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ORIGINAL ARTICLE

Evaluation of ocular surface and corneal parameters in face mask users

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Abstract

Purpose: This study aimed to investigate tear tests and corneal parameters in individuals who wear face masks.

Methods: A prospective study included 75 participants, all using surgical face masks due to new regulations during the COVID-19 pandemic. They were divided into groups according to the duration of face mask wear (<3 [Group 1], from 3 to 6 [Group 2], over 6 h/day [Group 3]). All participants underwent a detailed ophthalmological evaluation. The Schirmer test and tear break-up time (TBUT) scores were assessed. In addition, corneal parameters were measured using a Pentacam Scheimpflug camera.

Results: The values of TBUT and Schirmer test scores were significantly lower in Group 3 than in Groups 1 and 2 ($p<0.001$ for all). There was a statistically significant difference between the groups in the pachymetric measurements at the pupil center ($p<0.001$), and the finest point was significantly less in Group 3 than in Groups 1 and 2 ($p<0.001$). The scores of the TBUT and Schirmer tests were significantly positively correlated with the pachymetric measurements ($p<0.001$ for all).

Conclusion: We have determined that the cornea is affected by individuals who wear face masks. To be protected from the undesirable effects of mask use, the exposed upper parts of the mask can be taped with a flexible tape, and artificial tears can be used prophylactically.

Keywords: Dry eye; face mask; ocular surface; pandemic; schirmer's test; tear break-up time.

The last month of the year 2019 marked the eruption of a deadly epidemic in the Chinese city of Wuhan. The pandemic was a form of pneumonia that became a global concern due to its unknown cause. The pandemic created an alarming situation, and Chinese scientists started making efforts to discover the cause and cure of the disease. In January 2020, a genetic sequence of this disease (SARS-CoV-2) was isolated.[1] This pandemic was a respiratory tract infection known worldwide as COVID-19 (coronavirus disease). The pandemic rapidly crossed the boundaries of China to take the entire world by storm. By the year 2020, the entire world was in a panic situation due to the global pandemic.[2] In the year 2020, we observe the world adapting to the "new normal" due to the COVID-19 pandemic, ways of which include physical distancing, hand hygiene, and wearing a face mask.[3] In some countries, including Turkey, face mask use has become mandatory in all indoor spaces open to the public and outdoor spaces. This prolonged use of a facemask became a common practice but was soon found to have some negative consequences.

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Numerous studies available in the literature have explored the association between prolonged use of a face mask and dry eye conditions. An American ophthalmologist, D.E., was the first to observe mask-associated dry eye (MADE) in June 2020. He was the one to coin the word "made" while explaining the dry eye condition in his blog.[4] The latest research in this domain showed that individuals who use face masks regularly depict significantly more dry eye symptoms than those who wear masks occasionally.[5] Dry eye conditions are characterized by altered corneal morphology.[6] Over time, a number of tools based on various technologies have been developed for analyzing the cornea.[7] One of such tool is Pentacam, which employs the Scheimpflug imaging technique to find the corneal thickness, volume, and corneal spatial section. It is a non-contact device that uses a 3-D model for detailed analysis of corneal structure.[8] However, to the best of our knowledge, there has been no study investigating the corneal parameters of individuals who wear face masks, which are measured using a Scheimpflug image. Therefore, the purpose of this study was to investigate tear tests and corneal parameters by Scheimpflug imaging and also to clarify the associations between the severity of dry eye and corneal parameters in individuals who wear face masks.

Materials and Methods

Study Population and Design

This cross-sectional prospective study included 75 participants that were selected among patients who were attending the Ophthalmology Department of the Ankara City Hospital. Subjects were recruited among outpatients who routinely wore face masks and applied to our clinical center for routine check-ups or refractive error examinations. They were divided into groups according to the duration of surgical face mask wear (<3 [Group 1], from 3 to 6 [Group 2], over 6 h/day [Group 3]). Surgical face masks, also called medical masks, fall within the category of medical devices.[9] Measurements of the subjects' right eyes were included in the analyses. The study followed the tenets of the Declaration of Helsinki and was approved by the local ethics committee (Project No. 2382). All participants received oral and written information about the study, and each participant provided written informed consent.

Examination Protocol and Study Measurements

Each study participant underwent a detailed ophthalmic examination, including the assessment of uncorrected distant visual acuity (UDVA) and corrected distant visual acuity (CDVA) (both UDVA and CDVA were recorded using Snellen's chart), manifested spherical and cylindrical refractive errors, intraocular pressure (IOP) measured by Goldmann applanation tonometry, tear break-up time (TBUT), Schirmer test under topical anesthesia, and slit lamp examination. All participants underwent corneal topography using the Scheimpflug camera (Pentacam, Oculus, Germany) and specular microscopy using the non-contact specular microscope (Topcon SP3000P, Tokyo, Japan). Each measurement was taken between 10:00 and 11:00 a.m. by a single clinician (DMU). An experienced clinician (DMU) assessed the images; neither clinician knew which scans belonged to which group, however. We repeated both examinations and manual measurements at least 3 times and selected the results with the best quality for analysis. We excluded eyes with noisy or misaligned images. A dilated fundus examination was performed after all examinations and measurements. Ocular exclusion criteria for this study were as follows: Corneal pathology, dense media opacities, history of uveitis, glaucoma, ocular trauma, and previous intraocular surgery. Moreover, a history of systemic disease, such as hypertension or diabetes mellitus, pregnancies, and use of any medication also resulted in patients being excluded from the study.

Pentacam Scheimpflug Camera Measurements

The Pentacam (Oculus, Germany) system uses rotating Scheimpflug imaging for non-invasive and three-dimensional anterior segment evaluation. In this study, three-dimensional anterior chamber analysis modules were used. Pentacam Scheimpflug camera measurements were made in darkness to standardize all measurements for each patient. After the placement of the head in the appropriate position, the patient was asked to look at a blue fixation light. Only one measurement defined as "OK" by the unit for examination quality specification was selected for the study. The measurements of keratometry values (K1, corneal power of the flat axis; K2, corneal power of the steep axis; Kmax, maximum corneal power), anterior chamber volume, anterior chamber depth, corneal volume, elevation front and back (AE and PE), and central corneal thickness (CCT) were obtained in each Pentacam image.

Evaluation of Tear Condition

The TBUT test was applied with a sterile fluorescein strip located in the lower eyelid fornix. The participant was asked to blink 3 times and, after that, to look straight ahead without blinking. The time interval between a complete blink and the first emergence of a dry spot in the precorneal tear film was measured under cobalt blue-filtered light. The average of three successive measurements of the TBUT test was calculated. Afterward, a Schirmer test was performed under topical anesthesia. Three minutes later, one drop of proparacaine 0.5% was instilled, and the Schirmer test strip was inserted into the behind of the lower lid between the temporal and middle third of the eyelid. After 5 min, the strip was taken out, and the moist portion of the paper was measured in millimeters.

Statistical Analysis

All statistical analysis was performed using IBM SPSS for Windows version 23.0 software. Descriptive statistics for continuous variables were shown as mean±standard deviation or median (25–75th percentiles). Categorical variables were shown as the number of patients and percentage (%). Whether the distributions of continuous variables were normal or not was determined by the Shapiro–Wilk test, and the homogeneity of variances was evaluated by the Levene test. More than two independent groups were compared by one-way analysis of variance (ANOVA) or Welch's ANOVA. Pairwise comparisons were done by Tukey or Games–Howell tests. The Kruskal–Wallis test was used to compare groups when parametric test assumptions were not met. The Dunn test was used for post hoc comparisons. The difference between groups according to categorical variables was determined by the chi-square test. Correlations between continuous variables were given by the Spearman correlation coefficient. A $p<0.05$ was considered statistically significant.

Results

The study included 75 participants that were randomly selected among patients who were attending the ophthalmology department of the Ankara City Hospital. They were divided into groups according to duration of face mask wear (<3, from 3 to 6, over 6 h/day). The demographic and clinical features of all subjects are presented in Table 1. There was no statistically significant difference between the individuals who wear face masks regarding age, gender, visual acuity, and refraction ($p>0.05$ for all). The values of TBUT and Schirmer test scores were significantly lower in Group 3 than in Group 1 and Group 2 ($p<0.001$ for all) (Table 1).

Table 2 presents the corneal parameters measured by Pentacam.

There was a statistically significant difference between the groups in the pachymetric measurements at the pupil center ($p<0.001$), and the finest point was significantly less in Group 3 than in Groups 1 and 2 ($P < 0.001$). However, other corneal parameters and endothelial cell density were not statistically significantly different between the groups ($p>0.05$ for all) (Table 2).

Table 3 shows the correlations between the tear tests and corneal measurements. The scores of the TBUT and Schirmer tests were significantly positively correlated with the pachymetric measurements ($p<0.001$ for all). No statistically significant correlation emerged between the groups for other corneal parameters ($p>0.05$ for all) (Table 3).

Discussion

The effects of long-term use of masks on the cornea have not been discussed in the literature. In this study, which is the first prospective study on this subject in the literature, the impact of the use of face masks on the ocular surface and corneal parameters was investigated. Long-term use of face masks was found to shorten TBUT, reduce Schirmer measurements, and cause thinning of the cornea. Furthermore, this cross-sectional study shows an association between tear tests and pachymetric measurements.

Table 1. Comparison of demographic and clinical data of the groups

	Group 1 (n=25) Mean±SD	Group 2 (n=25) Mean±SD	Group 3 (n=25) Mean±SD	P-value
Age (years)	38.0±12.6	36.6±10.5	37.0±8.6	0.912
Gender (female/male)	15/10 (60%/40%)	14/11 (56%/44%)	14/11 (56%/44%)	0.947
UCVA (logMAR)	1 (0.8–1) 0.92±0.14	1 (0.75–1) 0.87±0.2	1 (0.8–1) 0.9±0.17	0.744
BCVA (logMAR)	1 (1–1) 1±0	1 (1–1) 1±0	1 (1–1) 1±0	1.000
Spherical equivalent (D)	−0.75 (−1.31–−0.56) −0.94±0.53	−1 (−1.75–−0.88) −1.42±0.52	−1 (−1.75–−0.75) −1.21±0.44	0.115
TBUT (s)	10 (8–11)[a]	9 (7.5–11.5)[a]	5 (3–6)[b]	<0.001
	9.44±2.36	9.08±2.31	5.28±2.95	
Schirmer test (mm/5 min)	10 (7–10)[a]	8 (6–10)[a]	3 (2–8)[b]	<0.001
	8.96±3.01	8.16±2.51	4.84±3.39	

UCVA: Uncorrected visual acuity; BCVA: Best-corrected visual acuity; TBUT: Tear break-up time; SD: Standard deviation.

Table 2. Comparisons of the corneal parameters and ECD of the groups

	Group 1 (n=25) Mean±SD	Group 2 (n=25) Mean±SD	Group 3 (n=25) Mean±SD	P-value
K1 (D)	43.25±1.61	43.68±1.70	42.82±1.44	0.167
K2 (D)	44.05±1.42	43.68±1.70	42.82±1.44	0.058
Kmax (D)	45.34±1.65	45.55±1.78	44.70±1.38	0.163
Thinnest CT (μm)	557 (547.5–569.5)[a] 562.04±29.23	530 (524–548.5)[b] 539±22.31	506 (499.5–530.5)[c]	<0.001
Central CT (μm)	541 (525–563.5) [a] 546.28±29.02	535 (528–551.5)[a] 543.2±22.02	519 (503–531.5)[b] 516.6±25.24	<0.001
Anterior elevation (D)	7.83 (7.68–8.14) 7.88±0.25	7.79 (7.62–7.94) 7.79±0.28	7.76 (7.64–7.95) 7.84±0.25	0.277
Posterior elevation (D)	6.46 (6.34–6.65) 6.46±0.2	6.41 (6.35–6.60) 6.45±0.21	6.41 (6.35–6.62) 6.49±0.21	0.991
Anterior chamber volume (mm^3)	167 (154–195) 172.28±30.13	134 (112–193) 151.76±43.27	136 (124.5–202) 156.08±43.01	0.132
Anterior chamber depth (mm)	3.06 (2.86–3.25) 2.79 (2.68–3.20)	2.79 (2.68–3.20) 2.87±0.37	2.73 (2.51–3.22) 2.84±0.39	0.114
Corneal volume (mm^3)	60.45±5.18	59.47±3.29	59.35±2.53	0.637
ECD (cells/mm^2)	2794 (2687–2848.5) 2811.32±187.37	2824 (2702.5–2854.5) 2779.08±109.54	2783 (2564–2756) 2745.12±131.88	0.311

K1: Corneal power of flat axis; K2: Corneal power of steep axis; Kmax: Maximum corneal power; CT: Corneal thickness; ECD: Endothelial cell density; SD: Standard deviation.

Moreover, earlier research studied the occurrence of dry eye symptoms in "office eye syndrome." The office eye syndrome is characterized by lower TBUT and consequently, eye irritation and dry eye conditions because of the air conditioning inside the office.[10] The current study indicated lower TBUT because of the regular use of facemasks. This may be attributed to the contact of the ocular surface with the air released through the nasal cavity while breathing. This air is of poor quality, and it heads toward the eye from beneath the mask. Consequently, there is a rise in the airflow and a potential evaporation of the tear film. The persistence of this process is expected to cause inflammation or irritation on the ocular surface. Another study was conducted to study the evidence of dry eye symptoms in patients under CPAP treatment. The study revealed that an incorrectly fixed CPAP mask is expected to lead to contact of leaked air with the eyes and cause dry eye symptoms.[11,12]

The effect of climatic factors such as temperature and humidity on the TBUT and the outcomes of the Schirmer test were studied during the Dry Eye Assessment and Management (DREAM) study. The DREAM study demonstrated a positive association between TBUT and humid climates. The study participants belonging to the Mediterranean region showed longer TBUT and better outcomes in the Schirmer test.[13] The current study indicated the association of prolonged use of a face mask with localized dryness in the eye, as evident from shorter TBUT and reduced measurements in the Schirmer test. This localized dryness could be attributed to the contact of exhalation coming out of the facemask with the ocular surface.

In healthy eyes, tear film is characterized by an isotonic or marginally hypotonic aqueous layer. However, dry eyes are characterized by a hypertonic tear film with greater osmolarity, leading to reduced corneal thickness in both tear deficient and evaporative dry eye conditions.[14-17] Green et al. performed ultrasonic pachymetry to measure CCT to reveal that 1-min long corneal drying causes a significant reduction in CCT.[14] In the study by Chan and Mandell, the hypotonicity of the bathing solutions was found to have a direct impact on the extent of corneal swelling.[18] The dry eye condition is characterized by an imbalance between MMP-1 and TIMP-1, which causes a reduction in corneal thickness. MMP-1 is involved in the degradation of extracellular matrix components of the corneal stroma. In dry eye, the levels of cytokines in the eye rise which results in destructive keratolysis of the cornea causing a reduction in corneal thickness or if aggravated may lead to ulceration.[19,20] The corneal thickness is also managed by the epithelium and endothelium through their pump and barrier functions. The same was indicated by Tuominen et al., who postulated that dehydration of the cornea and reduction in corneal thickness in dry eyes may be attributed to abnormalities in the epithelium's barrier function.[21] This study indicated a significant reduction in corneal thickness with the regular, prolonged use of facemasks. Our findings support both the literature and the hypothesis of this study.

Corneal thickness measurement provides indirect information about the corneal endothelium. The damage or loss of endothelial cells may cause an increase in cornea thickness by hampering the pump function of the endothelial layer.[22-24] In our study, we evaluated endothelial morphology through specular microscopy. However, we did not detect significant changes in endothelial morphology. Therefore, we have determined that the change in corneal thickness is not due to endothelial cell dysfunction.

Our study has some potential limitations. Our study is a single-center study with a relatively small sample size; the parameters need to be investigated in a larger patient group. We believe that this study will support further studies with larger study populations that may be planned to compare results during routine use of face masks to a period without face mask usage.

Conclusion

As a result, our study suggests that the corneal surface is affected in those individuals who wear face masks. Individuals using masks regularly for an extended duration appear more likely to show symptoms. To be protected from the undesirable effects of mask use, the exposed upper parts of the mask can be taped with a flexible tape, and artificial tears can be used prophylactically. The link between CCT and dry eye should also be considered when taking IOP measurements as well as in refractive surgery decisions.

Ethics Committee Approval: The study followed the tenets of the Declaration of Helsinki and was approved by the local ethics committee (Project No. 2382).

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Table 3. The correlations between the dry eye tests and corneal measurements

	K1 (D) r (p)	K2 (D) r (p)	Kmax (D) r (p)	Thinnest CT (µm) r (p)	Central CT (µm) r (p)	Anterior elevation (D) r (p)	Posterior elevation (D) r (p)	Anterior chamber Depth (mm) r (p)	Anterior chamber volume (mm³) r (p)	Corneal volume (mm³) r (p)	ECD (cells/mm²) r (p)
TBUT (s)	0.067 (0.570)	0.063 (0.594)	0.116 (0.320)	0.473 (<0.001)	0.448 (<0.001)	0.064 (0.585)	−0.029 (0.807)	0.068 (0.565)	0.079 (0.499)	0.047 (0.690)	0.206 (0.076)
Schirmer test (mm/5 min)	0.149 (0.202)	0.125 (0.286)	0.164 (0.160)	0.473 (<0.001)	0.446 (<0.001)	0.011 (0.72)	−0.208 (0.074)	0.079 (0.502)	0.092 (0.433)	−0.009 (0.938)	0.288 (0.012)

TBUT: Tear break-up time; K1: Corneal power of flat axis; K2: Corneal power of steep axis; Kmax: Maximum corneal power; CT: Corneal thickness; ECD: Endothelial cell density.

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