Mask-associated changes in ocular surface parameters

Victor TT Chan[1,2,3], MB, ChB, **Ka Wai Kam**[1,2,3], MB, BS, FCOphthHK, **Wilson WK Yip**[1,2,3], MB, ChB, FCOphthHK, **Alvin Lerrmann Young**[1,2,3] *, MB, BCh, BAO, FHKAM (Ophthalmology)

[1] *Department of Ophthalmology and Visual Sciences, Prince of Wales Hospital, Hong Kong SAR, China*
[2] *Department of Ophthalmology and Visual Sciences, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong SAR, China*
[3] *Department of Ophthalmology and Visual Sciences, Alice Ho Miu Ling Nethersole Hospital, Hong Kong SAR, China*

* Corresponding author: youngla@ha.org.hk

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Dry eye disease (DED) is a common, multifactorial condition characterised by a loss of homeostasis on the ocular surface. Although DED can be broadly classified into aqueous-deficient and evaporative subtypes, multiple mechanisms contribute to its initiation and persistence.

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic had adverse effects on the ocular surface, with dry eye being the most common ocular symptom.[1] As a public health measure, universal masking effectively reduced the spread of the pandemic. Due to the increased use of face masks during the pandemic, corresponding increases in ocular irritation and dry eye symptoms were observed among individuals who regularly wore face masks, including those who had no prior diagnosis of DED.[2] The association between dry eye and face mask use was first reported by Moshirfar et al[2] in 2020, using the term 'mask-associated dry eye' (MADE). Since then, there have been reports of increased dry eye symptoms and ocular surface instability among individuals with regular mask use. Therefore, we aimed to evaluate and summarise the changes in symptoms and ocular surface parameters after mask use among healthy individuals and individuals with preexisting DED.

We conducted a literature search in PubMed and Embase on 14 November 2022, using the search strategy of '(dry eye) AND (mask)' and '(keratoconjunctivitis sicca) AND (mask)'. We then performed a meta-analysis using RevMan software version 5.4 (The Cochrane Collaboration, London, United Kingdom) to identify any ocular surface parameters evaluated in at least three studies. We used means and standard deviations (SDs) to calculate standardised mean differences (SMDs) with 95% confidence intervals (CIs). All meta-analyses were carried out with random effects models, and heterogeneity was assessed via the Higgins I^2 test.

We identified 20 studies in Embase and 111 studies in PubMed, along with one additional study[3] retrieved from the references of the identified studies. Eighty-six records were excluded: duplicates (n=17), non-English publications (n=6), non-human studies (n=1), case reports (n=2), letters (n=6), and articles focused on irrelevant topics (n=54). We then retrieved 46 articles for full text review, with the exclusion of seven studies conducted via questionnaire, 18 studies discussing DED not related to mask use, three studies discussing other mask-associated complications, and three studies which did not include a control group (eg, non–mask-wearing condition) or did not exclude any confounding conditions. Ultimately, we included 15 articles in our analysis: three prospective studies with 79 healthy individuals and 133 individuals with DED, and 12 cross-sectional studies with 1148 healthy individuals and 73 individuals with DED.[3-17] The Table summarised our meta-analyses of the 12 articles related to mask-associated changes in ocular surface parameters.[3,6-8,10-17] One article[4] was excluded from the meta-analyses as it did not report the means and SDs of the parameters, while two articles[5,9] were not included as they only assessed the Ocular Surface Disease Index (OSDI) score.

Effects on the Ocular Surface Disease Index score

Two prospective studies[4,5] and four cross-sectional studies[6-9] assessed the effect of mask use on the OSDI score. The OSDI score provides an assessment of a range of ocular surface symptoms related to DED, including their severity and functional impact during the previous week. The score ranges from 0 to 100; an individual's status could be regarded as normal (0-12 points), mild disease (13-22 points), moderate disease (23-32 points), or severe disease (33-100 points). However, three of four cross-sectional studies inappropriately used the OSDI score to evaluate changes in ocular surface symptoms before and after mask use on the same day,[6-8] rendering their results invalid. In the cross-sectional study by Krolo et al,[9] individuals who wore masks for 3 to 6 hours per day demonstrated significantly higher OSDI scores compared with the <3 hours per day group (15.3

[interquartile range=8.3-47.7] vs 8.3 [interquartile range=0.0-35.1]; P=0.001). Similarly, the two prospective studies, one including 67 individuals with preexisting DED[5] and the other including 17 healthy individuals,[4] revealed significant increases in OSDI score between the mask-wearing period and pre–mask-wearing period (ie, 2019 and earlier).

Effects on tear film break-up time

Two prospective studies[4,10] and five cross-sectional studies[3,6,7,11,12] assessed the effect of mask use on tear film break-up time (TBUT). In the diagnosis of dry eye, a cut-off value of <5 or 10 seconds was adopted to define short TBUT. Although most studies showed a significantly shorter TBUT during periods of mask use,[3,6,7,11,12] D'Souza et al[4] reported an increase in TBUT during the face-mask–wearing period (ie, during the SARS-CoV-2 pandemic in 2020) compared with the pre–face-mask period (ie, end of 2019) without providing mean and SD values for TBUT. Additionally, Mastropasqua et al[10] reported a reduction of TBUT only in individuals with >6 hours of mask use per day, but not among individuals with shorter durations of mask use.

Meta-analyses of the six studies with available mean and SD values for TBUT[3,6,7,10-12] showed an SMD of -0.74 (95% CI=-1.17 to -0.31; P=0.0007) after mask use compared with mask-off conditions. Subgroup analyses of healthy individuals and individuals with DED revealed SMDs of -0.83 (95% CI=-1.32 to -0.34; P=0.001) and -0.23 (95% CI=-0.57 to 0.12; P=0.19), respectively (Table).

Effects on non-invasive tear film break-up time

Six cross-sectional studies assessed the effect of mask use on non-invasive TBUT (NI-TBUT).[8,13-17] Three studies reported a decrease in NI-TBUT with mask use,[13-15] whereas the remaining three studies showed no significant difference.[8,16,17]

Because Alanazi et al[13] reported median and interquartile range values only, their study was excluded from this meta-analysis. The remaining five studies[8,14-17] indicated no significant decrease in NI-TBUT after mask use, with an SMD of -0.22 (95% CI=-0.56 to 0.12; P=0.21) [Table].

Effects on Schirmer tear test-1 values

Two prospective studies[4,10] and five cross-sectional studies[3,6,11,12,16] assessed the Schirmer tear test-1 (STT-1) values. While three studies revealed a decrease in STT-1 values with mask use,[6,11,12] two studies showed an increase.[4,16] The remaining two studies[3,10] did not demonstrate any difference in STT-1 values with mask use.

Although D'Souza et al[4] measured STT-1 values in their study, they did not report mean and SD values; thus, their study was excluded from the meta-analysis. Among the remaining six studies,[3,6,10-12,16] the SMD was -0.36 (95% CI=-0.73 to 0.00; P=0.05). Subgroup analyses of healthy individuals and individuals with DED revealed SMDs of -0.26 (95% CI=-0.62 to 0.10; P=0.16) and -0.97 (95% CI=-1.34 to -0.61; P<0.001), respectively (Table).

Effects on tear meniscus height

Four cross-sectional studies assessed tear meniscus height (TMH)[3,8,16,17]; no prospective studies assessed TMH. The study by Schargus et al[17] included healthy individuals and individuals with DED. Although most studies showed a decrease in TMH with mask use,[3,8,16] one study could not replicate this finding.[17] Meta-analysis of the four studies[3,8,16,17] showed that TMH was not altered by mask use (SMD=-0.51; 95% CI=-1.17 to 0.14; P=0.12). Subgroup analyses of healthy individuals and individuals with DED demonstrated SMDs of -0.66 (95% CI=-1.43 to 0.12; P=0.10) and 0.05 (95% CI=-0.38 to 0.47; P=0.83), respectively (Table).

TABLE. Meta-analyses of mask-associated changes in ocular surface parameters

Outcomes	No. of participants		SMD (95% CI)	P value
	Mask on	Mask off		
TBUT[3,6,7,10-12]				
Overall	599	599	-0.74 (-1.17 to -0.31)	0.0007
Healthy individuals	533	533	-0.83 (-1.32 to -0.34)	0.001
Individuals with DED	66	66	-0.23 (-0.57 to 0.12)	0.19
NI-TBUT[8,13-17]				
Overall	284	321	-0.22 (-0.56 to 0.12)	0.21
Healthy individuals	211	248	-0.29 (-0.80 to 0.21)	0.26
Individuals with DED	73	73	-0.08 (-0.48 to 0.33)	0.71
STT-1 values[3,6,10-12,16]				
Overall	674	711	-0.36 (-0.73 to 0.00)	0.05
Healthy individuals	608	645	-0.26 (-0.62 to 0.10)	0.16
Individuals with DED	66	66	-0.97 (-1.34 to -0.61)	<0.001
TMH[3,8,16,17]				
Overall	298	335	-0.51 (-1.17 to 0.14)	0.12
Healthy individuals	256	293	-0.66 (-1.43 to 0.12)	0.10
Individuals with DED	42	42	0.05 (-0.38 to 0.47)	0.83

Abbreviations: 95% CI = 95% confidence interval; DED = dry eye disease; NI-TBUT = non-invasive tear film break-up time; SMD = standardised mean difference; STT-1 = Schirmer tear test-1; TBUT = tear film break-up time; TMH = tear meniscus height

Discussion

Our analyses showed that mask use was associated with significant decreases in TBUT. These decreases were more pronounced in healthy individuals than in individuals with DED. Conversely, subgroup analyses of STT-1 values showed larger decreases in aqueous production among individuals with preexisting DED. These findings suggest a distinct effect of mask use on individuals with an impaired ocular surface.

Intriguingly, mask use was not associated with any changes in NI-TBUT or TMH. Although decreases in NI-TBUT were observed in healthy individuals and individuals with dry eye, the inconsistent data collection (ie, use of different machines) likely contributed to the lack of statistically significant results. Tear meniscus height can be considered a surrogate for aqueous tear production; however, variations in TMH measurement exist (ie, by slit lamp or anterior segment optical coherence tomography). These variations could have introduced substantial imprecision, leading to a lack of statistical significance.

A possible mechanism for MADE involves the use of a poorly fitting mask and subsequent misdirection of exhaled air from the upper portion of the mask towards the ocular surface, causing increased airflow and accelerated tear film evaporation.[2] Air leakage can be visualised by the frequent fogging of glasses when using a loosely fitted mask or N95 respirator. Consistent with this hypothesis, there was increased rates of conjunctivitis, corneal ulcers, tear evaporation, and ocular irritation among patients with obstructive sleep apnoea who received continuous positive airway pressure with an ill-fitting mask.[18] A study also revealed that high airflow from supplementary oxygen reduces TBUT, TMH, and tear meniscus area.[19] Consequently, taping of the upper mask edge could potentially reduce air leaks and ensure a more stable ocular surface.

In addition to MADE, face mask use has been associated with microbial keratitis[20] and chalazion,[21] both of which are inflammatory conditions; there is now evidence to support a pro-inflammatory environment associated with mask use. Dry eye disease itself has a strong immunological component; thus, it is reasonable to anticipate altered ocular surface stability after mask use. In eyes with DED, the lack of tear growth factors and immunoglobulins disrupts normal barrier function, further promoting microbial infections.

Although the association between mask use and dry eye symptoms does not outweigh the protective benefits of masks against communicable diseases, ophthalmologists should emphasise the importance of proper mask fit and use; they should also educate the public about this association. Alternative strategies to prevent disease spread during pandemic period, such as vaccination, should be advocated along with universal masking. Lubricating eye drops can help restore the tear film, especially in individuals with additional risk factors (eg, recent ophthalmic surgery or preexisting DED). Based on their experience with the SARS-CoV-2 pandemic, members of the public are mentally prepared and knowledgeable about mask use as a component of personal protection. Face masks will remain essential for most healthcare workers, and mask-associated changes in the ocular surface will continue to be an important topic when SARS-CoV-2 is no longer a public health concern.

Limitations

Our systematic review was limited by the quality of the primary evidence. The confounding effect of co-existing ophthalmic conditions could not be completely eliminated; this may hinder assessments regarding the effects of mask use on the ocular surface. Information concerning ocular surface parameters before the SARS-CoV-2 pandemic was often unavailable, and the inclusion of a non-mask wearing control group during the pandemic was impractical in most studies.[3-7,13-16] Additionally, all studies assessed the effect of mask use on ocular surface parameters without blinding. Furthermore, there was no information regarding the type of mask used or whether fit testing had been performed.[4-7,9,11,13-15] Most studies did not specify the mask-wearing environment or the environment in which ocular surface parameters were measured.[5,6,10,13,15] Among studies that included individuals with DED, the type and number of lubricants used by participants were not specified or controlled.[5,10,14] Many studies utilised an inadequate wash-out period before measuring ocular surface parameters in a new condition (either mask-on or mask-off).[3,6,11,13-15,17] Finally, highly variable results were evident for all outcome measurements across studies, with statistically significant heterogeneity (I^2 values ranged from 74% to 93%; all Q test P values <0.05). Any mask-associated changes in ocular surface parameters should be prospectively investigated using larger, well-characterised sample populations.

Conclusion

Face mask use was associated with worsened ocular symptoms, tear film instability, and a marginal decrease in STT-1 values. Mask use may reduce NI-TBUT and TMH, depending on the assessment methods.

Author contributions

Concept or design: All authors.
Acquisition of data: VTT Chan, KW Kam.
Analysis or interpretation of data: All authors.
Drafting of the manuscript: All authors.
Critical revision of the manuscript for important intellectual content: All authors.

All authors had full access to the data, contributed to the study, approved the final version for publication, and take responsibility for its accuracy and integrity.

Conflicts of interest

All authors have disclosed no conflicts of interest.

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