Original Research

# A Comparative Analysis of Ocular Surface Parameters Before and After N95 Face Mask Use Among Healthcare Workers

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## ABSTRACT

**Objectives:** This study determined whether the use of an N95 face mask was associated with changes in ocular surface parameters and dry eye symptomatology among healthcare workers with no baseline dry eye disease.

**Methodology:** This was a prospective, analytical, quasi-experimental study. The ocular surface and dry eye symptomatology of 33 healthcare workers (n=66 eyes) were evaluated at baseline and 3 hours after use of 3M™ VFlex™ Particulate Respirator 9105 N95 mask (3M, Minnesota, USA). The following parameters were measured: ocular surface disease index (OSDI), tear break-up time (TBUT), tear break-up pattern (TBUP), non-invasive TBUT (NIKBUT), tear meniscus height (TMH), meibography, and bulbar conjunctival redness.

**Results:** Among all the parameters tested, only OSDI and bulbar redness showed significant changes when pre-N95 and post-N95 values were compared. Although each was interpreted as normal, the median OSDI score improved from 7 to 1 ($p < 0.001$). Median bulbar conjunctival redness score worsened from 0.9 to 1.1 ($p < 0.001$).

**Conclusion:** Among healthcare workers with no dry eye disease, the use of the 3M™ Vflex™ Particulate Respirator 9105 N95 mask was not associated with changes in TBUT, TBUP, NIKBUT, TMH, and meibogaphy. An improvement of dry eye symptoms was reported after VFlex™ mask use.

**Keywords:** *COVID-19; dry eye; face mask; mask-related dry eye; ocular surface*

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Dry eye disease (DED) is a pathology of the ocular surface associated with a dysfunction of the tear film properties. DED occurs in about 5 to 34% of the population worldwide.[1-3] Established risk factors include age, female sex, antihistamine intake, history of corneal refractive surgery, vitamin A deficiency, and exposure to dry, moving air.[4,5] During the COVID-19 pandemic, the use of face masks was implicated in the development and increased prevalence of DED; hence, the term mask-related dry eye (MADE) was introduced. Investigation of the ocular surface in relation to mask wear became relevant due to the increasing complaints of dry eye symptoms among face mask wearers. In one study, Krolo *et al*. investigated new-onset dry eye using the ocular surface disease index (OSDI) among face mask wearers. Face mask use of at least 3 hours per day was observed to contribute to newly-diagnosed mask-associated DED.[6] Dry, moving air is a significant risk factor in MADE because exhaled air travels up and out of the mask and comes in contact with the eyes. Moreover, poorly fitting masks increase this exposure by reverting airflow towards the eye rather than diverting expired air away from the eyes.[7] Because of this proposed relationship of dry eye and mask wear, a study looked at mask edge taping and its impact on the ocular surface, tear osmolarity, and dry eye symptomatology. After taping, most parameters improved when compared to using a face mask without taping.[8] Other factors have also been proven to prevent dry eye. The use of eyeglasses, for example, prevents DED as it increases periocular humidity.[9] However, the cumulative effect of mask and eyeglass use in the development or prevention of DED has yet to be studied.

This study aimed to determine whether the use of an N95 face mask is associated with changes in the ocular surface and DED symptomatology among healthcare workers with no DED at baseline. Results of the study may increase our understanding of MADE.

## METHODS

This was a prospective, analytical, quasi-experimental study. Healthcare workers (HCWs) from The Medical City (TMC), a tertiary hospital in Pasig City, Philippines, who did not have DED and who were not on any lubricant eye drops in the last three months were recruited. The diagnosis of non-DED was confirmed upon fulfillment of the following during initial screening: 1) an OSDI score below 13 or no rating of ≥ 2 in any OSDI item, and 2) a TBUT score of ≥ 5 seconds for both eyes. Medical students, those with history of any ocular disease, surgery or trauma, atopy, systemic or autoimmune diseases, use of systemic/ocular medications within the last three months, contact lens use, and prolonged exposure to direct, moving air were excluded. A signed informed consent was obtained from each study participant. This study was approved by the TMC Institutional Review Board.

The primary outcome measures were tear break-up time (TBUT), tear break-up pattern (TBUP), OSDI, non-invasive tear break-up time (NIKBUT), tear meniscus height (TMH), meibography, and eye redness measured before and after 3 hours of mask use. Secondary outcome measures included demographic characteristics such as age, eyeglass use, sex, and self-reported hours of visual display terminal (VDT) use. The OSDI score was computed using the following formula: *(sum of scores x 100) ÷ (total number of items answered x 4)*. For this study, one question from the OSDI questionnaire was eliminated (question number 6 - “Have problems with your eyes limited you in driving at night?”) making the total number of items only 11.

The following baseline ocular surface parameters were evaluated using the Keratograph 5M (K5) (Oculus, Inc., Missouri, USA): NIKBUT, TMH, meibography, and redness. Thereafter, TBUT and TBUP were measured under a slit-lamp biomicroscope using a 2% fluorescein strip moistened with non-preserved saline. After the excess saline was shaken off, the fluorescein strip was lightly touched on the lower lid margin of each eye. The participant was asked to blink several times and to briskly open the eye for the tear film evaluation. The time (in seconds) of the appearance of the first dark spot or line was recorded. TBUP was simultaneously determined during TBUT measurement. The average of three (3) measurements was calculated for each eye. After acquiring the baseline parameters, the participant was instructed to wear a National Institute for Occupational Safety and Health (NIOSH) approved

N95 mask 3M™ VFlex™ Particulate Respirator 9105 (3M, Minnesota, USA) provided by the principal investigator for standardization purposes. To ensure proper fit, the mask was worn in front of the principal investigator following the manufacturer guidelines for standard fit. Taping was not allowed during this time as taping is not a common practice with mask wear. The participant was then instructed to go through their usual daily work routine and to come back after 3 hours of accumulated mask use with minimal breaks in between (i.e. drinking of water is allowed but no meals in between). The same measurements (i.e., OSDI, K5, TBUT, and TBUP) were repeated after mask use. All tests were performed by the principal investigator.

*Statistical Analysis*

Sample size calculation was done using paired means in STATA 15.0. Assuming a correlation of 0.10 between TBUT score and mask use, a TBUT change of 8.3 ± 1.5, and adhering to a level of significance of 5% and a power of 90%, the computed sample size was 33 study participants (66 eyes).

Descriptive statistics were used to present the demographic profile of the participants. Means and standard deviations were used for continuous variables. Meanwhile, counts and percentages were used for categorical variables. To assess whether continuous variables (OSDI, TBUT, NIKBUT, TMH, and redness) had significant differences before and after N95 mask use, paired t-test was used for variables that were normally distributed, while Wilcoxon signed-rank test was used for variables that were non-normally distributed. Friedman's test was used for categorical variables (TBUP and Meiboscan grades). All statistical tests were done using SPSS ver. 27 (IBM, Illinois, USA).

## RESULTS

Thirty-three (33) HCWs were enrolled in the study. **Table 1** shows the demographic profile of the study participants. The mean age was 35 ± 8 years with the majority (45.5%) belonging to the 30-39 age group (n=15). There were 21 (63.6%) males and 12 (36.4%) females. Prescription eyeglasses were worn by 14 (42.4%) study participants. Mean VDT use was 9 ± 3 hours and the majority (57.6% or n= 19) used VDT for at least 8 hours a day.

**Table 1. Demographic Profile of Study Participants**

| Characteristics | N=33 |
|---|---|
| Mean age ± SD (in years) | 35 ± 8 |
| Age Group, n(%) (in years) | |
| 20 29 | 9 (27.3) |
| 30 - 39 | 15 (45.5) |
| 40 - 49 | 7 (21.2) |
| 50 and above | 2 (6.1) |
| Sex, n(%) | |
| Male | 21 (63.6) |
| Female | 12 (36.4) |
| Eyeglasses Use, n(%) | |
| Yes | 14 (42.4) |
| No | 19 (57.6) |
| VDT usage per day, n(%) | |
| Below 8 hours | 14 (42.4) |
| 8 hours and above | 19 (57.6) |
| Mean duration of VDT use ± SD (in hours) | 9 ± 3 |

*SD- standard deviation; VDT - video display terminal

The median pre-N95 OSDI score was significantly higher at 7 (IQR 4-11) compared to the median post-N95 OSDI score of 1 (IQR 0-4) ($p < 0.001$). For bulbar conjunctival redness, a significant difference ($p < 0.001$) was also noted between pre-N95 score which was 0.9 (IQR 0.8-12) compared to the post-N95 score which was 1.1 (IQR 0.9-1.4). There was no statistical significance ($p > 0.05$) between pre- and post-N95 mask use for TBUT, NIKBUT, and TMH (**Table 2**).

TBUP values were similar pre- and post-N95 use with dimple break (n = 28) and random break (n = 18) patterns representing most of the sample (p = 0.32). Meiboscan grading of the upper eyelids was also mostly grade 1 at both time points (n = 29 and 33, respectively) (p = 0.53). Similarly, Meiboscan grade distributions of the lower eyelids also had minimal change as majority were grade 0 at both time points (n = 29 and 28, respectively) (p=0.56). **Table 3** shows that Meiboscan values were mostly unchanged for both upper and lower eyelids.

**Table 2**. Comparison of Ocular Surface Characteristics and Symptomatology Before and After N95 Use

| Ocular Surface Parameter | Baseline | After N95 Mask Use | P-value |
|---|---|---|---|
| Median OSDI (IQR) | 7 (4- 11) | 1 (0 - 4) | *< 0.001* |
| Median TBUT (IQR) [c] | 10 (8 - 12) | 11 (8 - 13) | 0.22 |
| Mean NIKBUT (SD) [b] | 10.2 (3.3) | 10.2 (3.6) | 0.99 |
| Median TMH (IQR) [a] | 0.30 (0.24 - 0.34) | 0.28 (0.24 - 0.36) | 0.37 |
| Median Bulbar Redness[a] (IQR) | 0.9 (0.8 - 1.2) | 1.1 (0.9 - 1.4) | *< 0.001* |
| TBUP[c], n (%) | | | 0.32 |
| Line | 9 (13.6) | 9 (13.6) | |
| Dimple | 28 (42.4) | 27 (40.9) | |
| Spot | 11 (16.7) | 11 (16.7) | |
| Random | 18 (27.3) | 19 (28.8) | |
| Meiboscan Upper[c], n (%) | | | 0.53 |
| Grade 0 | 15 (22.7) | 14 (21.2) | |
| Grade 1 | 29 (43.9) | 33 (50.0) | |
| Grade 2 | 18 (27.3) | 15 (22.7) | |
| Grade 3 | 4 (6.1) | 4 (6.1) | |
| Meiboscan Lower[c], n (%) | | | 0.56 |
| Grade 0 | 29 (43.9) | 28 (42.4) | |
| Grade 1 | 24 (36.4) | 27 (40.9) | |
| Grade 2 | 12 (18.2) | 10 (15.2) | |
| Grade 3 | 1 (1.5) | 1 (1.5) | |

*OSDI - Ocular Surface Disease Index; TBUT - Tear Break-Up Time; NIKBUT - Non-invasive Tear Break-Up Time; TMH - Tear Meniscus Height; TBUP - Tear Break-Up Pattern; [a] P-value using Wilcoxon signed-rank test; [b] P-value using paired t-test; [c] P-value using Friedman's test

**Table 3**. Changes in Meiboscan Values Before and After N95 Use

| Parameter | n = 66 |
|---|---|
| Meiboscan of upper eyelid, n (%) | |
| No change | 56 (84.8) |
| Better | 6 (9.1) |
| Worse | 4 (6.1) |
| Meiboscan of lower eyelid, n (%) | |
| No change | 64 (97.0) |
| Better | 1 (1.5) |
| Worse | 1 (1.5) |

## DISCUSSION

The use of face masks, along with other regulatory measures of infection control, was heavily practiced during the past four years due to COVID-19. More than the eye-related signs from the coronavirus itself, ophthalmologists around the world received increased complaints of dry eye-related symptoms from prolonged face mask use. In the healthcare setting, N95 face mask was preferred due to its superior filtering capacity which prevents the spread of airborne and droplet infections. In this study, we determined whether an N95 face mask, specifically the VFlex™ respirator mask, was associated with significant changes in ocular surface parameters among HCWs. We found that after wearing the VFlex™ mask for 3 hours, HCWs had statistically significant lower OSDI scores and worse eye redness.

In this study, comparison of baseline and post-N95 mask values showed a significant decrease in median OSDI scores from 7 to 1 (p-value < 0.001). It can be deduced that participants in this study did not develop dry eye symptoms during VFlex™ mask wear. Krolo *et al.* had contradictory results wherein subjects who wore a surgical mask between 3 to 6 hours recorded significantly higher OSDI scores (15.3, IQR = 8.3 – 47.7) compared to subjects who wore the mask <3 hours per day (8.3, IQR = 0.0 – 35.1).[6] Similarly, Scalinci *et al.* reported that subjects who wore surgical masks for 6 hours at least 5 times a week showed a significant increase in the median OSDI score with the highest absolute increase of 12.5 compared to baseline.[10] Another study by Anwar *et al.* stratified subjects into 4 groups depending on the length of face mask use. Their result showed a positive correlation between OSDI and the length of mask use where a 4.2 increase in OSDI was seen for every 2.4 hour increase in mask use duration. [11] Baris *et al.* compared the pre- and post-surgical face mask OSDI among healthcare professionals who finished an 8-hour workday. The post-use mean OSDI was significantly higher at 27.4 ± 10.4 compared to the mean baseline OSDI score of 20.1 ± 8.3.[12]

The difference in the OSDI results of this study could be explained by the type of mask used. The VFlex™ respirator mask has a unique V-shaped pleated design and a nose clip that enables a better fit on the face. These render a proper seal despite facial movements and prevent expired air from coming in contact with the eyes. It can be inferred that the effect of the VFlex™ mask may be somehow comparable to mask-taping. This can be validated in future studies.

The same features of the VFlex™ mask may also explain why the other dry eye parameters in this study, namely the TBUT, TBUP, NIKBUT, TMH and meibography, showed no significant difference compared to baseline values. This contrasts with several MADE studies where most baseline dry eye parameters worsened after mask use.[11-13] The same study by Anwar *et. al.* found that participants using a face mask for longer periods had shorter TBUT and lower Schirmer I values.[11] In addition to the OSDI, Baris *et. al.* also measured the TBUT of healthcare professionals before and after an 8-hour work day and found that the baseline TBUT of 9.3 ±1.0 seconds was significantly reduced to 8.3 ±1.5 seconds afterwards.[12] These findings are further supported by a study done by Azzam *et. al.* that compared the TBUT and meibography values of surgical mask users versus N95 mask users.[13] Results showed that both masks caused dry eye and meibomian gland loss, with a higher loss of glands in the upper lids versus the lower lids.

Among all the parameters used to evaluate the ocular surface, bulbar conjunctival redness was the only one seen to have a significant change after wearing an N95 mask. Other factors could have caused the increased bulbar conjunctival redness. For instance, eye redness secondary to eye strain from prolonged use can be one of the possible causes. Exposure to irritants, such as dust and wind, can also be a possible etiology.

Future research should take into consideration certain limitations that the authors were not able to address. The first limitation is the use of only one type of N95 mask. Based on the studies cited, ocular surface values will vary depending on the mask used and the fit on the face. As such, it is recommended that future studies use different types of N95 masks and compare their effects on the ocular surface. Another limitation of this study is the short duration of mask use. Multiple studies have shown a significant increase in OSDI values and worsening of symptomatology in participants who wore surgical masks consistently for at least 6 hours a day.[10-12] As such, it is recommended that future research consider a longer duration of mask use or stratify the study population according to the duration of mask wear. Another important study limitation is operator bias. To address this, a different operator who is blinded to the baseline values can be assigned to measure the ocular parameters after mask wear. Finally, this study was limited to HCWs without DED. It is highly possible that HCWs with DED may have different results after mask wear due to an unstable tear film at baseline.

Amidst the numerous reports on the relationship of mask wear and dry eye, this study showed that 3 hours of VFlex™ N95 mask wear was not associated with significant ocular surface changes and dry eye symptoms among HCWs with no dry eye disease at baseline.

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