting DED remain unclear across studies. Our findings reveal meibomian gland dysfunction as a causal factor in DED abnormalities. The dry eye condition in type 2 DM appears to originate primarily from impaired meibomian gland function. Furthermore, our investigation provides compelling evidence that DM duration, HbA1c level, and diabetic peripheral neuropathy are significant and independent predictors of DED in type 2 DM.

The high prevalence of DED and meibomian gland dysfunction (MGD) in type 2 diabetic patients has clinical implications for practitioners. Type 2 diabetic patients with longer disease duration, poor glycemic control, and peripheral neuropathy require prompt referral for dry eye assessments, including meibomian gland function evaluation and subsequent treatment, to prevent further deterioration of ocular and general health conditions. Environmental modifications and lifestyle changes can delay progression or reverse ocular surface damage in these patients.

Study Limitations

The main limitation of our study is the inability to account for all confounding factors due to the multifactorial origin of meibomian gland dysfunction. Another limitation is the lack of a control group with DED (nondiabetic DED+), which prevented comparisons between diabetic and nondiabetic DED+ groups. Therefore, the interpretation of results should be approached cautiously. Future studies including diabetic DED+ and nondiabetic DED+ groups could provide further insights into whether meibomian gland dysfunction is a significant predictor for DED development in diabetic patients. However, our study assessed not only morphological changes in meibomian glands but also meibomian gland expressibility and eyelid margin characteristics.

Conclusion

In conclusion, type 2 DM is significantly associated with DED. Our findings suggest that the duration of DM and HbA1c level are strongly correlated with ocular surface abnormalities, including meibomian gland dysfunction. Therefore, DED should be carefully considered in type 2 diabetic patients with longer disease duration, poor glycemic control, and peripheral neuropathy.

Ethics Committee Approval: The study followed the principles of the Declaration of Helsinki and was approved by the İzmir Katip Celebi University Non-Interventional Clinical Studies Ethics Committee (162/2022). (date: 24.03.2022).

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