DOI:10.14744/bej.2022.94899
Beyoglu Eye J 2023; 8(1): 5-13

Original Article

Evaluation of Eyelid, Angle, and Anterior Segment Parameters Using Scheimpflug Camera and Topography System in Obstructive Sleep Apnea Syndrome

Irem Isik,[1] Serpil Yazgan,[2] Fatma Erboy,[3] Mustafa Dogan[4]

[1]Department of Ophthalmology, Bülent Ecevit University, Faculty of Medicine, Zonguldak, Türkiye
[2]Department of Ophthalmology, Inonu University Faculty of Medicine, Malatya, Türkiye
[3]Department of Thoracic Medicine, Bülent Ecevit University, Faculty of Medicine, Zonguldak, Türkiye
[4]Department of Ophthalmology, Afyon Kocatepe University, Faculty of Medicine, Afyon, Türkiye

Abstract

Objectives: The purpose of the study was to investigate the eyelid hyperlaxity, anterior segment, and corneal topographic parameters in patients with obstructive sleep apnea syndrome (OSAS) using Scheimpflug camera and topography system.

Methods: In this prospective and cross-sectional clinical study, 32 eyes of 32 patients with OSAS and thirty-two eyes of 32 healthy subjects were evaluated. The participants with OSAS were selected from those with an apnea-hypopnea index ≥ 15. The minimum corneal thickness (ThkMin), apical corneal thickness (ACT), central corneal thickness (CCT), pupillary diameter (PD), aqueous depth (AD), aqueous volume (AV), anterior chamber angle (ACA), horizontal anterior chamber diameter (HACD), corneal volume (CV), simulated K readings (sim-K), front and back corneal keratometric values at 3 mm, RMS/A values, highest point of ectasia on the anterior and posterior corneal surface (KVf, KVb), symmetry indices and keratoconus measurements were taken by combined Scheimpflug-Placido corneal topography and compared with healthy subjects. Upper eyelid hyperlaxity (UEH) and floppy eyelid syndrome were also evaluated.

Results: There were no statistically significant difference between groups in terms of age, gender, PD, ACT, CV, HACD, simK readings, front and back keratometric values, RMS/A-KVf and KVb values, symmetry indices, and keratoconus measurements ($p>0.05$). ThkMin, CCT, AD, AV, and ACA values were significantly higher in OSAS group compared to the control ($p<0.05$). UEH was detected in two cases in the control group (6.3%) and in 13 cases in the OSAS group (40.6%) and the difference was significant ($p<0.001$).

Conclusion: The anterior chamber depth, ACA, AV, CCT, and UEH increase in OSAS. These ocular morphological changes occurring in OSAS may explain why these patients prones to normotensive glaucoma.

Keywords: Angle parameters, anterior segment parameters, corneal topography, obstructive sleep apnea syndrome, scheimpflug imaging

Introduction

Obstructive sleep apnea syndrome (OSAS) is a disease characterized by recurrent total or partial upper airway collapse during sleep, interrupting or reducing the airflow, and afterward resulting in temporary awakening which causes restoration of flow of the upper airway (1). These intermittent complete (apnea) or partial (hypopnea) respiratory cessations decrease blood oxygen levels (hypoxia)1. The prevalence of OSAS is between 2% and 10% in females and 4–20% in males and obesity is a major risk factor for the

How to cite this article: Isik I, Yazgan S, Erboy F, Dogan M. Evaluation of Eyelid, Angle, and Anterior Segment Parameters Using Scheimpflug Camera and Topography System in Obstructive Sleep Apnea Syndrome. Beyoglu Eye J 2023; 8(1): 5-13.

Address for correspondence: Serpil Yazgan, MD. Department of Ophthalmology, Inonu University Faculty of Medicine, Malatya, Türkiye
Phone: +90 505 688 39 68 **E-mail:** serpily80@gmail.com

Submitted Date: October 22, 2021 **Revised Date:** January 03, 2023 **Accepted Date:** January 06, 2023 **Available Online Date:** March 01, 2023

Beyoglu Eye Training and Research Hospital - Available online at www.beyoglueye.com

development of OSAS (2). The OSAS diagnosis is based on anamnesis, clinical features, upper airway examination, and polysomnography (PSG) (2). PSG allows to measure apnea-hypopnea index (AHI), number of apnea-hypopnea attacks occurring per hour by recording the frequency of apnea-hypopnea occurring during the night (2). OSAS has been associated with many systemic diseases such as hypertension (HT) and cardiovascular disorders (3). Ocular diseases that are thought to be strongly associated with OSAS are floppy eyelid syndrome (FES), (4) upper eyelid hyperlaxity (UEH), (4,5) keratoconus, (5) konjunctivochalasis, (6) nonarteritic anterior ischemic optic neuropathy (NAION), (7) and normal tension glaucoma (NTG) (8). The researches on the clinical importance of OSAS and the diseases caused by OSAS are increasingly continuing. What inspired this study and led us to investigate the effects of the disease on the cornea and the anterior chamber structure of the eye is the existing relationship between OSAS and eye diseases such as keratoconus and normotensive glaucoma.

In this study, we aimed to compare the corneal topographic parameters and anterior segment findings measured by the combined Scheimpflug-Placido corneal topography method and the upper eyelid changes of the OSAS patients who were grouped according to their AHI with healthy controls.

Methods

In this prospective, cross-sectional, and comparative investigation, 64 right eyes of 64 participants were evaluated at The University, Medical Faculty, Department of Ophthalmology. The University-Local Ethics Committee approved the study protocol (Protokol Number; 2016-58-09.03). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki, and all of the participants provided written informed consent.

The study groups were selected from patients who have been diagnosed with OSAS by PSG in the Sleep Disorder Laboratory of the Department of Thoracic Medicine but have not yet been treated. The control group was selected from healthy volunteers who applied to the ophthalmology outpatient clinic with presbyopic complaints. Both the Berlin questionnaire (9) was applied and a complete physical examination was performed by a thoracic medicine specialist (FE) to the participants to be included in the control group to exclude possible OSAS cases. The subjects who had a total score of <2 in the Berlin questionnaire and had no additional ocular and systemic diseases except controlled HT were included in the control group.

The patients who were <18 years old, who had any corneal diseases, ocular diseases requires continued medication (diseases such as glaucoma, uveitis, dry eyes, etc.), previous operation history of the eye in the past 6 months, contact lens use within last 4 weeks, the best corrected visual acuity (BCVA) <20/30 with spherical and cylindrical refraction exceeding ±3 diopter were excluded from the study. Patients who have systemic diseases that may affect the biomechanics of the cornea, such as Sjögren's Disease, chronic renal failure, diabetes mellitus (DM), liver diseases, chronic obstructive pulmonary diseases, rheumatic, and oncological disorders were also excluded from the study.

The study group was selected according to their AHI value. While mild OSAS cases (AHI <15) were excluded, 32 eyes of 32 patients with moderate to severe OSAS (AHI ≥15; number of moderate case=16 and number of severe case=16) were included in the study (Group 1). The control group was determined as "Group 0" and 32 eyes of 32 patients were recruited in Group 0. Only the right eyes of the subjects were evaluated in both groups.

Ophthalmological Examination

The BCVA examination with Snellen chart, intraocular pressure (IOP) measurement with Goldmann applanation tonometer, biomicroscopic anterior segment examination, and fundus examination were performed by the same ophthalmologist in each patient. Cases detected glaucoma in fundus examination and IOP measurements according to the European Glaucoma Society guidelines (10) were excluded from the study. The eyes of the participants were evaluated for (UEH; easily everted upper eyelids) and FES. It was considered as UEH if tarsal plate turn easily with gentle traction on the upper eyelid. If papillary conjunctivitis was accompanied by UEH, it was defined as FES (11). All ophthalmic examinations and measurements were done for each individual in the identical testing room under standard condition by same experienced person (Il) in the same time zone (between 9 and 12 a.m) without pupil dilation. Participants were also compared with regard to systemic conditions such as systemic HT and body-mass index (BMI). Corneal topography and anterior segment measurements were obtained by the Scheimpflug method by Sirius Topography system (CSO SIRIUS 3D Rotating Scheimpflug Camera and Topography System V.3.2).

Evaluation of the Cornea and Anterior Segment Structures of the Eye by Sirius 3D Rotating Scheimpflug Camera and Topography System

The measurements were obtained by non-contact method by monitoring the corneal apex marked by the device on the computer screen. The measurement process was performed in the first 4–8 s after the eye blink to avoid the adverse effects of the irregularity of the tear film layer. The images obtained after 3 consecutive scans were recorded. The right eyes of participants were compared in terms of

pupillary diameter, aqueous depth (AD), anterior chamber volume (AV), iridocorneal anterior chamber angle (ACA), horizontal anterior chamber diameter (HACD), corneal volume (CV), thinnest point of cornea (ThkMin), apical corneal thickness (ACT), central corneal thickness (CCT), simulated K readings (simK1;horizontal axis and simK2;vertical axis), highest point of ectasia on the anterior corneal surface (KVf-Keratoconus Vertex front), highest point of ectasia on the posterior corneal surface (KVb-Keratoconus Vertexback), the symmetry index of the anterior curvature (SIf-Symmetry Indexfront), the symmetry index of the posterior curvature (SIb-Symmetry Indexback), front and back corneal keratometric values at 3 mm (Ant-K1, Ant-K2, Post-K1, Post-K2 values [K1; horizontal meridian, K2; vertical meridian]), root-mean-square values (RMSf/A6mm and RMSf/A 8mm; Root mean square values of the difference between the altimetry and an aspheric-toric best fit surface in the 6 mm and 8mm zone for the anterior surfaces of cornea, respectively) which are the corneal shape index within 8 mm and keratoconus screening classification values. All parameters listed above were obtained with the Sirius 3D rotating Scheimpflug camera and topography system.

Statistical Analysis

Statistical analyses were performed using Statistical Package for the Social Sciences 19.0 software. According to the power analysis, it was determined by taking α=0.05 and 1-β (power)=0.80, and it was calculated that at least 32 subjects were needed to compare the parameters. Continuous variables were expressed as mean±standard deviation or median (minimum–maximum), and categorical variables as frequency and percent. Distribution of data was determined by Shapiro-Wilk's test. Pearson Chi-square test and Yates Chi-square test were used to determine the difference between groups for categorical variables. Continuous variables were compared with independent sample t test or the Mann-Whitney U test according to the distribution. P-value of <0.05 was considered statistically significant for all tests.

Results

There was no difference in age and gender between groups [p=0.442, p=0.534, respectively, Table 1]. The rate of systemic HT and BMI was observed significantly higher in OSAS group than in the control [p=0.046, p<0.001, respectively, Table 1]. There was also no significant difference between groups regarding IOP (p=0.483). UEH was detected in 2 cases (6.3%) in the control group and in 13 cases (40.6%) in the OSAS group, and the difference was statistically significant (p<0.001). FES was not detected in the groups.

Keratoconus screening parameters and shape indices such as SIf, SIb, KVf, KVb, RMSf /A-6 mm, and RMSf /A-8 mm were not significantly different between the groups

Table 1. Comparison of the groups in terms of demographic conditions and upper eyelid hyperlaxity

	Age, year, median (min-max)	Gender Female, n (%) Male, n (%)	BMI median (min-max)	HT, n (%)	IOP, mmHg Median (min-max)	UEH, n (%)	Spherical RE, median (min-max)	Cylindrical RE, median (min-max)
Group 0 (n=32)	51 (40–70)	8 (25) 24 (75)	24.6 (18.2–27.8)	3 (9.4)	16 (12–24)	2 (6.3%)	0.50 ([–2.00]–1.75)	[–0.25] ([–2.50]–1.75)
Group 1 (n=32)	53 (30–76)	6 (16.1) 26 (81.2)	31.2 (24.3–64.5)	9 (28.1)	16 (10–22)	13 (40.6%)	0.25 ([–1.75] –2.00)	[–0.50] ([–2.50]–2.00)
p	0.442*	0.534**	<0.001*	0.046**	0.483*	<0.001**	0.576*	0.796*

Group 0: Control group, Group 1: OSAS group, BMI: body mass index, HT: hypertension, UEH: upper eyelid hyperlaxity, RE: Refractive error. * The Mann–Whitney U test, ** Pearson Chi-square test or Fisher's Exact test.

(p>0.05) (Table 2). No keratoconus was observed in the OSAS and control groups. There was no significant difference in the rate of suspicion of keratoconus between the two groups (p=0.554) (Table 2). The ThkMin and CCT values were significantly higher in OSAS group [p=0.05 and p=0.049, respectively, Tables 2 and 3, Fig. 1]. No significant difference detected between groups for pupil diameter, ACT, simulated K values (Sim-k1 and Sim-k2), horizontal and vertical keratometry values in the 3 mm zone of the corneal anterior surface and in the 3 mm zone of the corneal posterior surface (Ant-K1, Ant-K2, Post-K1, and Post-K2) and HACD (p=0.395, p=0.501, p=0.101, p=0.088, p=0.092, p=0.153, p=0.294, p=0.205, and p=0.124, respectively) (Tables 2 and 3).

However, there was a significant difference between

Table 2. Comparison of the groups with regard to keratoconus screening parameters and shape indices

Parameters	Group 0 (n=32)	Group 1 (n=32)	p
SIb, diopter, median (min-max)	0.01 ([–0.16]–0.40)	0.00 ([–0.33]–0.29)	0.503*
KVf, µm, median (min-max)	5 (2–15)	5 (2–28)	0.791*
KVb, µm, median (min-max)	10 (7–31)	11 (6–34)	0.331*
RMSf/A (6mm), median (min-max)	0.03 (0.02–0.11)	0.03 (0.02–0.19)	0.508*
RMSf/A (8 mm), median (min-max)	0.06 (0.03–0.14)	0.05 (0.03–0.28)	0.647*
ThkMin, µm, median (min-max)	535 (472–591)	555 (456–608)	0.050*
keratoconus suspect, n (%)	2 (6.8)	1 (3.2)	0.554**
Sim-k1, diopter (median (min-max)	43.07 (41.05–46.52)	42.32 (40.19–45.17	0.101*
Sim-k2, diopter, median (min-max)	43.84 (41.75–47.38)	42.94 (40.51–45.66)	0.088*
Ant-K1, diopter, median (min-max)	43.09 (41.16–46.55)	42.48 (39.35–45.12)	0.092*
Ant-K2,diopter, median (min-max)	44.05 (41.89–47.51)	43.11 (40.34–45.96)	0.153*
Post-K1, diopter, median (min-max)	[–6.00] ([–6.55]–[–5.54])	[–5.96] ([–6.43]–[–5.49])	0.294*
Post-K2, diopter, median (min-max)	[–6.30] ([–6.92]–[–5.93])	[–6.23] ([–6.97]–[–5.82])	0.205*

SIf: The Symmetry Index of the anterior curvature, SIb: The Symmetry Index of the posterior curvature, KVf: Highest point of ectasia on the anterior corneal surface, KVb: Highest point of ectasia on the posterior corneal surface, RMSf/A (6mm): Root mean square value of the difference between the altimetry and an asphero-toric best fit surface in the 6 mm zone for the anterior surfaces of cornea. RMSf/A (8mm): Root mean square value of the difference between the altimetry and an asphero-toric best fit surface in the 8 mm zone for the anterior surfaces of cornea, ThkMin: Thinnest point of cornea, simK1: simulating keratometric value of the horizontal meridien, simK2: simulating kreatometric value of the vertical meridien, Ant-K1: keratometric value of the horizontal meridian in the 3 mm zone for the anterior surface of cornea., Ant-K2: keratometric value of the vertical meridian in the 3 mm zone for the anterior surface of cornea, Post-K1: keratometric value of the horizontal meridian in the 3 mm zone for the posterior surface of cornea, Post-K2: keratometric value of the horizontal meridian in the 3 mm zone for the posterior surface of cornea. *The Mann–Whitney U test, **Pearson Chi-square test or Fisher's Exact test.

Table 3. Comparison of the groups for angle and the other anterior segment parameters

Parameters	Group 0	Group 1	p*
PD (mm), median (min-max)	2.97 (2.11–3.60)	3.06 (2.06–3.88)	0.395
ACT (µm), median (min-max)	569 (554–688)	570 (495–639)	0.501
CCT (µm), median (min-max)	537 (470–600)	559 (460–610)	0.049
AD (mm), median (min-max)	2.64 (1.90–3.15)	2.90 (2.12–4.44)	0.012
AV (mm^3), median (min-max)	124 (82–171)	141 (97–199)	0.034
ACA (degree), median (min-max)	37 (27–47)	45 (28–63)	<0.001
HACD (mm), median (min-max)	11.68 (11.01–12.64)	11.90 (10.47–12.80)	0.124
CV (mm^3), median (min-max)	56.00 (51.30–65.80)	58.3 (51.40–65.00)	0.064

PD: Pupil diameter, ACT: Apical corneal thickness, CCT: Central corneal thickness, AD: Aqueous depth, AV: Anterior chamber (aqueous) volume, ACA: Iridocorneal (anterior chamber) angle, HACD: Horizontal Anterior Chamber Diameter. CV: Corneal Volume (indicates the corneal volume within a diameter equal to 10 mm), *The Mann–Whitney U test.

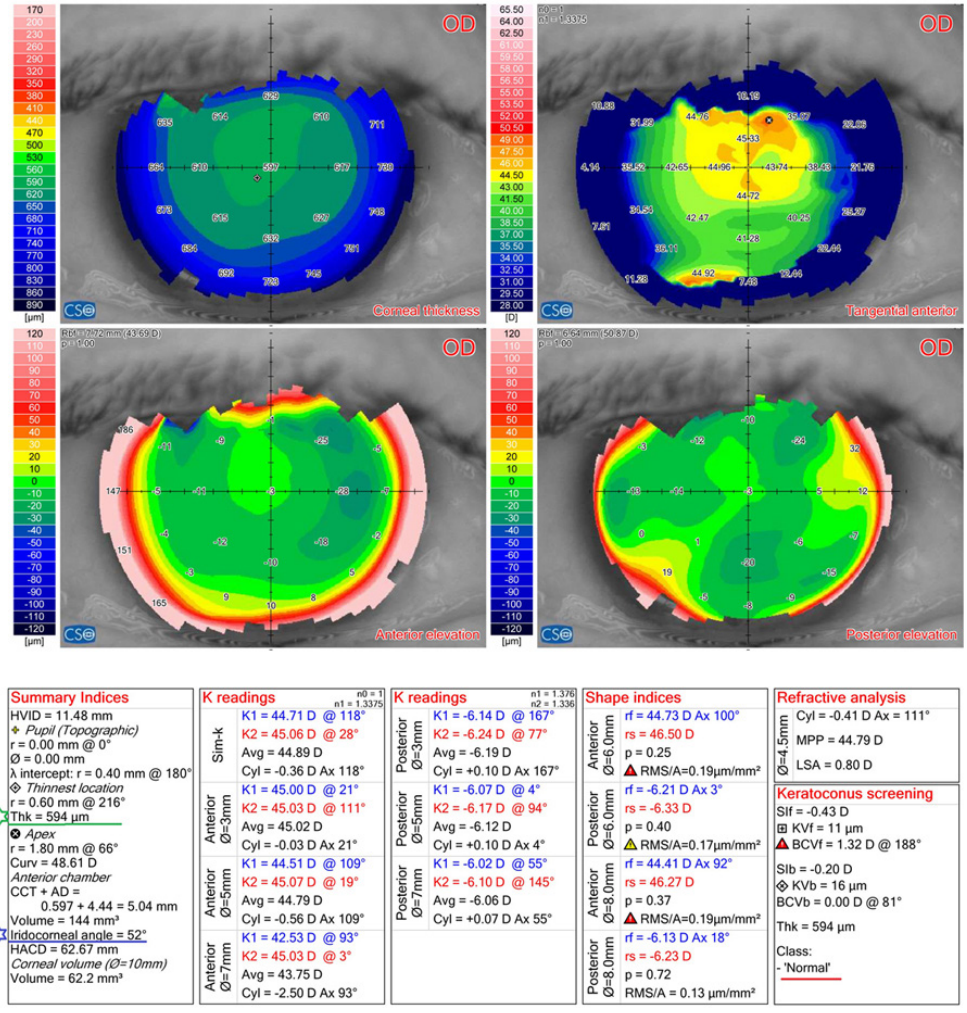

Figure 1. Scheimpflug camera and topography system images of the right eye of a patient with severe OSAS. This image shows pachymetric and refractive maps of the cornea, anterior and posterior elevation maps, and all global measurement results, including anterior segment parameters. In this eye, it is seen that the minimum corneal thickness (Thkmin) value is 594 micrometers (green asterix and line) and the iridocorneal angle value is 52° (blue asterix and line). It is also seen in the measurement results that the keratoconus screening classification of this eye is "normal" (red line).

groups in terms of AD, aqueous volume (AV) and ACA (p=0.012, p=0.034, and p<0.001, respectively) (Table 3 and Fig. 2). The CV value is higher in OSAS grup; however, the significance was not different [p=0.064, Table 3].

Discussion

It is thought that the health of many organs, especially the cardiovascular system and eye, is affected during hypoxia-hypercarbia attacks in OSAS (3). In cases with OSAS, there is an increase in eyelid and corneal diseases such as UEH, FES, conjunctivochalasis and keratoconus, as well as the frequency of ocular diseases such as NAION and NTG, which are thought to be of vascular origin (4-8). In our study, systemic HT rate and BMI values were found to be higher in the OSAS group, as expected (1-3). IOP measurement was made in the morning hours (between 9 and 12 am) in our study, and there was no significant difference between groups in terms of IOP values. Studies have shown that OSAS patients have high nocturnal IOP values, whereas IOP measured during the day are within normal limits (11). Since our primary aim was not to detect NTG cases, we did not apply RNFL analysis or visual field examinations to OSAS cases. We measured IOP and evaluated the optic nerve in the non-dilated fundus examination to exclude glaucoma cases from the study. The purpose of excluding the cases with glaucoma in the study was not to disturb the standardization in the study groups.

One of the surprising results in our study was that the rate of FES and UEH in OSAS cases was not as high as stated in some studies (12,13). FES was not detected in OSAS and control group; however, the rate of UEH was significantly

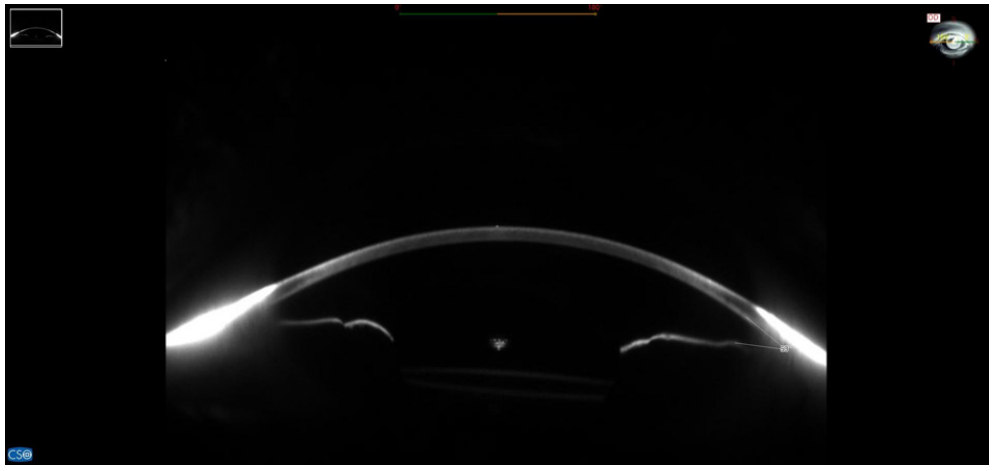

Figure 2. Scheimpflug camera system image of the right eye of the same patient (Fig. 1).This image shows the horizontal section of the anterior segment and the angle region (iridocorneal angle value is 52°).

higher OSAS group (40.6%) than control (6.3%) in our study. In a study conducted by Chambe et al., (12) they investigated FES rate of patients who applied to the sleep clinic. They have found that the rate of FES were 15.8% in 38 patients who were not diagnosed with OSAS, 25.8% in 69 patients with mild-moderate OSAS (AHI value of 5–30), and 40% in 20 patients with severe OSAS (AHI> 30). In the same study, it was stated that the rate of UEH was 70% in severe OSAS cases, and this rate was almost twice the result of our study. However, the rate of FES detected in cases without OSAS in this study was also quite high. In our study, contrary to that study, the number of OSAS cases comprised both moderate and severe OSAS equally. In a meta-analysis study by Fowler et al. (13) investigating the causes of FES and eyelid laxity, they found that the rate of eyelid laxity in OSAS cases was 16%. In the same study, this rate was 6.8% in keratoconus patients and that the eyelid laxity syndrome showed a significant association with the patient's side of sleeping preference. In another case report, floppy eyelid and superficial punctate keratopathy were detected in a child with OSAS with adenoid hypertrophy, and the family stated that the child had a habit of sleeping in the prone position (14). In the most studies investigating the relationship between eyelid hyperlaxity syndrome and OSAS, it was associated the increased FES rate in OSAS with the increment in matrix metalloproteinase activity triggered by reasons such as hypoxia-reperfusion damage, leptin resistance or mechanical friction, and elastin breakdown in tars tissue (15). In fact, the reasons such as the mechanical friction of the eyelid to the surface due to the sleeping position (formed by the prone or side sleeping position) that creates pressure on the eye are discussed in the etiology of UEH and FES (16). As a matter of fact, some studies have shown that the frequency of apnea-hypopnea attacks increases in the supine position (17). For this reason, it has been determined that obese children with OSAS prefer prone sleep posture most frequently to reduce snoring and apnea-hypopnea attacks while sleeping at night (18). Some studies have shown that FES was more severe in the eye corresponding to the side where the patient prefers to sleep (16). In fact, the prone sleeping position not only causes mechanical friction on the eyelid, but also means that the cornea and globe are exposed to chronic pressure overnight. Thus, with the effect of gravity and pressure, the weight of the globe overlaps the anterior chamber structure of the eye. In dynamic MRI, it has been shown how short--term eye scratching compresses the globe and anterior chamber, and changes the shape of the globe (19).

When we evaluated the results of our study, it was observed that the ACA widened, AD and AV increased, and central cornea thickened in the OSAS group. We could not find any study in the literature that confirms our findings or defends the opposite result. We thought that these results we obtained could be explained by the sleeping position of the patients. Unfortunately, as our patients' sleep position preferences are not questioned, we are unable to provide information on this issue. For this reason, we felt the need to review the publications on the general sleep position preferences of OSAS patients (17,18,20). Because sleeping in the prone position may cause the anterior chamber fluid to move to the iridocorneal angle by pressing the center of the globe, thus causing both the angle to be enlarged and the IOP to be at high levels. When the compression effect disappears during the day, IOP can be measured at normal levels, but the ACA and corneal changes we obtained in our study may become permanent with the effect of chronic nocturnal globe pressure. Thus, high IOP values during the night may occur in eyes exposed to chronic pressure in OSAS. Of course, in the light of the data of our study, there is a need for clinical studies investigating the effects of sleeping in the prone position on the shape

of the globe. OSAS cases with a diagnosis of glaucoma and glaucoma suspected were not included in our study to homogenize the study groups and avoid bias. Because the main subject of this study was to examine the changes in cornea and anterior segment parameters in patients with moderate and severe OSAS, nocturnal IOP measurements were also not performed. In a study performed by Carnero et al., (11) the nocturnal IOP values of patients with OSAS were investigated using a contact lens sensor. In this study, 20 cases with OSAS were divided into two groups according to their AHI index, and they stated that in severe OSAS cases with an AHI index of >30, IOP elevation (acrophase) occurred for a long time in the nocturnal period. This study also showed us that the main cause of glaucomatous optic nerve damage in OSAS cases may be the IOP values that rise at night and remain high for a long time. Fang et al. (20) stated that IOP is significantly higher not only in the prone position but also in the supine position compared to the upright posture in OSAS. In a study by Lee et al. (21) in which they evaluated IOP according to the lying position, they measured IOP in the supine position and right and left lateral decubitus positions. According to the results of that study, while no significant increase in IOP was detected in the supine position, IOP increased significantly in the lateral decubitus postures regardless of the side. The objective changes in angle parameters of OSAS cases we detected in our study actually support that glaucoma occurring in OSAS may cause by mechanical reasons rather than vascular theory. In a study of 7 cases using contact lens sensor, it was shown that IOP decreased during apnea attacks in patients with OSAS; therefore, typical glaucomatous optic nerve changes that are thought to occur due to IOP elevation cannot be explained solely by hypoxia attacks and vascular theory in OSAS (22). In addition, Cohen et al. (23) investigated the effect of nocturnal continuous positive airway pressure (CPAP) treatment on the IOP of OSAS cases. In that study, it was determined that OSAS patients had high nocturnal IOP measurements; however, CPAP treatment had no therapeutic effect on nocturnal IOP values. The result of that study is another proof the nocturnal IOP elevation in OSAS cases cannot be explained by vascular theory alone. In fact, the changes in angle parameters of patients with OSAS detected in our study and the glaucomatous damage occurred in OSAS may also be explained by the increase in episcleral venous pressure caused by globe compression. A matter of course, our hypotheses that we put forward to reveal the causes of anterior segment changes in OSAS cases need to be proven by further clinical studies.

Other clinical results in our study that contradicted the literature results were that there was no difference between the OSAS group and the control group regarding keratoconus screening parameters and corneal shape indices such as SIf, SIb, KVf, KVb, RMSf /A-6 mm, and RMSf/A-8 mm values (5,24). In many studies investigating the relationship between OSAS and keratoconus, OSAS and eyelid laxity were investigated in cases with keratoconus (5,24). We investigated the presence of keratoconus in OSAS cases contrary to those studies, and we limited the refractive error value of the groups up to 3 diopters in our study. Therefore, the lack of significant difference between our study groups in terms of keratoconus and topographic parameters may have resulted from this refractive limitation. In a study by Pihlblad et al. (5) in which they investigated OSAS, eyelid laxity and keratometric parameters in keratoconus patients, they found an increase in corneal diameter in keratoconus patients with OSAS. In our study, corneal diameter was not evaluated, however, HACD and CV were found to be higher in cases with OSAS, although the difference was not statistically significant.

In OSAS cases, we expected corneal thinning due to the sleeping position and chronic mechanical friction. However, according to our study results, in contrast to keratoconus disease, we found an increase in CCT and minimal corneal thickness (ThkMin) values in OSAS cases. We made our examinations between 09.00 and 12.00 a.m to make homogeneous measurements in participants. The difference between IOP values in the both prone and supine sleeping position and the IOP values in the sitting position of OSAS cases is significantly higher than in the normal control group (20). OSAS cases have prolonged nocturnal IOP elevation secondary to increased episcleral pressure. In healthy people, corneal thickening is observed due to hydration in the morning hours compared to the later hours of the day (25,26). Although the expected situation in pseudoexfoliative syndrome (PEXS) is thinning of the cornea, studies have shown that diurnal corneal thickness fluctuations and increased corneal thickness values in the morning are much higher in patients with PEXS (27,28). Prolonged nocturnal IOP elevation may be the reason for the increased corneal thickness in OSAS cases, we observed in our study as shown in PEX cases. Further clinical studies are needed to elucidate this issue.

Thus, one of the limitations of our study is that it is not compared with morning data by making measurements again in the afternoon. We included only moderate and severe OSAS cases with an AHI index ≥15 to the study group to strengthen our findings. Due to the effects of DM on corneal biomechanics and increased glycosylation augments corneal collagen stability we excluded the patients with DM, which has a high rate of association with OSAS (29,30).

Conclusion

According to the data we obtained in current study, the ACA widened and the anterior chamber depth and volume increased in cases of moderate and severe OSAS. These mechanical changes occurred in the eye may responsible for NTG in OSAS. For this reason, IOP monitoring of patients with OSAS who have NTG in their natural sleeping positions during nocturnal period becomes important. Thus, if IOP increase occurs depending on the sleeping positions, this situation can be detected and glaucoma can be prevented in these cases by changing sleeping posture or developing a method to prevent this situation.

Disclosures

Ethics Committee Approval: The study was approved by the Bülent Ecevit University Clinical Research Ethics Committee (no: 2016-58-09/03).

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Funding: This research has earned no particular grant from any state, commercial, or non-profit funding agency.

Acknowledgments: We appreciate to Mustafa Çağatay Büyükuysal for statistical evaluation of the article data.

Authorship Contributions: Conception: S.Y.; Design – S.Y., M.D.; Supervision – S.Y., M.D.; Materials – F.E.; Data Collection and/or Processing – I.I., F.E.; Analysis and/or Interpretation – S.Y., I.I.; Literature Search – S.Y., I.I.; Writing – I.I., S.Y.; Critical Reviews – S.Y., M.D.

References

1. Yaggi HK, Strohl KP. Adult obstructive sleep apnea/hypopnea syndrome: Definitions, risk factors, and pathogenesis. Clin Chest Med 2010;31:179–86. [CrossRef]
2. Jordan AS, McSharry DG, Malhotra A. Adult obstructive sleep apnoea. Lancet 2014;383:736-47. [CrossRef]
3. Gonzaga C, Bertolami A, Bertolami M, Amodeo C, Calhoun D. Obstructive sleep apnea, hypertension and cardiovascular diseases. J Hum Hypertens 2015;29:705–12. [CrossRef]
4. Mojon DS, Goldblum D, Fleischhauer J, Chiou AG, Frueh BE, Hess CW, et al. Eyelid, conjunctival, and corneal findings in sleep apnea syndrome. Ophthalmology 1999;106:1182–5. [CrossRef]
5. Pihlblad MS, Schaefer DP. Eyelid laxity, obesity, and obstructive sleep apnea in keratoconus. Cornea 2013;32:1232–6. [CrossRef]
6. Acar M, Firat H, Yüceege M, Doğan AS, Çalişkan S, Gürdal C. The presence of conjunctivochalasis in obstructive sleep apnea patients. Eye Contact Lens 2018;44:S163–6. [CrossRef]
7. Aptel F, Khayi H, Pépin JL, Tamisier R, Levy P, Romanet JP, et al. Association of nonarteritic ischemic optic neuropathy with obstructive sleep apnea syndrome: Consequences for obstructive sleep apnea screening and treatment. JAMA Ophthalmol 2015;133:797–804. [CrossRef]
8. Chuang LH, Koh YY, Chen HSL, Lo YL, Yu CC, Yeung L, et al. Normal tension glaucoma in obstructive sleep apnea syndrome: A structural and functional study. Medicine (Baltimore) 2020;99:e19468. [CrossRef]
9. Netzer NC, Stoohs RA, Netzer CM, Clark K, Strohl KP. Using the Berlin Questionnaire to identify patients at risk for the sleep apnea syndrome. Ann Intern Med 1999;131:485–91. [CrossRef]
10. Terminology and Guidelines for Glaucoma. European Glaucoma Society. 5th ed. Available from: https://www.eugs.org/eng/egs_guidelines_download.asp
11. Carnero E, Bragard J, Urrestarazu E, Rivas E, Polo V, Larrosa JM, et al. Continuous intraocular pressure monitoring in patients with obstructive sleep apnea syndrome using a contact lens sensor. PLoS One 2020;15:e0229856. [CrossRef]
12. Chambe J, Laib S, Hubbard J, Erhardt C, Ruppert E, Schroder C, et al. Floppy eyelid syndrome is associated with obstructive sleep apnoea: A prospective study on 127 patients. J Sleep Res 2012;21:308–15. [CrossRef]
13. Fowler AM, Dutton JJ. Floppy eyelid syndrome as a subset of lax eyelid conditions: Relationships and clinical relevance (an ASOPRS thesis). Ophthalmic Plast Reconstr Surg 2010;26:195–204. [CrossRef]
14. Gao YY, Wang HJ, Wu Y. Superficial punctate keratopathy in a pediatric patient was related to adenoid hypertrophy and obstructive sleep apnea syndrome: A case report. BMC Ophthalmol 2018;18:55. [CrossRef]
15. Idowu OO, Ashraf DC, Vagefi MR, Kersten RC, Winn BJ. Floppy eyelid syndrome: Ocular and systemic associations. Curr Opin Ophthalmol 2019;30:513–24. [CrossRef]
16. Miyamoto C, Espírito Santo LC, Roisman L, Moreno Pde A, Cariello AJ, Osaki MH. Floppy eyelid syndrome: Review. Arq Bras Oftalmol 2011;74:64–6. [CrossRef]
17. Yalciner G, Bababemez MA, Gul F. Association of sleep time in supine position with apnea-hypopnea index as evidenced by successive polysomnography. Sleep Breath 2017;21:289–94.
18. Dayyat E, Maarafeya MM, Capdevila OS, Kheirandish-Gozal L, Montgomery-Downs HE, Gozal D. Nocturnal body position in sleeping children with and without obstructive sleep apnea. Pediatr Pulmonol 2007;42:374–9. [CrossRef]
19. The Keratoconus Diary. Available from: https://www.defeatkeratoconus.com/imaged-impact-of-eye-rubbing.
20. Fang SY, Wan Abdul Halim WH, Mat Baki M, Din NM. Effect of prolonged supine position on the intraocular pressure in patients with obstructive sleep apnea syndrome. Graefes Arch Clin Exp Ophthalmol 2018;256:783–90. [CrossRef]
21. Lee TE, Yoo C, Lin SC, Kim YY. Effect of different head positions in lateral decubitus posture on intraocular pressure in treated patients with open-angle glaucoma. Am J Ophthalmol 2015;160:929–36.e4. [CrossRef]
22. Shinmei Y, Nitta T, Saito H, Ohguchi T, Kijima R, Chin S, et al. Continuous intraocular pressure monitoring during nocturnal sleep in patients with obstructive sleep apnea syndrome. Invest Ophthalmol Vis Sci 2016;57:2824–30. [CrossRef]

23. Cohen Y, Ben-Mair E, Rosenzweig E, Shechter-Amir D, Solomon AS. The effect of nocturnal CPAP therapy on the intraocular pressure of patients with sleep apnea syndrome. Graefes Arch Clin Exp Ophthalmol 2015;253:2263–71. [CrossRef]
24. Saidel MA, Paik JY, Garcia C, Russo P, Cao D, Bouchard C. Prevalence of sleep apnea syndrome and high-risk characteristics among keratoconus patients. Cornea 2012;31:600–3. [CrossRef]
25. Hamilton KE, Pye DC, Aggarwala S, Evian S, Khosla J, Perera R. Diurnal variation of central corneal thickness and Goldmann applanation tonometry estimates of intraocular pressure. J Glaucoma 2007;16:29–35. [CrossRef]
26. Shao P, Seiler TG, Eltony AM, Ramier A, Kwok SJJ, Scarcelli G, et al. Effects of corneal hydration on brillouin microscopy *in vivo*. Invest Ophthalmol Vis Sci 2018;59:3020–7. [CrossRef]
27. Syed Z, Srikanth K, Nagarajan S. Diurnal variation of central corneal thickness and intraocular pressure in eyes with pseudoexfoliation. Indian J Ophthalmol 2019;67:1607–9. [CrossRef]
28. Inoue K, Okugawa K, Oshika T, Amano S. Morphological study of corneal endothelium and corneal thickness in pseudoexfoliation syndrome. Jpn J Ophthalmol 2003;47:235–9. [CrossRef]
29. Yazgan S, Celik U, Kaldırım H, Ayar O, Elbay A, Aykut V, et al. Evaluation of the relationship between corneal biomechanic and HbA1C levels in Type 2 diabetes patients. Clin Ophthalmol 2014;8:1549–53. [CrossRef]
30. McKay TB, Priyadarsini S, Karamichos D. Mechanisms of collagen crosslinking in diabetes and keratoconus. Cells 2019;8:1239. [CrossRef]