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ORIGINAL RESEARCH

Investigating Mask-Associated Dry Eye and Contributing Factors in Healthcare Providers

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Purpose: To evaluate mask-associated dry eye among healthcare providers and assess the impact of glasses, contact lenses, and mask types on ocular surface parameters.

Patients and Methods: This prospective study included 50 healthcare providers who wore face masks throughout the day and 10 control subjects who did not. Ocular surface assessments were conducted in the morning and after a full workday. Assessments included the Ocular Surface Disease Index (OSDI), tear osmolarity, tear breakup time (TBUT), ocular staining score, Schirmer I test, and LipiView™ interferometer parameters: lipid layer thickness (LLT), Meibomian gland dropout (MGd), incomplete/complete blinks, and partial blinking rate (PBR).

Results: Fifty healthcare providers (mean age 39.83 ± 12.3 years) and 10 controls (mean age 29.40 ± 14.43 years) were included. Mask use averaged 7.15 ± 1.15 hours daily. Mask use was associated with a significant increase in OSDI scores compared to controls (mean change 4.50 ± 10.17 vs −1.00 ± 1.94; P = 0.041) and a larger decrease in TBUT in the right eye (mean change −1.65 ± 3.37 vs 0.30 ± 1.57; P = 0.008) and left eye (mean change −1.40 ± 2.91 vs −1.20 ± 1.93; P = 0.046). No significant changes were observed in tear osmolarity, LLT, MGd, or Schirmer I results. Glasses were correlated with a smaller decrease in TBUT in the right eye (r^2 = 0.085, P = 0.044) and left eye (r^2 = 0.125, P = 0.013).

Conclusion: Mask use is associated with increased OSDI scores and decreased TBUT, potentially worsening dry eye disease. Glasses may offer some protection, but further research is needed to fully address mask-associated dry eye.

Keywords: dry eye, tear break-up time, tear film

Introduction

Face masks have become an ordinary and necessary measure to reduce the spread of infectious diseases, including COVID-19. Despite the decline of the pandemic's initial peak, face masks are widely used, especially in healthcare settings. Many institutions strongly recommend masking,[1,2] whereas some healthcare facilities still require masks indoors.[3–5] This continued use of masks is particularly relevant as we see periodic rises in COVID-19 cases, underscoring the likelihood that masking remains a standard practice in healthcare settings.

The widespread adoption of face masks has particularly impacted healthcare providers. Throughout the pandemic, many have seen an increase in ocular complaints such as red eye, irritation, tearing, and eye discomfort symptoms among mask users, particularly those who require prolonged face mask use throughout the day.[6,7] This rise in dry eye symptoms associated with mask use has been termed "mask-associated dry eye" (MADE). Although several studies have investigated MADE, there has been a lack of consensus regarding its clinical correlation to dry eye disease. For example, while some studies report worsening dry eye parameters such as TBUT and Schirmer I results,[8,9] others have shown no significant changes.[10,11] These conflicting findings suggest that MADE is likely a multifactorial phenomenon, potentially influenced by factors such as the type of face mask and pre-existing dry eye conditions, though these variables are not always fully accounted for in the analysis. Our study aims to contribute to the current literature by evaluating the impact

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of MADE on subjective symptoms and objective ocular surface parameters, while considering potential confounding factors to provide a clearer understanding of the effects of face mask use on dry eye disease.

The possible mechanism of mask-associated dry eye is not yet clear. One hypothesis is that airflow leaking from the upper edge of a mask may affect tear film stability, ocular symptoms, corneal temperature, and conjunctival blood flow, contributing to MADE.[6] Previous studies have found increased dry eye symptoms and ocular surface irritation with powered air-purifying respirators, chemical protection hoods, and continuous positive airway pressure devices that cause air regurgitation in the nasolacrimal system.[12–14] In a similar mechanism, face masks may change the average direction of exhaled air from the nose and mouth and increase airflow upward across an individual's eyes.[15] This upward air movement may accelerate tear film evaporation and may cause dry eye.[6] Another possible mechanism is when individuals tape along the nasal edge to seal or hold masks in place. The tape can adhere to the skin and interfere with eyelid movements, preventing complete blinks and possibly causing lagophthalmos.[16]

Given the ongoing necessity of mask use and the lack of a comprehensive understanding of MADE, our study aims to evaluate the impact of prolonged mask use on dry eye symptoms and ocular surface health among ophthalmic healthcare providers and compare it with a control match group. While accounting for potential confounders, we focus on providing a clearer and more comprehensive understanding of the factors contributing to MADE and its effects on ocular health.

Materials and Methods

Patients

This prospective, single-center study was conducted at the Shiley Eye Institute, Viterbi Family Department of Ophthalmology at the University of California, San Diego (UCSD), during the COVID-19 pandemic in 2022, when face masks were mandated for all healthcare professionals in the facilities.

Fifty ophthalmic healthcare providers from Shiley Eye Institute were recruited. All participants wore face masks in compliance with hospital policy. At the time of the study, UCSD was operating under "red" tier restrictions, always requiring masks. Inclusion criteria for the study were well-fitting mask use throughout the day and being 18 years or older at the time of enrollment. Data was collected for 100 eyes from the 50 participants. Ten individuals whose work did not require wearing a mask were recruited as controls, with data available for 20 eyes of the 10 participants.

The study was approved by the University of California, San Diego Institutional Review Board (IRB) and Human Research Protections Program. It remained Health Information Portability and Accountability Act (HIPAA) compliant and adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from all subjects after an explanation of the study's nature and possible consequences.

Demographic information, such as age and sex, and ocular history were collected. The type of mask used and the use of glasses or contact lenses were also recorded.

Ocular Surface Assessments

Ocular surface assessments were conducted twice daily: in the morning and after a full day of mask use for the healthcare providers and in the morning and after a full workday for controls. Ocular surface assessments were performed in the following order: The Ocular Surface Disease Index (OSDI) questionnaire (score 0–100 with higher scores representing more significant disability),[17] the LipiView interferometer, tear osmolarity, fluorescein tear breakup time test (TBUT), ocular staining score graded by the National Eye Institute Scale, Schirmer I tear test with local anesthesia.[18]

The LipiView interferometer performed automated measurements of the lipid layer thickness of the tear film (LLT), the dynamic lower lid Meibomian imaging, and the partial blinking rate (PBR) (Figure 1). A single examiner evaluated the lower lid Meibomian dropout (MGd).[19] A 20-second video documented the interference pattern of the tear film for every patient. Analysis of this video resulted in measuring interferometric color units (ICUs) for each eye recorded. One ICU approximately reflects 1 nm of the LLT.[20] The number of partial and total blinking events was recorded, and the PBR was calculated as the ratio of partial blinks to total blinks.

The ocular surface was stained with fluorescein, and the participant was instructed to blink afterward. TBUT and corneal fluorescein staining were observed through a slit lamp with a cobalt blue filter. The TBUT was evaluated three

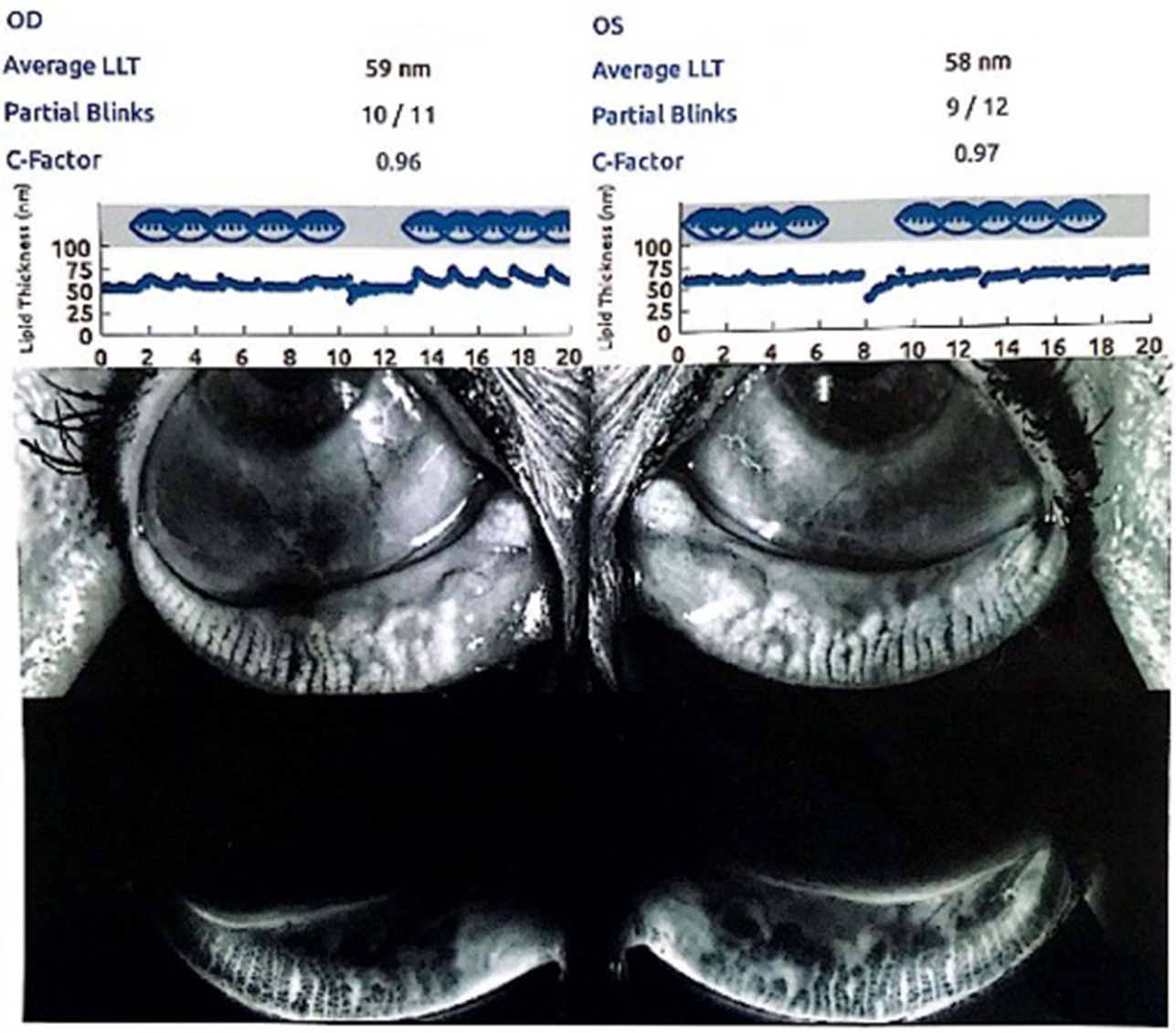

Figure 1 A LipiView summary report output of one representative participant. Participant with 10/11 partial blinks in the right eye and 9/12 partial blinks in the left eye. Mild to moderate Meibomian gland dropout is noted in both eyes. C-Factor represents the reliability of the measurements.
Abbreviation: LLT, lipid layer thickness.

times for each eye by a single, experienced examiner. The average time was then recorded.[21] Fluorescein staining was graded 0–3 based on the National Eye Institute (NEI) scale as previously described.[22,23] Fluorescein staining grade was determined by first assessing the right eye, followed immediately by the left eye. The examiner applied fluorescein to both eyes simultaneously, then promptly evaluated the right eyes staining grade, followed by the left eye's assessment.

Tear osmolarity was assessed by a clinical osmometer (TearLab Corporation, San Diego, CA, USA). Fifty nanoliter tear samples were collected from the lower lid tear meniscus of both eyes. A positive result was defined as larger than 308 mOsm/L in either eye or an interocular difference >8 mOsm/L.[24]

The Schirmer I test was performed by folding the Schirmer paper strip (Whatman No.41) at the notch and hooking the folded end over the temporal one-third of the lower lid margin. One drop of 0.5% proparacaine hydrochloride was instilled as topical anesthesia (Alcon laboratories Inc., s.a. Alcon-Couvreur n.v). After instillation, excess fluid was gently blotted from the lower fornix using a clean, lint-free tissue. A 3-minute waiting period was observed to allow the anesthetic to take effect while minimizing residual fluid on the ocular surface. The Schirmer strip was then inserted, and the length of wetting from the notch was measured after 5 minutes to obtain the final score.[21]

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Statistical Analysis

Both nonparametric and parametric statistical tests were used to assess the differences in the dry eye parameters. For the OSDI questionnaire scores, the Wilcoxon signed-rank test was applied to compare morning and afternoon OSDI scores within each group (mask-wearing and control), and the Mann–Whitney *U*-test was used to compare the difference between the morning and afternoon ODSI scores between the two groups.

For all other dry eye parameters, such as LLT, tear osmolarity, MGd, PBR, number of complete, incomplete, and total blinks, TBUT, ocular staining score, and the Schirmer I tear test, paired t-tests were used to compare morning and afternoon values within each group. Independent t-tests were conducted to assess the differences in changes from morning to afternoon between the mask-wearing and control groups. All statistical tests were two-tailed, and a p-value of less than 0.05 was considered statistically significant.

Finally, linear regression analysis was conducted to assess the effect of glasses, history of dry eye, punctal plugs, contacts, and different types of mask used on the dry eye parameters that were found statistically significant to determine these factors affected the measurements. Data analysis was performed using JPM software (SAS Institute Inc., Cary, NC).

Results

For the mask-wearing group, fifty participants (mean age 39.83 ± 12.3, 13 males, 37 females) were recruited. All participants were healthcare providers at Shiley Eye Institute with a mean of 7.15 ± 1.15 hours of mask use (range 5.00 to 9.50 hours). Forty-six participants used surgical masks, 2 used KN95 masks, and 2 used N95 masks. Of the 46 participants who used surgical masks, 8 participants wore two surgical masks. Nineteen participants used glasses, and 9 participants used contact lenses. Eleven participants had a previous diagnosis of dry eye, and 5 participants had punctal plugs. The control group consisted of 10 participants (mean age 29.40 ± 14.43 years; 6 males, 4 females) who did not wear masks. In the control group, 3 participants wore glasses. No control participants had a history of dry eye, punctal plugs, or wore contacts. Control participants underwent dry eye measurements after a full workday, with a mean interval of 6.28 ± 1.22 hours between measurements (range 5.00 to 8.33 hours).

Ocular surface assessment results are summarized in Table 1 and Table 2. In the control group, most dry eye parameters did not change significantly between morning and afternoon measurements. However, the PBR in the right eye significantly increased from the morning (mean 0.56 ± 0.26) to the end of the day (mean 0.70 ± 0.28; P = 0.008), and the number of incomplete blinks in the right eye also increased significantly from morning (mean 4.90 ± 3.66) to the end of the day (mean 6.30 ± 3.80; P = 0.045). No significant differences were observed in OSDI, tear osmolarity, LLT, MGd,

Table 1 Ocular Surface Assessments in the Control Group – Comparison Between Morning and Post-Workday Measurements

	Morning (mean ± SD)	End of Work Day (mean ± SD)	P
OSDI	4.50 ± 4.65	3.50 ± 4.30	0.250
Tear film osmolarity, mOsm/L			
OD	303.10 ± 10.64	302.40 ± 8.25	0.860
OS	302.40 ± 8.25	302.50 ± 6.55	0.078
LLT, nm			
OD	60.90 ± 21.04	57.90 ± 12.05	0.555
OS	63.90 ± 24.27	60.90 ± 18.58	0.612

(*Continued*)

Table 1 (Continued).

	Morning (mean ± SD)	End of Work Day (mean ± SD)	P
MGd, %			
OD	9.00 ± 21.58	9.50 ± 21.40	0.343
OS	9.50 ± 24.99	9.58 ± 25.14	0.343
PBR			
OD	0.56 ± 0.26	0.70 ± 0.28	**0.008****
OS	0.65 ± 0.33	0.14 ± 0.14	0.883
Number of incomplete blinks			
OD	4.90 ± 3.67	6.30 ± 3.80	**0.045***
OS	5.90 ± 3.84	6.00 ± 5.10	0.917
Number of complete blinks			
OD	3.50 ± 2.51	2.50 ± 2.42	0.280
OS	3.10 ± 3.14	2.80 ± 2.94	0.822
Number of total blinks			
OD	8.30 ± 4.72	8.80 ± 2.86	0.651
OS	8.90 ± 4.93	8.80 ± 3.85	0.891
TBUT, s			
OD	10.10 ± 1.20	10.70 ± 1.64	0.260
OS	11.00 ± 2.21	12.70 ± 1.89	0.152
Fluorescein staining grade			
OD	0.10 ± 0.32	0.20 ± 0.42	0.343
OS	0.20 ± 0.42	0.10 ± 0.32	0.343
Schirmer test, mm			
OD	24.10 ± 9.15	22.70 ± 10.35	0.617
OS	21.90 ± 9.18	22.40 ± 8.51	0.854

Notes: Number of incomplete blinks, number of incomplete blinks per 20s as measured by LipiView. Number of complete blinks, number of total blinks minus incomplete blinks. Number of total blinks, number of total blinks per 20s as measured by LipiView. *$P < 0.05$; **$P < 0.01$, significant values are bolded.

PBR in the left eye, number of incomplete blinks in the left eye, number of complete blinks, total blinks per 20 seconds, TBUT, fluorescein staining grade, or Schirmer I test (Table 1).

In the mask-wearing group, the morning OSDI score (mean 21.07 ± 20.36) significantly increased after mask use at the end of the day (mean 25.56 ± 22.29; $P = 0.004$). Morning TBUT in the right eye (mean 11.46 ± 2.92) significantly decreased after mask use at the end of the day (mean 9.81 ± 3.03; $P = 0.001$). Morning TBUT in the left eye (mean 11.34 ± 3.02) significantly decreased after mask use at the end of the day (mean 9.94 ± 3.39; $P = 0.002$). Morning Schirmer I test in the right eye (mean 14.23 ± 6.86) significantly decreased after mask use at the end of the day (mean 11.78 ± 5.45; $P = 0.008$). Tear osmolarity, LLT, MGd, PBR, number of incomplete blinks, number of complete blinks, total blinks per

Table 2 Ocular Surface Assessments in the Mask-Wearing Group – Comparison Between Morning and Post-Workday Measurements

	Morning (mean ± SD)	After Mask Use (mean ± SD)	P
OSDI	21.07 ± 20.36	25.56 ± 22.29	**0.004****
Tear film osmolarity, mOsm/L			
OD	293.07 ± 10.00	290.54 ± 9.28	0.181
OS	291.78 ± 12.18	292.78 ± 11.05	0.673
LLT, nm			
OD	56.16 ± 22.39	56.22 ± 21.52	0.981
OS	59.14 ± 22.55	60.55 ± 22.12	0.668
MGd, %			
OD	29.69 ± 27.12	28.65 ± 27.77	0.485
OS	32.98 ± 27.1	32.45 ± 26.02	0.743
PBR			
OD	0.56 ± 0.34	0.55 ± 0.32	0.749
OS	0.55 ± 0.34	0.58 ± 0.35	0.603
Number of incomplete blinks			
OD	5.90 ± 4.23	6.53 ± 4.78	0.224
OS	5.92 ± 4.35	6.69 ± 5.08	0.269
Number of complete blinks			
OD	5.10 ± 5.03	5.49 ± 4.93	0.461
OS	5.53 ± 6.08	4.59 ± 4.56	0.252
Number of total blinks			
OD	10.86 ± 5.00	11.67 ± 5.30	0.170
OS	11.27 ± 6.02	11.35 ± 5.02	0.895
TBUT, s			
OD	11.46 ± 2.92	9.81 ± 3.03	**0.001****
OS	11.33 ± 3.02	9.94 ± 3.39	**0.002****
Fluorescein staining grade			
OD	0.27 ± 0.49	0.31 ± 0.51	0.159
OS	0.33 ± 0.52	0.38 ± 0.53	0.485
Schirmer test, mm			
OD	14.23 ± 6.86	11.78 ± 5.45	**0.008****
OS	13.13 ± 6.21	11.56 ± 6.29	0.082

Notes: Number of incomplete blinks, number of incomplete blinks per 20s as measured by LipiView. Number of complete blinks, number of total blinks minus incomplete blinks. Number of total blinks, number of total blinks per 20s as measured by LipiView. **$P < 0.01$, significant values are bolded.

20 seconds, fluorescein staining grade, and Schirmer I test of the left eye showed no significant difference between morning and after mask use (Table 2).

When comparing the differences between morning and afternoon measurements, the mask-wearing groups showed significantly greater changes compared to the control group in several parameters. The mean change in OSDI from morning to afternoon was significantly greater in the mask-wearing group (mean 4.50 ± 10.17) compared to the control group (mean −1.00 ± 1.94; P = 0.041). Similarly, the changes in TBUT for both eyes were significantly lower in the mask-wearing group (right eye: mean −1.65 ± 3.37; left eye: mean −1.40 ± 2.91) compared to the control group (right eye: mean 0.30 ± 1.57; P=0.008, left eye: mean −1.20 ± 1.93; P=0.046) Interestingly, while the change in right eye PBR from morning to afternoon was significantly lower in the mask-wearing group (mean −0.01 ± 0.26) compared to the control group (mean 0.14 ± 0.14, P = 0.013), the mean change in the mask wearing group was almost negligible at −0.01. (Table 3).

A linear regression analysis was performed to explore potential correlations between the use of glasses, contact lenses, punctal plugs, pre-existing dry eye, and different types of masks on dry eye parameters, demonstrating significant differences between the mask-wearing and control groups (OSDI, TBUT). In the control group, no significant correlations were observed between PBR in the right eye, the number of incomplete blinks in the right eye, and the use of glasses. In the mask-wearing group, no significant correlations were found between the OSDI score and the Schirmer I test in the right eye with any of the abovementioned factors. However, a positive correlation was observed between TBUT and the use of glasses in both the right eye (r^2 = 0.085, P = 0.044) and the left eye (r^2 = 0.125, P = 0.013) (Table 4).

To further explore these findings, a model excluding the 19 mask-wearing participants and 3 control participants who wore glasses was compared to the original model to evaluate the mean change of TBUT between the right and the left eyes in the mask-wearing and control groups. After excluding participants who wore glasses, the mean change of TBUT

Table 3 Comparative Analysis of Ocular Surface Parameter Changes Between Control and Mask-Wearing Groups

	Mean Change in Control Group	Mean Change in Mask-Wearing Group	P value
OSDI	−1.00 ± 1.94	4.49 ± 10.17	**0.041***
Tear film osmolarity, mOsm/L			
OD	−0.6 ± 10.47	−2.52 ± 12.58	0.619
OS	−5.7 ± 9.08	0.89 ± 14.02	0.078
LLT, nm			
OD	−3 ± 15.46	0.61 ± 18.29	0.566
OS	−3 ± 18.06	1.41 ± 22.86	0.479
MGd, %			
OD	0.5 ± 1.58	−1.04 ± 10.26	0.328
OS	−0.5 ± 1.58	−0.52 ± 10.93	0.990
PBR			
OD	0.14 ± 0.14	−0.01 ± 0.26	0.013*
OS	−0.22 ± 0.44	0.03 ± 0.36	0.758
Number of incomplete blinks			
OD	1.4 ± 1.90	0.63 ± 3.60	0.353
OS	0.10 ± 2.96	0.77 ± 4.86	0.645

(*Continued*)

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Table 3 (Continued).

	Mean Change in Control Group	Mean Change in Mask-Wearing Group	P value
Number of complete blinks			
OD	−1.00 ± 2.75	0.39 ± 3.66	0.202
OS	−0.30 ± 4.08	−0.94 ± 5.67	0.663
Number of total blinks			
OD	0.5 ± 3.37	0.82 ± 4.12	0.815
OS	−0.10 ± 2.23	0.08 ± 4.31	0.986
TBUT, s			
OD	0.60 ± 1.58	− 1.65 ± 3.37	**0.003****
OS	1.70 ± 3.43	−1.40 ± 2.91	**0.021***
Fluorescein staining grade			
OD	0.1 ± 0.32	0.04 ± 0.20	0.706
OS	−0.1 ± 0.32	0.04 ± 0.41	0.240
Schirmer test, mm			
OD	−1.40 ± 8.55	−2.45 ± 6.01	0.720
OS	0.50 ± 8.37	−1.58 ± 6.09	0.764

Notes: Number of incomplete blinks, number of incomplete blinks per 20s as measured by LipiView. Number of complete blinks, number of total blinks minus incomplete blinks. Number of total blinks, number of total blinks per 20s as measured by LipiView. *$P < 0.05$; **$P < 0.01$, significant values are bolded.

Table 4 Linear Regression Analysis of the Impact of Various Factors on OSDI and TBUT

Factor	OSDI		TBUT Change OD		TBUT Change OS	
	R^2	P-value	R^2	P-value	R^2	P-value
Glasses	0.006	0.597	0.085	**0.044***	0.125	**0.013***
Contacts	0.001	0.798	0.002	0.762	0.072	0.065
Dry Eye	0.002	0.752	0.031	0.231	0.081	0.051
N95 Mask	0.012	0.456	0.043	0.156	0.043	0.229

Notes: *$P < 0.05$, significant values are bolded.

in the right eye remained significantly lower in the mask-wearing group (mean −0.81 ± 1.96) compared to the control group (1.70 ± 3.26, P = 0.049). Mean change of TBUT in the left eye also remained significantly lower in the mask-wearing group (mean −0.48 ± 2.58) compared to the control group (1.70 ± 3.36, P = 0.44).

Discussion

As current trends in COVID-19 cases suggest the ongoing need for masks, particularly in healthcare and other high-risk settings, MADE is poised to affect a significant portion of the population, especially among those who wear masks for prolonged periods, such as healthcare providers. MADE has been recognized for exacerbating dry eye symptoms and

impacting specific ocular surface parameters.[8,9] However, findings from existing studies are not consistent, suggesting that multiple variables likely contribute to MADE. The impact of factors such as glasses, contact lenses, different types of masks, and a history of dry eye disease remains underexplored. Our study aimed to evaluate ocular surface assessments in the morning and after prolonged mask use to determine whether mask use is associated with worsening dry eye measurements while also investigating how various factors may influence these outcomes.

Our control group, consisting of participants without a history of dry eye disease, ocular irritation, or contact lens use, exhibited minimal changes in ocular surface parameters and dry eye symptoms throughout the day. Specifically, OSDI, TBUT, and Schirmer I test showed no statistical difference between the morning and after a full workday, suggesting that those in the control group did not exhibit a worsening of symptomatic or ocular surface parameters throughout the day. This stability contrasts with the worsening of symptoms and ocular surface parameters reported in other studies. However, most of these studies were conducted on patients with a history of dry eye disease.[25–27] Given the healthy status of our control group, it is likely that the lack of significant differences reflects the stability of their ocular surface, allowing for a sharp distinction between the symptoms of control subjects and mask-wearing participants.

Our study indicates that mask use is significantly associated with an increase in OSDI questionnaire score, a widely used measure of dry eye symptom severity, where higher scores represent greater disability. Previous studies, including a large survey study on mask-associated symptoms done by Boccardo, have reported similar findings, with significant increases in self-reported ocular discomfort in those who wore a mask.[7,28,29] The estimated minimal clinically important difference (MCID) for the OSDI questionnaire ranges from 4.5 to 7.3 in patients with mild to moderate symptoms.[21] In our study, the mean increase OSDI score was 4.5, suggesting that healthcare providers with mask use throughout the day may benefit from clinical management of mild to moderate symptoms. As face masks have become essential for controlling the spread of COVID-19 and another infectious disease, understanding the symptoms that may deter mask use and negatively impact quality of life is crucial.

Furthermore, our results indicate that mask use is significantly associated with a decrease in TBUT, a measure of tear film stability. Tear film stability can be influenced by any of the three layers: the aqueous, lipid, or mucin layer.[22–24] A reduction of the volume of the aqueous layer can decrease TBUT.[30] Similarly, a reduction of the lipid layer can accelerate the evaporation of the tear film, decreasing TBUT - a phenomenon termed “evaporative dry eye” by Lemp in 1995.[31] Lastly, mucin layer dysfunction can reduce the thickness of the tear film, which can also reduce TBUT.[32,33] Our study primarily involved participants wearing surgical masks rather than formally fitted N95 or KN95 respirators. This observation may align with the hypothesis that poorly fitting masks may increase upward airflow over the eyes, leading to evaporation and reduction in the aqueous component of the tear film.[34]

The significant increase in OSDI scores and decrease in TBUT among mask-wearers, compared to the control group, suggest that mask-wearing primarily affects tear film stability. This is pattern is consistent with evaporative dry eye mechanisms, where increased tear evaporation leads to tear film instability and ocular surface discomfort.[10,16] Interestingly, while the Schirmer test showed a decrease in tear secretion in the right eye of the mask-wearing group, there was no significant difference when comparing changes between the mask-wearing and control groups. This suggests that tear production may not be significantly impacted by mask use, further supporting the hypothesis that tear film instability, rather than reduced tear production, is the primary issue associated with mask-associated dry eye symptoms.

Another possible explanation is that the buildup of humidity inside poorly fitting masks reaches the eyes, down-regulating efferent signals of the lacrimal gland and leading to reduced production and volume of the aqueous component of tears. However, in our study, there was no significant difference in the Schirmer I test - a measure of tear volume and lacrimal gland secretions – between non-mask and mask users, making this theory less likely. Diurnal changes in tear film stability may also account for our findings in TBUT; however, there is controversy over whether TBUT is influenced by the time of day. Several studies have found that TBUT varies throughout the day,[25,35] while others found no significant differences in TBUT between morning and evening.[30,36,37]

The dry eye parameters measured by the LipiView interferometer - LLT, MGd, and blinking measurements - did not significantly change between morning and after mask use at the end of the day compared to controls. These findings were

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expected as these parameters are primarily related to tear film quality, such as the lipid layer and mucin function,[17,38,39] and we did not anticipate that mask use and its evaporative effect on the tear film would affect the tear film quality.

Finally, when stratifying the mask-wearing group by factors such as wearing glasses, contact lenses, different types of masks, punctal plugs, and prior history of dry eye disease, linear regression analysis revealed a correlation between the wearing of glasses and a smaller decrease in TBUT scores over the course of the day. While the R^2 values were relatively low, the relationship was statistically significant, suggesting that wearing glasses has a notable, albeit small, impact on TBUT change. This finding may imply that glasses might act as a protective barrier by reducing the amount of air flow exposed to the eyes, thereby slightly offsetting the increased upward airflow produced by the mask. This could lead to less evaporation and a smaller loss of the aqueous component of the tear film. Interestingly, the type of mask and a history of dry eye disease did not correlate with any significant dry eye parameters.

It is important to note that while our study found significant differences in OSDI scores between masked and unmasked groups, there was a notable difference in baseline OSDI scores. Our analysis focused on the change in scores within each group rather than direct comparisons of absolute scores between groups, mitigating concerns about baseline differences. Additionally, all participants in the mask-wearing group were regular mask users, which could have affected their baseline measurements and response to prolonged mask wear during the study period. However, our study also examined objective measures such as TBUT, strengthening our findings.

Several limitations should be considered. First, as noted above, all participants were already regular mask users at the time of participation, potentially influencing baseline measurements. Second, inability to mask subjects and examiners to the time of day during assessments may have introduced bias, although this is inherently challenging in this type of study. Another limitation was the sample size difference between mask-wearing subjects and controls, due to the limited availability of healthcare providers not required to wear masks during the study period. This imbalance may have contributed to asymmetric results, as seen in some measures such as PBR and incomplete blinks. The small control group size may have amplified individual variability effects, especially in areas where the mask-wearing group showed minimal change. Furthermore, the groups were not age- and sex-matched, potentially introducing confounding factors. The older mean age of healthcare providers could contribute to a higher baseline prevalence of dry eye symptoms. Other variables, such as occupation-specific factors and screen time, could have independently affected dry eye symptoms. Lastly, while we stratified our analysis based on various patient characteristics, the resulting subgroup sample sizes were small, potentially contributing to the lack of significant differences observed in some comparisons.

Future studies may benefit from age-stratifying analyses to better isolate mask-wearing effects from age-related changes. Furthermore, longitudinal studies examining participants before and after initiating mask use, along with larger, balanced sample sizes and improved group matching, would increase statistical reliability. Detailed assessments of confounding factors and the inclusion of inflammatory marker (eg, MMP-9, IL-6, TNF-α) tests provide deeper insights into the complex interplay between mask use and ocular surface health.

Conclusion

Dry eye disease affects approximately 5–50% of the population, and following the COVID-19 pandemic, the impact of face masks on the ocular surface has emerged as an important public health concern.[40] Our study demonstrates that mask use is associated with an increased OSDI score and decreased TBUT, possibly due to its effect on tear film evaporation. As such, mask use may contribute to the development or exacerbation of dry eye disease, particularly in healthcare providers who wear masks for prolonged periods. Furthermore, wearing glasses may offer a protective measure against MADE, though further investigation is needed to better understand the interplay between various factors that influence the effect of the face masks' impact on the ocular surface. Despite the prevalence of MADE symptoms and their effects, we fully support the continued use of masks in reducing disease transmission. Our study demonstrates the importance of further exploring the effects of mask use on dry eye so we can develop more effective strategies for understanding and treating this condition.

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