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The impact of long-term wearing of protective masks on the development of dry eye disease – literature review

Zofia Głowala, Sylwia Hejna

Faculty of Medicine, Collegium Medicum, Cardinal Stefan Wyszynski University, Warsaw, Poland

Summary: The outbreak of the COVID-19 pandemic and the need for widespread use of personal protective equipment have drawn attention to the emerging problem of dry eye disease associated with prolonged wearing of a protective mask (MADE – "Mask-Associated Dry Eye"). Several factors, including unnatural airflow, hypercapnic stress, inflammation, and low air humidity, contribute to the formation and progression of MADE. Research results indicate a negative impact on the eye surface due to wearing protective masks, the symptoms of which include dryness and irritation of the eyes, blurred vision, shortened tear film breakdown time, the presence of inflammatory markers, and corneal hyperalgesia. Understanding the mechanisms and symptoms of MADE is important to develop effective preventive strategies to protect long-term mask users from developing or progressing dry eye disease. In the context of potential future pandemics that may necessitate the use of masks, further research is needed to better understand this condition.

Key words: dry eye, tear film, ocular surface, mask, mask-related dry eye disease.

Introduction

The use of protective masks has increased with the SARS-CoV-2 coronavirus pandemic. Due to pandemic-related restrictions, prolonged mask usage became a necessity for many individuals, which was associated with discomfort and various ailments. At that time, a higher incidence of dry eye symptoms was observed among people wearing face masks for a long time. This contributed to the formulation of a new medical term: "MADE" (Mask-Associated Dry Eye) by ophthalmologist DE White [1]. This acronym refers to the increase in the occurrence of dry eye symptoms with the time and frequency of wearing a protective mask [2].

In our review, we assess the impact of long-term use of a protective mask on the development of dry eye disease (DED). Improper wearing or improper fitting of the mask can lead to increased airflow towards the eyes, thereby disturbing the normal physiological conditions on the surface of and around the eye [3]. This is associated with numerous eye symptoms, such as dryness, pain, and inflammation. Understanding the pathophysiology and identifying the factors that influence the development of MADE will enable the development of appropriate preventive strategies and treatments for this condition. This is an important public health issue because eye irritation and discomfort caused by prolonged mask wearing may lead some people to discontinue wearing masks [4]. Despite the official end of the COVID-19 pandemic, mask use will continue, especially by healthcare personnel and patients, making it important to determine the impact of prolonged mask wearing on ocular structures.

Aim of the study

The aim of the study is to determine the effect of long-term wearing of protective masks on the development of DED. The topic was developed taking into account the mechanisms of the development of mask-related dry eye diseaseand the symptoms accompanying this disease, which allows for a comprehensive understanding of its pathophysiology. Selected preventive measures and strategies that allow for the complete or partial reduction of the development of MADE were also discussed.

Methodology

We conducted a systematic search of the PubMed database for relevant articles published up to August 2024. Our searches included the following key words: "dry eye", "tear film", and "ocular surface" consistently paired with the fixed term "mask". Then, to complete the review, we reviewed the PubMed database again using the phrase "mask-related dry eye disease" (MADE). We included articles with free, full access. Based on the title and abstract, we excluded duplicate publications and those not related to the studied topic. Then after full-text evaluation we excluded irrelevant articles. Additional information was extracted from the reference lists of relevant articles. In total, we included 34 studies in this review.

Mechanisms of MADE

There are several pathophysiological mechanisms that may contribute to the development of MADE, including both physical and behavioural factors.

1. Upward airflow towards the eye

One of the most frequently mentioned factors is improper airflow. A protective mask, especially one that is poorly fitted, can cause air to leak from the upper edge of the mask during exhalation. This air rises upwards towards the eyes, which increases tear film evaporation [5, 6]. The effect of water vapour flowing through the cornea outweighs the benefits of increased moisture around the eyes created when wearing a mask [7]. Constant exposure to warm air leads to destabilisation and decreased tear fluid formation, which in turn contributes to the development of irritation or inflammation of the ocular surface. A similar phenomenon has been proven to occur with the use of air-purifying respirators and mechanical and positive pressure ventilation (CPAP) [8, 9].

Depending on the type of mask and its seal, the differences in airflow can be significant. Surgical masks usually do not fit tightly to the face, especially around the nose and cheeks, and therefore may have a greater impact on the deterioration of tear film parameters [10]. N95 masks are designed to minimise the effect of air leakage. However, some studies have shown that wearing them

is associated with higher scores on the Ocular Surface Disease Index (OSDI) [11, 12], and a greater risk of dry eye compared to surgical masks [11–13], probably because N95 masks, by adhering more tightly to the skin, tighten the lower eyelid, which makes the surface of the eye more prone to drying. Therefore, it is important that the mask is not placed too close to the eyes [12].

2. Hypercapnic stress

Another possible mechanism is hypercapnia of air exhaled through the mask. In the closed space between the face and the mask, carbon dioxide accumulates [14], which increases the concentration of CO_2 in the air flowing directly in front of the eyes and may lead to local changes in the tear film microenvironment. Increased expression of mucin responsible for tear stability and higher levels of pro-pain factors were observed, which was associated with more eye complaints [4].

3. Inflammation

The TFOS DEWS II report emphasised the role of inflammation in the pathophysiology of DED [15]. Mastropasqua et al. showed an increase in cellular and molecular markers of inflammation (dendritic cells and HLA-DR), especially in patients with a history of dry eye [16]. Inflammation of the ocular surface is not only a consequence of but also a factor intensifying MADE, which was confirmed in a recent study in which the level of proinflammatory cytokines positively correlated with OSDI results [17]. IL-1ß and MMP-9 levels were significantly lower in the group using masks <2 hours per day (or <16 hours per week), so the intensity of inflammation depends on the prolonged time of wearing them [17].

4. Air humidity

Air humidity is an additional parameter modulating tear film stability. In patients living in dry, windy regions of China, a higher incidence of MADE cases was observed [18]. Moreover, in closed rooms with low humidity, such as air-conditioned offices, wearing masks may lead to even greater drying of the ocular surface. Low humidity increases tear evaporation, which, combined with the already impaired airflow resulting from wearing a mask, may contribute to the exacerbation of MADE symptoms.

5. Use of electronic device displays

In addition, the COVID-19 pandemic forced many people to study and work remotely. It has been identified that students exposed to prolonged use of video display terminals (VDTs) were more likely to report symptoms of ocular discomfort [6]. Time spent in front of electronic device screens is associated with reduced blinking frequency, which carries the risk of increased tear evaporation and aggravates DED.

6. Lifestyle/Behavioural factors

Another study assessed additional factors in the COVID era that affect ocular surface health, such as dietary habits, pandemic-related stress, sleep disorders, and psychiatric problems. The authors thus draw attention to the multifactorial mechanism of MADE development [19].

MADE symptoms

Long-term wearing of a protective mask leads to the occurrence of ocular discomfort, which was confirmed by a survey conducted by Boccardo [20]. Of the 3605 study participants, 18% reported increased symptoms of dry eye when wearing a protective mask. A higher incidence of MADE symptoms was observed in women and in people wearing glasses or contact lenses [18, 20]. However, some studies do not confirm that there is a significant correlation between the change in eye parameters and female gender [21, 22].

The unnatural flow of exhaled air near the eyes causes one of the most frequently reported symptoms of MADE, which is dry eyes. As a result of long-term wearing of a protective mask, changes occur in the production of tears, their evaporation, and maintaining proper hydration of the eye surface. The lipid layer of the eye surface is disturbed [23], which additionally intensifies the feeling of dryness. In the Schirmer I test, which allows for the measurement of tear production (using filter paper placed inside the lower eyelid and assessing the moisture content after 5 minutes), reduced values were observed in people using protective masks [10].

Other clinical parameters that are used to assess tear film stability and deterioration as a result of wearing a protective mask are tear break-up time (TBUT) and non-invasive break-up time (NIBUT). Interestingly, the TBUT and NITBUT values are shortened not only after long periods of wearing a protective mask, i.e. 8 hours [24] and 9 hours [25], respectively, but also as a result of short-term wearing. This fact is confirmed by the study conducted by Alanazi et al., who compared NITBUT results before and after 1 hour of wearing a protective mask and showed a decrease by as much as 5 seconds [26]. TBUT values are also lower after only one hour of wearing a face mask [10].

Another symptom of MADE provoked by the unnatural route of exhaled air may be an increased sensation of pain from the cornea. Some researchers postulate that drying of the eyes and their inadequate hydration may cause inflammation. This in turn may contribute to corneal hyperalgesia [27]. The study by Mastropasqua et al. confirmed the presence of inflammatory markers, such as dendritic cells in confocal microscopy and HLA-DR expression in impression cytology in people wearing protective masks for 3 hours a day for 3 months. Additionally, a shortened TBUT and increased staining of the eye surface with fluorescein and Lissamine were observed. These parameters are higher especially in people with DED, but they are also elevated in healthy people [16].

An increase in the content of carbon dioxide in the eye area may also lead to changes in the range of sensation of the corneal nerve, which has been confirmed in studies on animal models [28]. Additionally, carbon dioxide disrupts the water vapour pressure gradient, thereby increasing dry eyes. In a "vicious circle" mechanism, this drives inflammation and increases sensations from the cornea.

An objective symptom caused by long-term wearing of a protective mask, which also contributes to insufficient moistening of the eyes and their drying, is a reduction in the area of the meibomian glands [29, 30]. The reduced ability to secrete lipids by the limited number of active meibomian glands contributes to the destabilisation of the tear film and its faster evaporation. Consequently, this intensifies ocular symptoms.

Researchers unanimously found increased OSDI scores in people using protective masks for a long time. In a cohort study by Krolo et al., increased OSDI scores were found in patients without DED when the mask was worn for 3 hours [31]. Also, in people with previously diagnosed dry eye syndrome, a study by Scalinci et al. showed that long-term (over 6 hours) and constant (5 days a week) wearing of a protective mask is associated with an increase in OSDI questionnaire scores [32].

Other subjective symptoms resulting from long-term wearing of a protective mask, especially one that does not fit around the nose, include eye irritation, burning, tearing, and foreign body sensation in the eye. Some report increased sensitivity to light, eye fatigue, and blurred or decreased vision [5].

Symptoms resulting from long-term wearing of masks occur with both surgical masks and N95 masks [10, 13]. The results of studies on this subject are inconsistent. According to Shalaby, the results of TBUT, corneal fluorescein staining, and the Schirmer test

are associated with poorer outcomes in participants using surgical masks. This is probably related to their weaker adhesion to the surface of the nose and, therefore, to the increased flow of exhaled air around the eyes. However, Azzam et al. observed a significant increase in objective symptoms in the group with tighter-fitting masks (N95). Gupta et al. also observed a significant increase in objective symptoms in the group with tighter-fitting masks (N95). Gupta et al. find a higher incidence of DED among people using N95 masks than in those using surgical or cotton masks [12]. Due to these discrepancies, it is not possible to clearly determine which masks may be more likely to intensify symptoms resulting from their long-term use. Further research is needed in this area.

The negative impact of a face mask may be more limited in the presence of a healthy eye surface. Some authors hypothesise that in healthy people, tear film homeostasis mechanisms may be able to counteract the effects of wearing a protective mask, at least in the short term [30].

Preventive measures

In recent months, the number of reported coronavirus (SARS--CoV-2) infections has decreased; hence, the reduced need to wear masks. However, new outbreaks of infectious diseases may appear in the future, which may again require the use of protective measures. Implementation of appropriate preventive strategies can reduce the risk of developing MADE, especially in vulnerable groups such as the elderly, people with pre-existing dry eye syndrome, and healthcare workers.

It was observed that as many as 70% of students wore loosely fitted masks, which was associated with a higher incidence of DED symptoms [12]. Therefore, educating patients on the importance of proper mask fitting is crucial. It is necessary to ensure that the mask fits tightly to the nose and cheeks, which minimises air leakage upwards. It is worth noting that regardless of the type of mask used, a deterioration in tear fluid parameters was observed in each case [10, 21], and even the highest quality mask material will not prevent DED if it is not properly fitted [12]. Additionally, if necessary, sticking tape along the upper edge of the mask can significantly reduce the flow of exhaled water vapor towards the eyes and thus increase the stability of the tear film [27]. On the other hand, it should be remembered that this simple procedure can disrupt the physiological movement of the lower eyelid and its mechanical ectropion with secondary failure to close the eyelids [2]. Furthermore, repeated application and removal of adhesive tape can irritate and damage the skin. Disruption of its continuity promotes the penetration of pathogens and, as a result, the development of infections [33].

Studies indicate that MADE is directly related to prolonged use of a face mask [18, 32]. Therefore, whenever possible, regular breaks in wearing it should be taken.

Using moisturising eye drops (as directed by the doctor) can be helpful in preventing and reducing the symptoms of MADE. Products containing preservatives, which can exacerbate existing inflammation, should be avoided, and remember to apply both before and after putting on the mask.

Finally, it is recommended that the time in air-conditioned rooms and dry environments be limited, and the 20:20:20 rule should be followed [29, 34]. This method involves looking away from the screen every 20 minutes and focusing on an object at least 20 feet away for at least 20 seconds. Taking short breaks regularly allows the eyes to rest from digital devices, which reduces the risk of dry eyes and eye strain.

Summary and conclusions

Long-term wearing of protective masks may adversely affect eye health, causing DED(MADE). Previous publications show that its pathophysiology is complex, which should be taken into account when incorporating effective prophylaxis and when developing treatment for this problem.

To prevent MADE, physicians should be aware of the risk of its occurrence, to properly educate patients, especially in the area of proper fit of protective masks to the face.

Further studies should take into account not only the immediate consequences of wearing a mask, but also the long-term consequences. In addition, it is important to include a control group consisting of people who do not use protective masks, which has not been possible so far due to pandemic restrictions. Inclusion of a control group would allow data to be obtained on diurnal changes in ocular surface parameters, and observation covering a larger cohort would allow for better assessment of the diversity of the course of MADE in the population.

There are discrepancies and limited results on the influence of environmental and sociodemographic factors or comorbidities on the development of MADE. The correlation between the type of mask used and the severity of DED also remains unclear. Therefore, a detailed analysis of these elements in future studies would help to understand the aetiopathogenesis of MADE and determine its diagnostic criteria.

Considering the involvement of inflammatory markers in the pathomechanism of MADE, it seems reasonable to conduct studies aimed at assessing potential therapeutic options. Such a study could bring significant benefits in the treatment of patients with-DED.

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Reprint requests to:
Zofia Głowala, PhD, MD (e-mail zosiaglowala@gmail.com)
Faculty of Medicine, Collegium Medicum, Cardinal Stefan Wyszynski University
Wóycickiego 1/3, 01-938 Warsaw, Poland