CIRUGIA Y CIRUJANOS

ORIGINAL ARTICLE

Impact of prolonged surgical mask versus KN95 respirator use on tear film stability in healthcare workers

Impacto del uso prolongado de mascarillas quirúrgicas frente a respiradores KN95 en la estabilidad de la película lagrimal en profesionales sanitarios

*Wenwen Wei[1], Yanli Shi[2], and Qingjun Hu[1]**

[1]Department of Ophthalmology; [2]Department of Clinical Laboratory. Civil Aviation General Hospital, Civil Aviation Medical College of Peking University, Beijing, China

Abstract

Objectives: *This study aimed to evaluate and compare the effects of prolonged daily wear of a surgical mask (SM) versus a KN95 respirator on tear film stability in healthcare workers.* **Methods:** *Forty-eight healthcare workers (96 eyes) were randomly assigned to wear either an SM or a KN95 respirator. Corneal fluorescein staining (FS), tear film break-up time (BUT), Schirmer I test (SIt), and the ocular surface disease index (OSDI) questionnaire were assessed at baseline without a mask (T0), after 8 h of continuous wear (T1), and after 1 week of daily wear (≥ 8 h/day, T2).* **Results:** *In the SM group, the FS score at T2 was significantly higher than at T0 and T1 (both $p < 0.05$). In the KN95 group, the FS score at T2 was significantly higher than at T0 ($p < 0.05$). BUT decreased significantly and progressively from T0 to T2 in both groups (all $p < 0.0167$). No significant changes in SIt or OSDI scores were observed over time within either group. Furthermore, no significant differences in FS, BUT, SIt, or OSDI scores were found between the two mask groups at any time point.* **Conclusions:** *Prolonged daily use of both SM and KN95 respirators over 1 week negatively affected tear film stability in healthcare workers, as indicated by a significant reduction in BUT and altered FS scores. The similar magnitude of effect for both mask types suggests that the impact is related to mask wear in general rather than to a specific design. These preliminary findings warrant confirmation in larger, controlled studies with longer follow-up periods.*

Keywords: *Wearing mask. Mask-associated dry eye. Tear film stability. Healthcare work.*

Resumen

Objetivo: *Evaluar y comparar los efectos del uso prolongado diario de una mascarilla quirúrgica (MS) frente a una mascarilla KN95 sobre la estabilidad de la película lagrimal en profesionales sanitarios.* **Métodos:** *Cuarenta y ocho profesionales sanitarios (96 ojos) fueron asignados aleatoriamente a usar MS o mascarilla KN95. Se evaluaron la tinción corneal con fluoresceína (FS), el tiempo de ruptura de la película lagrimal (BUT), la prueba de Schirmer I (SIt) y el cuestionario del Índice de Enfermedad de la Superficie Ocular (OSDI) al inicio sin mascarilla (T0), tras 8 horas de uso continuo (T1) y tras una semana de uso diario (≥ 8 h/día, T2).* **Resultados:** *En el grupo MS, la puntuación de FS en T2 fue significativamente mayor que en T0 y T1 ($p < 0.05$ en ambos casos). En el grupo KN95, la puntuación de FS en T2 fue significativamente mayor que en T0 ($p < 0.05$). El BUT disminuyó de manera significativa y progresiva de T0 a T2 en ambos grupos ($p < 0.0167$ para todos). No se observaron cambios significativos en las puntuaciones de SIt y OSDI a lo largo del tiempo en ninguno de los grupos. Además, no se encontraron diferencias significativas en las puntuaciones de FS, BUT, SIt y OSDI entre los dos grupos en ningún momento.* **Conclusiones:** *El uso prolongado diario de SM y KN95 durante una semana afectó negativamente la estabilidad de la película lagrimal en el personal sanitario, como indican una reducción significativa del BUT y una alteración en las puntuaciones de*

***Correspondence:**
Qingjun Hu
E-mail: huqingjun858@outlook.com

Date of reception: 07-02-2026
Date of acceptance: 28-02-2026
DOI: 10.24875/CIRU.26000056

Cir Cir. (ahead of print)
Contents available at PubMed
www.cirugiaycirujanos.com

FS. La magnitud similar del efecto con ambos tipos de mascarilla sugiere que el impacto está relacionado con el uso de la mascarilla en general y no con un diseño específico. Estos hallazgos preliminares justifican su confirmación mediante estudios controlados más amplios y con periodos de seguimiento más largos.

Palabras clave: *Uso de mascarilla. Ojo seco asociado a mascarilla. Estabilidad de la película lagrimal. Trabajo sanitario.*

Introduction

The global rise in respiratory-transmitted diseases, particularly following the COVID-19 pandemic, has solidified mask-wearing as a crucial public health intervention.[1] As the use of masks has become prevalent, concerns have arisen regarding their potential effects on ocular surface health.[2] Specifically, extended mask wear is increasingly linked to eye irritation and the onset of mask-associated dry eye (MADE),[3] a condition that can diminish both visual quality and overall well-being. Research indicates that changes to the tear film may occur even after brief periods of mask use.[4]

Healthcare workers constitute a critical demographic for investigating this issue due to their occupational necessity to wear high-filtration masks for prolonged durations.[5] Studies indicate that within this population, extended mask usage is associated with an increased incidence of ocular and nasal discomfort, frequently accompanied by headaches and diminished concentration.[6,7] In support of this, a survey involving 333 healthcare workers found that nearly 70% reported symptoms consistent with MADE.[8] This significant prevalence highlights the urgent need for objective assessments of mask-induced tear film instability in clinical environments.

Although awareness of MADE is increasing, there is a lack of comprehensive studies comparing the effects of different mask types, such as surgical masks (SMs) and KN95 respirators, on the ocular surface. To fill this research gap, we designed the present study to evaluate and contrast the impact of prolonged SM versus KN95 wear on tear film stability among healthcare workers. Our assessment included fluorescein staining (FS), break-up time (BUT), Schirmer I test (Sit), and ocular surface disease index (OSDI) scores at three specific timepoints related to mask exposure.

Methods

Subjects

Forty-eight healthcare workers (96 eyes) were recruited from the Civil Aviation General Hospital between July and August 2023. Participants were instructed to maintain their normal daily routines. Inclusion required strict adherence to a standardized mask-wearing protocol that emphasized proper fit and a minimum daily use of 8 h. The inclusion criteria were as follows: (1) good general health and the ability to cooperate with examinations; (2) willingness to wear the assigned study mask as instructed; and (3) no mask use for at least 48 h before the baseline assessment. Exclusion criteria included a history of keratoconus, intraocular surgery, or active ocular surface disease; recent contact lens use or ocular medication; the presence of strabismus, nystagmus, uveitis, or glaucoma; and inability to attend follow-up appointments.

Given the universal mask mandates in effect during the pandemic and the ethical constraints of assigning healthcare workers to an unmasked control group, this study did not include a non-masked control arm.

Mask protocols

Participants were randomly assigned to wear either a standard SM or a KN95 respirator (3M Company, equivalent to N95) through a straightforward 1:1 randomization method. All subsequent evaluations were conducted by a single-skilled ophthalmologist, unaware of the group allocation, in a standardized examination room to maintain uniformity.

Procedure

At the baseline visit (T0), conducted in the morning before mask application, participants first completed the OSDI questionnaire. Subsequently, clinical assessments were carried out in the following order: FS, BUT, and SIt were conducted for both eyes. FS assessment entailed the application of a fluorescein strip to the lower conjunctival sac, followed by the grading of corneal staining under cobalt-blue slit-lamp illumination.[9] BUT was measured 3 times/eye, and the results were averaged. SIt involved placing standardized filter strips in the lateral canthus for 5 min. Following baseline measurements, participants were provided with their designated mask type and received standardized instructions on proper wearing procedures. The initial post-intervention evaluation (T1) was conducted immediately after wearing the mask for 8 consecutive h, including a short, supervised lunch and hydration break. After completing a week of daily mask usage (≥ 8 h/day), participants returned for a final follow-up visit (T2), during which all questionnaires and clinical assessments were repeated identically. Throughout the study, participant log sheets and periodic checks by the research team were used to meticulously monitor mask fit, compliance with wearing protocols, and daily duration.

Statistical analysis

Statistical analysis was performed using Statistical Package for Social Sciences 21.0 (IBM, USA). Continuous variables were assessed for normality. Normally distributed data were presented as mean ± standard deviation and analyzed using a repeated-measures analysis of variance (ANOVA). Non-normally distributed data were expressed as median (interquartile range) and analyzed using nonparametric tests: the Friedman test with *post hoc* Wilcoxon signed-rank tests for within-group comparisons, and the Mann-Whitney U test for between-group comparisons. Categorical data were compared using the Chi-square test. For repeated-measures ANOVA, the Greenhouse-Geisser correction was applied when sphericity was violated. Multiple comparisons were adjusted using the Bonferroni correction. The statistical significance level was set at $\alpha = 0.05$.

Results

Baseline data distribution

A total of 48 subjects completed the study. The SM group comprised 25 subjects (5 males, 20 females; mean age 47.48 ± 15.26 years). The KN95 group consisted of 23 subjects (5 males, 18 females; mean age 43.00 ± 15.01 years). No significant differences were observed between groups in gender distribution ($p = 0.999$) or mean age ($p = 0.312$). First, we assessed the distribution of all key outcome measures at baseline (T0) to inform the selection of appropriate statistical tests. As shown in figure 1, the data for tear BUT, FS, and ocular surface disease index (OSDI) scores did not follow a normal distribution.

Temporal changes in ocular surface parameters

The temporal changes in the key ocular surface parameters across the three time points are summarized for both mask groups in figure 2. As shown in the data, FS scores increased notably over the study period. In the SM group, the median FS score at T2 was significantly higher than at T0 ($p = 0.001$) and T1 ($p = 0.002$). In the KN95 group, the FS score at T2 was also significantly higher than at T0 ($p = 0.002$), though other differences were not statistically significant after Bonferroni correction (Table 1). Conversely, a significant and consistent decline in Tear BUT was observed in both groups across the study duration (Fig. 2). Both the SM and KN95 groups experienced a significant decrease in BUT from T0 to T1 and T2 (all $p < 0.0167$), as detailed in table 2. Despite these clear trends, no significant differences were found between the mask groups for FS or BUT at any specific time point. Concurrently, no statistically significant differences in SIt were observed across time points or between groups (Table 3). In terms of subjective symptoms, OSDI scores remained stable throughout the study, with no significant changes observed over time or between groups, a finding supported by the visual data, as shown in figure 2 and detailed in table 4.

Magnitude and significance of changes from T0 to T2

To consolidate the overall impact from baseline (T0) to the study's endpoint (T2), the magnitude of change and its corresponding statistical significance are presented in figure 3. The most pronounced changes occurred in the objective clinical signs. As detailed in figure 3, BUT decreased substantially by approximately 50%, while FS scores exhibited a large percentage increase from baseline (over 175%). These changes were highly statistically significant for both groups. In stark contrast, the change in subjective OSDI scores was minimal and failed to reach statistical significance, reinforcing the key observation that subjective symptoms did not change despite clear and significant alterations in objective clinical signs.

Individual variability and inter-parameter correlations

Beyond group-level averages, figure 4 reveals considerable variability in individual participant

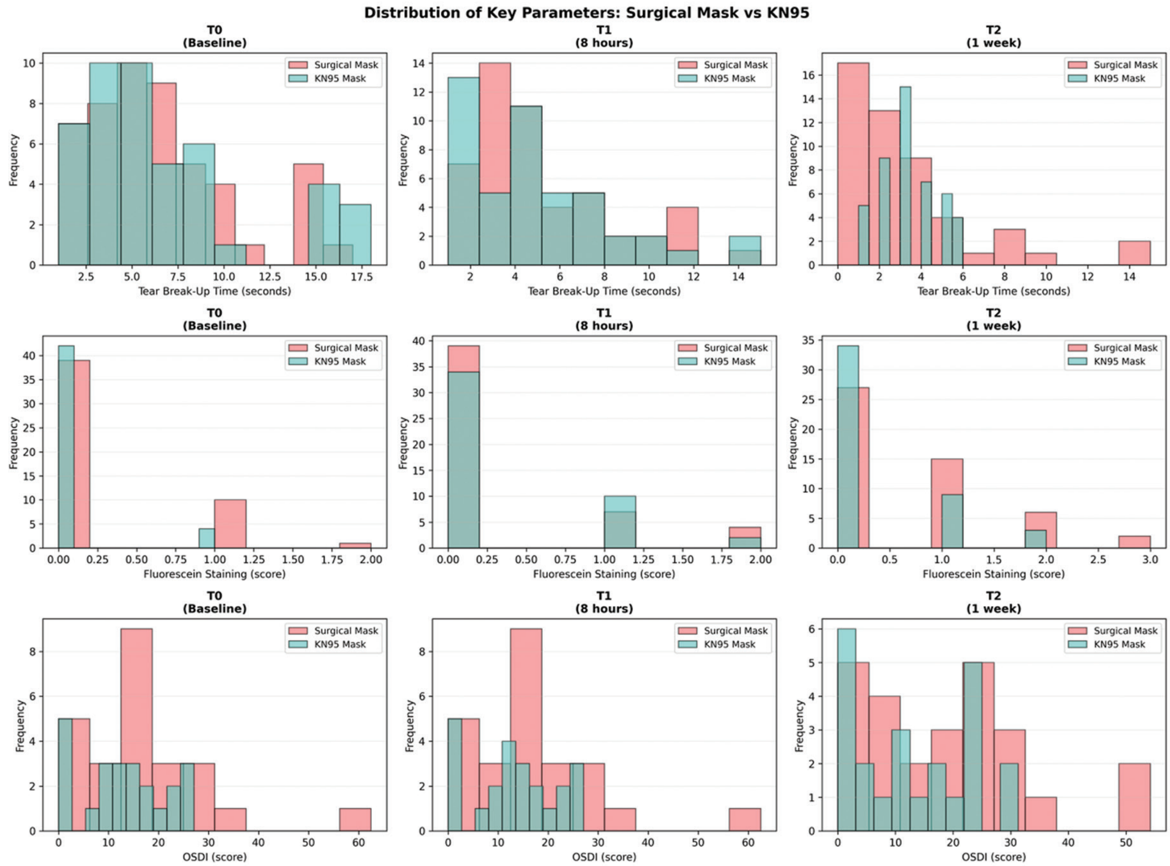

Figure 1. *Histograms showing the data distribution of tear break-up time, fluorescein staining, and ocular surface disease index at baseline (T0).*

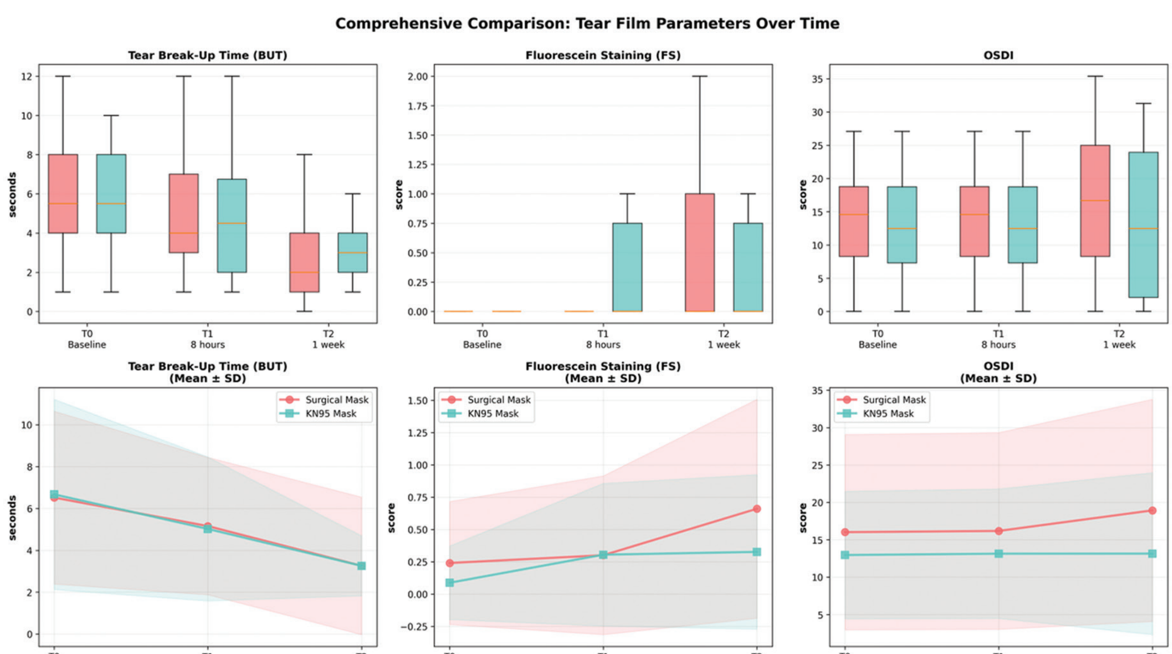

Figure 2. *Temporal changes in ocular surface parameters. Boxplots and trendlines illustrating the changes in fluorescein staining, tear break-up time, and ocular surface disease index from baseline (T0) to T1 and T2 for both mask groups.*

Table 1. FS, BUT, SIt, and OSDI before and after mask wearing in subjects within both groups

Parameters	SM group			p	KN95 group			p
	T0	T1	T2		T0	T1	T2	
FS[ab]	0 (0, 0)	0 (0, 0)	0 (0, 1)	0.000	0 (0, 0)	0 (0, 1)	0 (0, 1)	0.012
BUT[ab] (s)	6.52±4.13	4.00 (3.00, 7.00)	2.00 (1.00, 4.00)	0.000	3.50 (3.75, 8.00)	5.02±3.14	3.00 (2.00, 4.00)	0.000
SIt[a] (mm)	2.00 (0, 7.75)	3.00 (0, 8.25)	1.00 (0, 5.00)	0.160	2.00 (0, 15.00)	1.00 (0, 10.00)	2.00 (0, 12.00)	0.192
OSDI[c]	16.02±13.07	16.18±13.16	18.93±14.87		12.96±8.54	13.14±8.67	13.14±10.83	

[a]Friedman's test was performed to compare within-group differences.
[b]*Post hoc* tests were performed to follow-up significant within-group differences.
[c]Repeated ANOVA.
FS: fluorescein staining; BUT: break-up time; SIt: Schirmer I test; OSDI: ocular surface disease index; ANOVA: analysis of variance.

Table 2. FS, BUT *post hoc* Wilcoxon test within both groups

Within-group comparison	SM group			KN95 group		
	T0 versus T1	T0 versus T2	T1 versus T2	T0	T1	T2
FS	0.317	0.001	0.002	0.019	0.002	0.870
BUT (s)	0.014	0.000	0.000	0.001	0.000	0.000

p-corrected for multiple comparisons; $p < 0.05/3 \approx 0.0167$ was deemed statistically different.
FS: fluorescein staining; BUT: break-up time; SM: surgical mask.

Table 3. OSDI repeated ANOVA

Source of variation	F	p
Time × group interaction effect	1.771	0.190
Time effect	2.049	0.159
Group effect	1.453	0.234

OSDI: ocular surface disease index; ANOVA: analysis of variance.

Table 4. Comparison of FS, BUT, and SIt at each time between the two groups

Parameters and time	SM group versus KN95 group			
	Mann-Whitney U	Wilcoxon W	*Z*	p
FS				
T0	995.000	2076.000	−1.806	0.071
T1	1116.000	2391.000	−0.335	0.738
T2	904.500	1985.500	−2.112	0.035
BUT				
T0	1141.000	2222.000	−0.66	0.947
T1	1107.500	2188.500	−0.314	0.753
T2	868.000	2143.000	−2.106	0.035
SIt				
T0	1057.500	2332.500	−0.691	0.490
T1	1110.500	2191.500	−0.297	0.767
T2	912.000	2187.000	−1.783	0.075

p-corrected for multiple comparisons; $p < 0.05/3 \approx 0.0167$ was deemed statistically different.
FS: fluorescein staining; BUT: break-up time; SM: surgical mask; SIt: Schirmer I test.

trajectories in response to mask-wearing. While the group trend for BUT was a clear decline, the scatter plots show that some individuals' measurements remained stable while others experienced a more severe decrease, a pattern of variability also seen for FS and OSDI scores. This highlights that mean trends may not fully capture the range of patient experiences. Further analysis, visualized in the accompanying correlation heatmaps in figure 4, provides deeper insight into the complex interrelationships between tear film stability, epithelial damage, and subjective symptoms, suggesting that these factors do not always change in direct concert at the individual level during the study.

Discussion

This prospective study evaluated the short-term effects of prolonged use of SM and KN95 respirators on tear film stability in healthcare workers. The key finding is that both mask types led to a significant and progressive worsening of tear film stability over 1 week, as evidenced by reductions in BUT and changes in FS scores.

Substantial evidence correlates prolonged mask-wearing with exacerbated dry eye symptoms.[10,11] For example, individuals wearing masks for more than 12 h daily showed notably lower BUT and higher OSDI scores than those with shorter exposure durations.[12] Likewise, a study that classified dry eye patients based

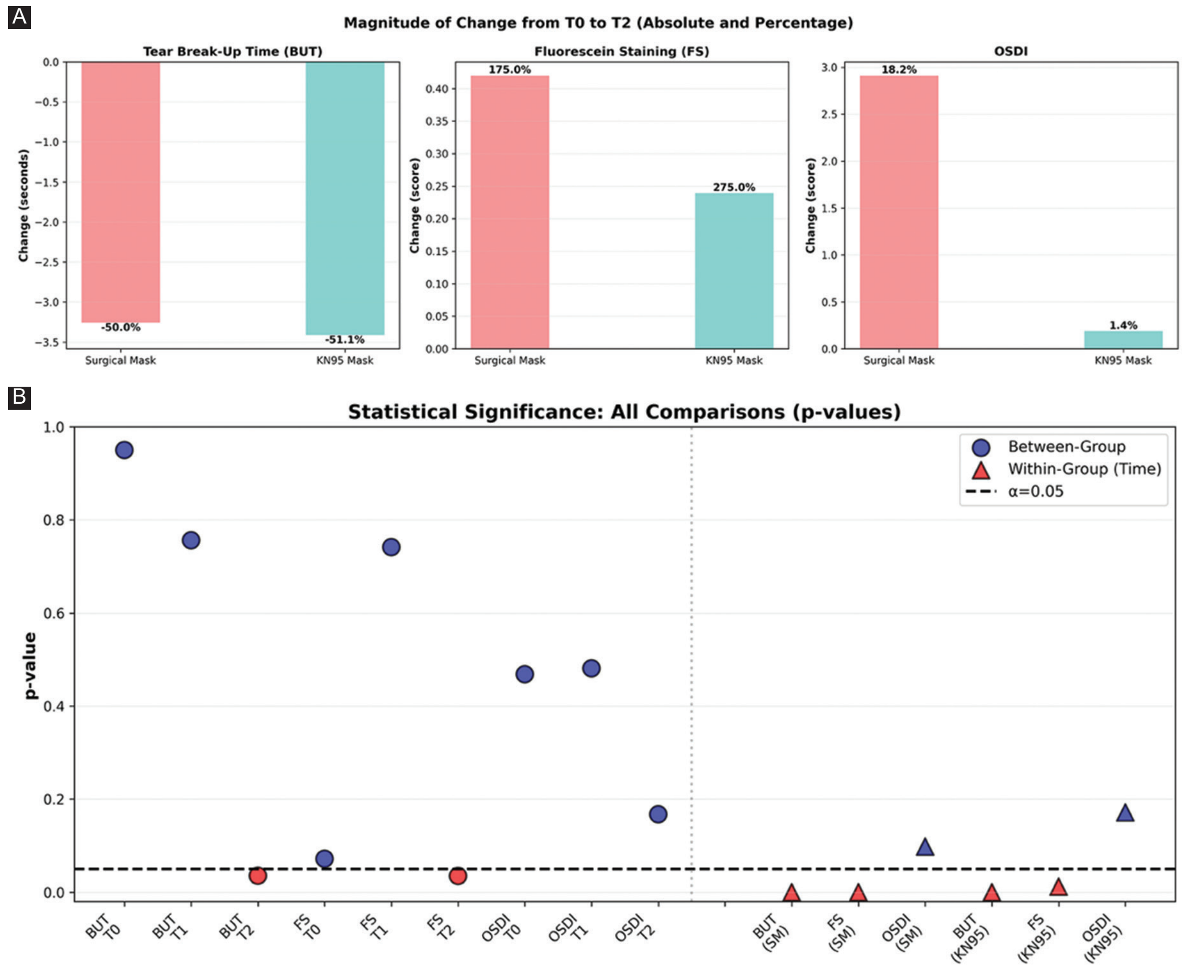

Figure 3. A *and* **B:** *Magnitude and statistical significance of change from T0 to T2. Bar charts summarizing the absolute and percentage change in ocular parameters and the corresponding statistical significance (p-values) of these changes.*

on daily mask wear time revealed that the cohort wearing masks for over 6 h exhibited significantly inferior BUT, FS, and Sit outcomes after 3 months, in contrast to those wearing masks for shorter periods.[13] Our findings align with this trend, as our study showed a significant decline in BUT in both the SM and KN95 groups within 1 week. The observed reduction in BUT aligns with the proposed pathophysiology of MADE, where upward airflow from mask edges ("chimney effect") accelerates tear film evaporation.[14,15] Our findings in BUT are consistent with the previous studies.[16-18]

In the current study, the significant increase in FS scores after 1 week suggests that prolonged exposure to this altered microenvironment may lead to mild corneal epithelial disruption. Aksoy and Simsek detected worse FS after 8 h mask wearing, while after 15 consecutive days of wearing a mask for more than 8 h daily, FS scores showed no significant change from baseline. Possible reasons include the cornea's inherent tendency toward self-repair. The lack of significant change in SIt indicates that the primary mechanism may be increased evaporation rather than reduced tear secretion, which is consistent with the evaporative subtype of dry eye. Although the mean OSDI scores were higher after 1 week than at baseline in both groups, the change was not statistically significant. In a study comparing 215 healthcare workers and 149 controls, healthcare workers who wore masks for more than 6 h/day had a higher mean OSDI score than healthy controls who wore masks for < 2 h.[19] Our findings differ from the report by Scalinci et al.[10] The absence of a significant change in OSDI scores despite objective signs of deterioration may reflect the short observation period, a lag in symptom perception, or adaptation in this cohort of healthcare workers accustomed to prolonged mask use.

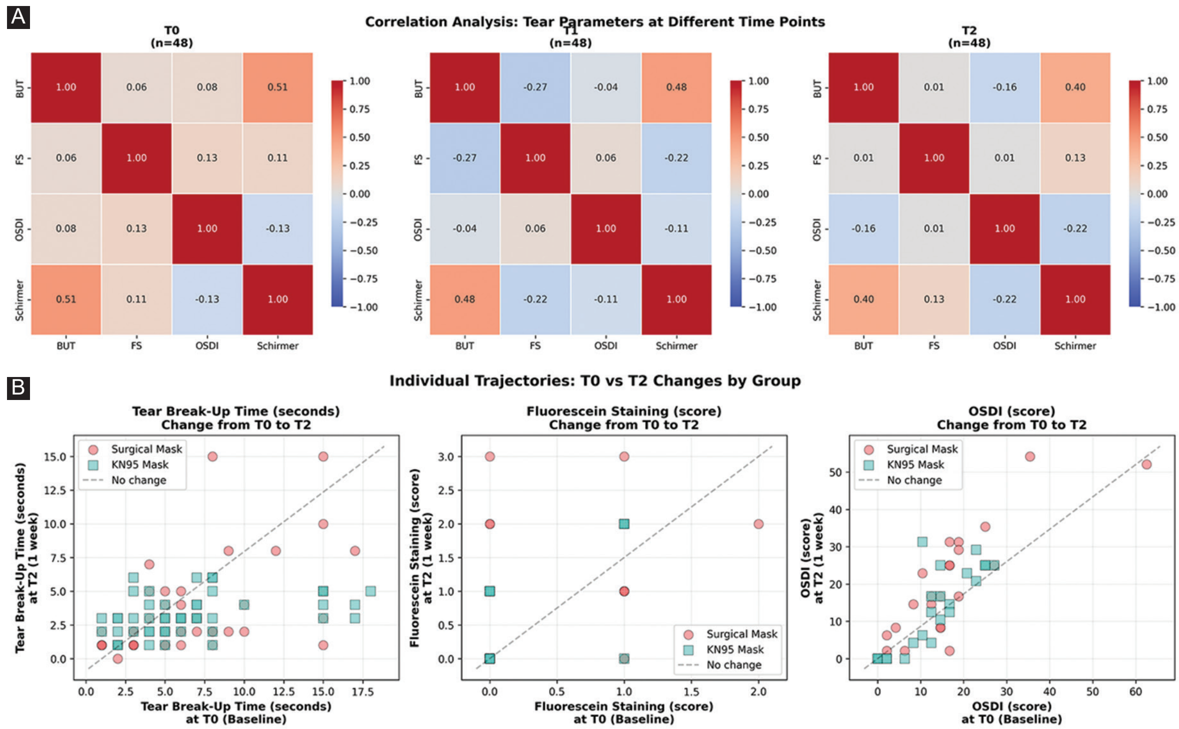

Figure 4. A *and* **B:** *Individual trajectories and inter-parameter correlations. Scatter plots of individual participant trajectories for each parameter, alongside heatmaps showing correlations between metrics.*

Notably, we found no significant differences in any objective or subjective parameter between the SM and KN95 groups at any time points. Shalaby and Eldesouky[20] reported deterioration in BUT, SIt, FS, and OSDI with both mask types, with greater worsening with SM than with N95 respirators. The discrepancy may be due to differences in observation periods. The aforementioned study observed the effect of the two different types of face masks for only 1 h, whereas our study observed for a longer period. While D'Souza et al.[21] compared the ocular surface clinical parameters of 17 ophthalmologists before (end of 2019) and during the COVID-19 pandemic (2020). The result showed a significant increase in OSDI after mask adoption, with no significant changes in SIt or BUT, findings that are quite similar to ours. Aksoy and Simsek[22] reported a significant reduction in BUT and SIt, along with significant increases in FS and OSDI scores, after 8 h of mask wear compared with baseline. After 15 consecutive days of wearing a mask for more than 8 h daily, BUT, SIt, and FS scores showed no significant change from baseline, whereas OSDI scores remained significantly elevated. Taking all of the above findings into account, this suggests that the negative impact on tear film stability may be a general consequence of prolonged mask wear, rather than specific to mask type or filtration efficiency under the conditions of this study.

Moshirfar et al. reported a significant increase in the prevalence of dry eye among patients and healthcare personnel required to wear masks for extended durations.[23] Our cohort exhibited signs of ocular surface compromise at baseline (T0), consistent with previous findings of a high prevalence of dry eye in this professional group.[8,24] This observation is further supported by the work of Penbe et al., who found that mask-wearing healthcare professionals had significantly lower non-invasive tear BUTs and higher OSDI scores compared to controls.[25] Collectively, these findings suggest that routine, prolonged mask use likely exacerbates an existing occupational vulnerability among healthcare workers.

Various constraints must be considered when analyzing our results. The limited sample size and the absence of a control group without masks, due to pandemic infection control measures, prevent us from attributing the observed changes solely to mask-wearing. In addition, the 1-week monitoring period is insufficient to determine whether these effects are temporary adaptations or enduring consequences. Subsequent studies with larger participant pools, controlled methodologies, and longer follow-up periods are crucial to validate these initial findings and elucidate the lasting clinical significance of MADE in healthcare settings.

Conclusions

Prolonged daily use of both SMs and KN95 respirators for 1 week negatively affected tear film stability among healthcare workers. The similar magnitude of effect for both mask types highlights the importance of considering ocular surface health in occupational settings that require extended mask use.

Funding

This study was funded by the Youth Program of Civil Aviation Medical Center (Civil Aviation General Hospital) (Grant No. 202228). The funder had no role in the study design, data collection, analysis, or reporting.

Conflicts of interest

The authors declare no conflicts of interest.

Ethical considerations

Protection of human subjects and animals. The authors declare that the procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation and with the World Medical Association and the Declaration of Helsinki. The procedures were authorized by the Institutional Ethics Committee.

Confidentiality, informed consent, and ethical approval. The authors have followed their institution's confidentiality protocols, obtained informed consent from all patients, and secured approval from the Ethics Committee. SAGER guidelines have been followed as applicable to the nature of the study. This study was approved by the Ethics Committee of Civil Aviation General Hospital (Approval No.: 2022-L-K-057) and complied with the principles outlined in the Declaration of Helsinki.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing or creation of the content of this manuscript.

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