Acıbadem Univ. Sağlık Bilim. Derg. 2025; 16 (2)
https://doi.org/10.31067/acusaglik.1409550

ORIGINAL ARTICLE / ARAŞTIRMA YAZISI

Ophthalmology / Göz Hastalıkları

Investigation of Corneal Changes in Contact Lens Users

Mübeccel Bulut[1], Ayşe Sevgi Karadağ[2]

[1] Kahramanmaraş Necip Fazıl City Hospital, Department of Ophtalmology, Kahramanmaraş, Turkey

[2] İstanbul Dunya Göz Hospital, Department of Ophtalmology, İstanbul, Turkey

Mübeccel BULUT
0000-0003-1311-2282

Ayşe Sevgi KARADAĞ
0000-0002-7662-6531

Correspondence: Mübeccel Bulut
Kahramanmaraş Necip Fazıl City Hospital, Department of Ophtalmology, Kahramanmaraş, Turkey
Phone: +90 344 228 28 00
E-mail: mubeccelbagdas@gmail.com

Received: 25.12.2023
Accepted: 16.12.2024

ABSTRACT

Purpose: Analysed the effects of contact lens use on the structural characteristics of the cornea.

Methods: Corneal changes analized by OCT, topography and specular microscope. Schirmer test was performed.

Results: Epithelial thickness, posterior K2, the number of endothelial cells and their density were found to be different in lens users and control group. When subgrouped according to duration of lens, endothelial cell numbers were statistically different between subgroups.

Conclusion: Silicon hydrogel lenses have hypoxic effects on the corneal structure. Recently refractive surgery has become popular. Most patients who want to undergo refractive surgery have used contact lenses in the past. That's why it's important to know the effect of contact lenses on the corneal structure.

Keywords: Anterior segment OCT, Contact Lens, Sirius topography, Specular microscopy

ÖZET

Amaç: Kontakt lens kullanımının, korneanın yapısal özellikleri üzerindeki etkilerini, değerlendirmek.

Metodlar: Kornea değişiklikleri; OCT(Optik Koherens Tomografi) kornea topografisi ve speküler mikroskopi kullanılarak analiz edildi. Schirmer testi yapıldı.

Bulgular: Gruplar arasında; posterior K2, epitel kalınlığı, endotel hücre sayısı ve endotel hücre yoğunluğu farklı bulundu. Kontakt lens kullanıcıları lens kullanım sürelerine göre gruplandırıldığı zaman endotel hücre sayıları farklılık gösterdi.

Tartışma: Silikon hidrojel lenslerin kornea yapısına hipoksik etkileri vardır. Son zamanlarda refraktif cerrahi oldukça populer hale gelmiştir. Refraktif cerrahi olmak isteyen hastaların bir çoğu geçmişinde kontakt lens kullanmıştır. Bu nedenle kontakt lenslerin korneaya olan etkilerini bilmek önemlidir.

Anahtar Kelimeler: Ön segment OKT, Kontakt Lens, Sirius topografisi, speküler mikroskopi

Cornea has an important role in the formation of visual function. Stroma, which creates about 90% of the cornea, is the main component that determines the mechanical and refractive characteristics of the cornea(1).The maintenance of hydration in the stroma is largely dependent on endothelial activity. The endothelium sustains the osmotic gradient required for this function through Na-K ATPases and carbonic anhydrase enzymes. The number (500 cells/mm^2) and morphology of the endothelial cells are critical for the transparency of the cornea. The increase in the cell size (polymegathism) and the differences in cellular shape (pleomorphism) also affect the endothelial function(2).

Contact lenses leads to hypoxi for cornea and adversely affects oxygen-dependent metabolic activity(1). Hypoxia converts the corneal metabolism, which is normally aerobic, to anaerobic glycolysis, resulting in the backlog of lactic acid in the stroma. Lactic acid affects endothelial morphology and function by creating edema and stromal acidosis. Long-term persistent stromal edema causes changes in keratocyte morphology and function(3,4).

Contact lenses have been used to correct refractive errors since the early 19th century. Gas-permeable hard contact lenses and soft hydrogel lenses were introduced in the 1970s, and starting from 1998, high-permeability silicon hydrogel lenses have been widely used(5,6).

PMMA is the first material to be used for contact lens production. It is durable, transparent and highly wettable; however, due to its relatively high hypoxic activity, it is not preferred for lens manufacturing nowadays. The most commonly used rigid, gas permeable lenses are silicone acrylates, because of their high oxygen permeability due to silicone and optical transparency provided by PMMA(7,8).

Soft contact lenses are made of hydrogels and silicone hydrogels. Hydrogel lenses have water-retaining ability. This ability enables improvement in oxygen permeability, elasticity, light refractive strength and tensile strength(9,10). Silicone hydrogel lenses are produced by combining the water retention property of the hydrogel with the oxygen permeability of the silicone. Lotrafilcon A and Balafilcon A are the first silicone hydrogel lenses(11).

Hypoxic effects such as thinning in the corneal epithelium, limbal hyperemia and vascularization, microcyst formation, stromal thinning, and alteration of endothelial morphology that are observed after the use of hydrogel contact lenses were not observed in patients who use of silicone hydrogel lenses(12,13).

Modulus is a parameter which shows the deformation resistance of the contact lens and its mechanical properties. High modulus silicone hydrogel lenses are more rigid and resistant to deformation. High modulus lenses do not fully fit on the surface of the cornea and conjunctiva, which causes them to form a variable aqueous phase profile, particularly pronounced in the midperifera, and reflect the valve pressure more. As a result of contact between the protective mucin layer and lens epithelium, they may cause damage to the epithelium(14).

Material and Methods

95 patients with refractive error, who have been using contact lenses for at least 3 months and a minimum of 8 hours a day were analyzed (Group 1). Patients who has any ocular surface diseases, corneal ectasia diseases, degenerative myopia, a cylindrical refraction defect of more than -2 degrees, and ocular trauma or surgery were not included. 95 patients were divided to groups according to duration of lens use. Patients who used lenses for 18 months or less were called Group 3, who used lenses for 19 months or more called Group 4. The patients had removed their lenses 8-12 hours before the examination. Measurements were performed in the morning to prevent diurnal effect. Control group consisting of 95 subjects who applied to our clinic and did not have any pathology in ophthalmologic examination (Group 2).

Stromal and epithelial thickness was measured with Heidelberg Spectralis Optical Coherence Tomography anterior segment module (AS – OCT (Heidelberg Engineering, Germany). Thickness were measured by using the central cornea typical vertex reflex by the same trained personnel.

Central corneal thickness(CCT), posterior K1 and K2 were obtained with the Sirius® topography(Costruzione Strumenti Ophthalmici, Florence, Italy). Endothelial values were obtained using a Nidek Cem 530 specular microscope. Schirmer test was performed without using topical anesthesia and the eye was closed for 5 minutes after placement of a tape at the junction of the lateral and middle one third of the conjunctival sac. Five minutes later, the amount of wetting in the strip was recorded in millimeters.

Statistical Analysis

SPSS for Windows 21.0 was used for analysis. Mean, standard deviation, frequency and percentage values were used to evaluate the study data. The Kolmogorov-Smirnov test was used to determine whether the quantitative data met the normal distribution parameters. In the comparison of the two groups, t-test was used to compare the normally distributed variables and Mann-Whitney U test was used for the non-normally distributed variables. In comparison of more than two groups, Kruskal-Wallis test was used for variables with normal distribution and ANOVA with non-normal distribution. Chi-square test was used to compare categorical data. P <0.05 was considered statistically significant.

Results

21 were male and 74 were female in group 1. 23 were male and 72 were female in group 2. The mean age of 22.8 in group 1, and 23.8 in group 2. Terms of gender distribution and mean age were similar in groups. The mean CCT was 538.02 µm, 5.72 D for posterior K1, and 6.32 D posterior K2 in group 1. In group 2, mean values were 535.09 µm for CCT, 5.76 D for posterior K1, and 6.13 D for posterior K2(**Table 1**). Posterior K2 was statistically significant ($p<0.05$).

Table 1: The comparison of topographic values of Groups 1 and 2

	Group	Number	Mean	Std. Dev.	T-test value	P value
CCT	1	190	538.02	35.69	0.92	0.35
	2	190	535.09	33.86		
postk1	1	190	5.72	0.32	-1.14	0.25
	2	190	5.76	0.23		
postk2	1	190	6.32	0.52	4.50	0.00
	2	190	6.13	0.25		

CCT: central corneal thickness, postk: posterior keratometry, std:standard

Table 2: The comparison of schirmer, anterior segment OCT, specular values between groups

	Group	Number	Mean	Std. Dev.	t-test value	p value
Schirmer	1	190	22.73	8.29	0.33	0.73
	2	190	22.42	9.31		
Stromal t	1	190	446.69	36.29	0.54	0.53
	2	190	459.66	35.68		
Epithelial thickness	1	190	27.76	5.93	-2.88	0.00
	2	190	29.73	7.22		
Hex. cell	1	190	68.44	4.89	-0.53	0.59
	2	190	68.72	5.43		
Endothel den	1	190	2772.40	247.69	2.39	0.01
	2	190	2709.80	261.16		
Endothelial cell number	1	190	214.13	48.22	6.79	0.00
	2	190	180.77	47.43		

stromal t: stromal thickness, Hex: hexagonal, Endothel den: endothelial cell density

Epithelial thickness was 27.7 µm in group 1 and 29.7 µm in the group 2, and the difference was statistically significant. Endothelial density was 2772 in group 1 and 2709 in group 2, and there was a significant difference. Endothelial counts of the two groups, which were 214.1 in group 1 and 180.7 in group 2, were also statistically significantly different. On the other hand, the hexagonal cell count, stromal thickness and schirmer test results were similar between groups. (**Table 2**).

Patients wearing contact lens were further divided into 2 subgroups according to the duration of lens use. Group 3 consisted of 50.5% of the cases (48 cases), while Group 4 was 49.5% (47 cases). The mean age of Group 3 was 21.52 ± 3.31 years, and of these patients 18.75% were men and 81.25% were women. Similarly, the mean age of group 4 was 24.19 ± 4.99 years and of these 25.53% were men and 74.47% were women. Gender ratios were similar between the groups.

In Group 3; 23.78 for schirmer, 534 µm for CCT, 5.77 D for posterior K1, 6.37 D for posterior K2, 27.64 µm for epithelial thickness, 456.90 µm for stromal thickness, 68.79 for hexagonal cell ratio, 2784.7 for endothelial cell density, and 214.13 for endothelial number. In Group 4, 21.65 for schirmer, 542.89 µm for CCT, 5.68 D for posterior K1, 6.26 D for posterior K2, 27.88 µm for epithelial thickness, 466.48 µm for stromal thickness, 68.08 for hexagonal cell ratio, 2759.8 for endothelial cell density, and endothelial number was 188.99. Between Groups 3 and 4, there was only a difference between the endothelial cell numbers (**Table 3**).

Table 3: The comparison of topographical, specular and OCT values between Groups 3 ve 4

	Duration of contact lens wear	Number	Mean	SD	t test value	P value
Schirmer	0-18 months	96	23.78	8.54	1.77	0.07
	>19 months	94	21.65	7.93		
CCT	0-18 months	96	534.00	38.96	-1.72	0.08
	>19 months	94	542.89	31.60		
postk1	0-18 months	96	5.77	0.37	1.89	0.06
	>19 months	94	5.68	0.26		
postk2	0-18 months	96	6.37	0.65	1.43	0.15
	>19 months	94	6.26	0.33		
Stromal t.	0-18 months	96	456.90	40.21	-1.82	0.07
	>19 months	94	466.48	31.38		
Epithel d.	0-18 months	96	27.64	5.82	-0.26	0.78
	>19 months	94	27.88	6.08		
Hex. Cell	0-18 months	96	68.79	4.77	0.99	0.32
	>19 months	94	68.08	5.00		
Endothelial cell density	0-18 months	96	2784.7	251.89	0.69	0.49
	>19 months	94	2759.8	244.03		
Endothelial cell number	0-18 months	96	214.13	48.22	5.26	0.00
	>19 months	94	188.99	44.74		

postk: posterior keratometry, stromal t:stromal thickness, Hex: hexagonal, Endothel d.:endothelial density

Discussion

The objectives of the development of this technology has been to provide the best visual acuity, to ensure that the lens conforms to the architecture of the cornea and not to limit the metabolic activity within the cornea. Contact lenses create a hypoxic environment and adversely affect corneal metabolism. Hypoxic effects have been minimized by the development of silicon hydrogel lenses. However, these lenses may adversely affect the corneal architecture as a result of mechanical and inflammatory effects due to their high stiffness modulus parameters(15,16).

Studies have also shown that the use of contact lenses is more common among women as we found(16,17). Women may prefer to wear contact lenses more due to aesthetic reasons, and they may have higher dexterity than men which is required for contact lens use.

Corneal refractive change has also been reported after use of soft lenses, and this change has been attributed to corneal edema(18–20). Silicon hydrogel lenses have high stiffness modulus and low water content, causing indentation effects on the conjunctiva and cornea, leading to central corneal flattening and epithelial lesions. The epithelial indentation effect was seen as post-lens debris, mucin balls or lipid plugs after removing the lens(21).

Topographic data showed there was no difference in posterior K1 and CCT between groups, whereas posterior K2 was significantly higher in group 1 compared to the control group. In group 3 and 4, we found that central corneal thickness, posterior K1 and posterior K2 were not different between the subgroups.

In a study, the patients were followed for 12 months during lens use and for 3 months after stopping lens wearing, and shown that the maximum flattening of the anterior curvature was observed at the 3rd month of contact lens wear, and the anterior curvature values increased again in the next 9 months. Observed that these values returned back to the initial values 3 months after stopping contact lens wear and a maximum thinning of the central corneal thickness at 12 months of lens wear(22). Other studies showed that hard gas permeable lenses and soft contact lenses (hydrogel and silicone hydrogel) affect corneal structure by causing flattening or steepness in the cornea, regular or irregular astigmatism, and loss of radial symmetry(19,21,23,24).The effect of soft contact lenses on the anterior curvature refraction ability may be due to the rearrangement of the corneal tissue caused by the mechanical interaction between the silicon hydrogel lens and the corneal surface, rather than the hypoxia. The compression effect of the contact lens on the cornea, the higher reflection of the valve pressures compared to the hydrogel lenses, and damage to the epithelium structure may result in changes in the anterior curvature(22,23).On the other hand, the effect on the posterior curvature may be hypoxic rather than mechanical. Nevertheless, further studies are needed to understand the effect of contact lenses on the posterior curvature.

Tyagi showed that silicone hydrogel lenses generally result in flattening of the anterior curvature and steepening of the posterior curvature(13). In this study, the topographic values were obtained 10 minutes after removing the lens which had been in use for 8 hours. In our study, there was a period of 8-12 hours without lens. This period was chosen to evaluate the cornea independently from the mechanical effects. These studies suggest that the topographic findings that are measured before keratorefractive surgery in patients wearing contact lenses may be misleading, especially in the early period. While CCT and stromal thickness did not differ significantly between the group 1 and 2, epithelial thickness was measured to be significantly lower in group 1. We did not observe a significant difference in epithelial thickness between the subgroups. Thus, the results of our study show that epithelial thickness decreases with the use of contact lenses; however, this was not exacarbated after 18 months of use.

There are studies suggesting that the soft contact lenses effect cct. This effect is usually in the acute phase. The fact that it is not seen at later stages suggests that the cornea may undergo an adaptation process(22,25).

Nourouzi et al.(22), showed that the mean cct measured by pachymetry was 550 when the lens was first removed, and that 74% of the patients had corneal stabilization within the first week and 26% in the second week after stopping lens use. Mean cct 15 days after stopping contact lens use were measured to be as 521.

Yıldız et al. (17)found the CCT measured through anterior segment was higher in lens users than in healthy subjects. It was observed that epithelial thickness measured by anterior segment OCT was lower in contact lens users. When lens wearers were further subgrouped as wearing less than 1 year or more than 1 year, there was no difference in terms of epithelial thickness between these groups, while the cct in the group wearing contact lenses for less than a year was found to be closer to the control group compared to patients wearing for more than 1 year(17). Lack of observation of the early effects of contact lenses in the later periods suggests that the cornea may adapt to the contact lenses with various mechanisms.

With a different approach, here, we evaluated the stromal thickness and epithelial thickness separately with the help of Heidelberg Spectralis OCT anterior segment module. Although we did not observe a difference in stromal thickness and cct by topography measurements, we found that the epithelial thickness decreased in group 1. Decreased epithelial thickness further suggest the formation of stromal edema. Although reduction in epithelial thickness is associated with stiffness modulus, stromal edema may be a response to epithelial damage or may be related to oxygen permeability of the lens.

Contact lenses may cause dry eye symptoms as a result of the lacrimal gland suppression due to the increase in evaporation and tear osmolarity by dividing the tear film layer into two and decrease the corneal sensitivity(22). It has been shown that half of the contact lens users stop using contact lenses due to dry eye symptoms(25).

Schirmer test results were not found to be significantly different between the groups. In the literature, studies investigating the presence of dry eye in patients wearing contact lenses generally found tear breakage time and the results of symptom analyzing questionnaires to be significantly different from the healthy controls, but no significant results were found with the schirmer test(23).

Plemorphism and polymegathism are biological indicators of endothelial function. Studies on conventional hydrogel lenses have shown that endothelial function is impaired due to hypoxia(24).

In our specular results, we did not find any difference in the percentage of hexagonal cells in contact lens users compared to the control group, but we found the endothelial cell number and density to be higher than the controls. When we subgrouped found that the percentage of hexagonal cells and endothelial cell density were not different, while the number of endothelial cells was lower in patients who have used contact lenses for more than 18 months. The mean age of the contact lens using patients was lower than the control group, although the difference was not statistically significant. This may have caused the endothelial cell number and density to be high in patients wearing contact lenses. The lower endothelial cell number in contact lens users over 18 months may also be explained by the age difference, or it may be due to hypoxic effects of the contact lenses since although the oxygen permeability of silicone hydrogel lenses is high, hypoxic effects may still be observed in the long term.In another study examining soft contact lenses in relation to the duration of use, it was observed that cell density andnumber of hexagonal cells decreased statistically significantly over 5 years of use(13).

In the study conducted by Kettesy et al.(26), silicone hydrogel lens (lotrafilcon b) was applied to patients who have been using hydrogel contact lenses for 5-6 years or participants who had never used any lens before, and the patients were followed at 2 weeks, 1 month, 3 months, 6 months and after that, every 6 months for 3 years and their specular values were compared. They found significant decrease in endothelial cell count in hydrogel lens users during the follow-up visits. In silicon hydrogel lens wearers, they observed an increase in cell density for up to 2 years after a decrease in the first month and then a decrease again in the third year. This study suggests that lotrafilcon B provides adequate oxygenation to the cornea after 3 years of use. An increase in percentage of hexagonal cells was observed in lotrafilcon B users after the first month(26).

The limitations of this study were that groups were not homogeneous and the lens usage duration was short (maximum 4 years). Further studies using homogenous groups in which the lenses are classified according to Dk/t and stiffness modulus would be important. Recently, due to expanded use of soft contact lenses and increased demand for keratorefractive surgery, it would be useful to know the effects of these lenses on the cornea in order to prevent complications regarding keratorefractive surgery.

Declarations

Funding

This study had received no financial support.

Conflicts of Interest/Competing Interests

The authors declared no potential conflicts of interest concerning the research, authorship, and publication of this article.

Ethics Approval

The study was approved by the Adıyaman University Medical Faculty Local Ethics Committee (2017/2-12).

Availability of Data and Material

We can provide all the original data.

Authors' Contributions

MB: Study design, data collection, literature search, writing of the manuscript; AS: Study design, literature search, writing of the manuscript

Acknowledgment

Non Applicable.

REFERENCES

1. Shah S, Laiquzzaman M, Cunliffe I, Mantry S. The use of the Reichert ocular response analyser to establish the relationship between ocular hysteresis, corneal resistance factor and central corneal thickness in normal eyes. Contact Lens Anterior Eye. 2006 Dec;29(5):257–62. DOI:10.1016/j.clae.2006.09.006
2. McMahon TiT, Polse KA, McNamara N, Viana MAG. Recovery from Induced Corneal Edema and Endothelial Morphology after Long-Term PMMA Contact Lens Wear. Optom Vis Sci. 1996 Mar;73(3):184–8. DOI:10.1097/00006324-199603000-00010
3. Bergmanson JP, Chu LW. Corneal response to rigid contact lens wear. Br J Ophthalmol. 1982 Oct 1;66(10):667–75. DOI:10.1136/bjo.66.10.667
4. Thoft RA. Corneal Glucose Flux. Arch Ophthalmol. 1971 Dec 1;86(6):685. DOI:10.1001/archopht.1971.01000010687013
5. Heitz RF. History of contact lenses. In: CLAO Guide to Basic Science and Clinical Practice. Boston, MA: Little Brown&Co; 1984. p. 667–75.
6. McMahon TT, Zadnik K. Twenty-five Years of Contact Lenses. Cornea. 2000 Sep;19(5):730–40. DOI:10.1097/00003226-200009000-00018
7. Temel A. Sert Kontakt Lensler (Materyal, Tasarım, Uygulama). MN Oftalmol. 1994;(1):21–4.
8. Pastewski B, Lee A. Contact Lens Care (Part 1). Am Drug. 1985;192:117–39.
9. Engle J. Contact Lens Care. Am Drug. 1990;201(1):54–65.
10. Geleneksel Kontakt Lensler, Kontakt Lensler ve Uygulanması. TOD Eğitim Yayınları-4. 2005;69–92.
11. Dillehay SM. Does the Level of Available Oxygen Impact Comfort in Contact Lens Wear?: A Review of the Literature. Eye Contact Lens Sci Clin Pract. 2007 May;33(3):148–55. DOI:10.1097/01.icl.0000245572.66698.b1
12. Holden BA, Mertz GW. Critical oxygen levels to avoid corneal edema for daily and extended wear contact lenses. Invest Ophthalmol Vis Sci. 1984 Oct;25(10):1161–7.
13. Lee JS, Park WS, Lee SH, Oum BS, Cho BM. A comparative study of corneal endothelial changes induced by different durations of soft contact lens wear. Graefe's Arch Clin Exp Ophthalmol. 2001 Jan;239(1):1–4. DOI:10.1007/s004170000223
14. Schornack M. Hydrogel contact lens-induced corneal warpage. Contact Lens Anterior Eye. 2003 Sep;26(3):153–9. DOI:10.1016/S1367-0484(03)00026-2
15. Collins MJ, Buehren T, Trevor T, Statham M, Hansen J, Cavanagh DA. Factors Influencing Lid Pressure on the Cornea. Eye Contact Lens Sci Clin Pract. 2006 Jul;32(4):168–73. DOI:10.1097/01.icl.0000189193.28870.81
16. Radaie-Moghadam S, Hashemi H, Jafarzadehpur E, Yekta A, Khabazkhoob M. Corneal biomechanical changes following toric soft contact lens wear. J Ophthalmic Vis Res. 2016;11(2):131. DOI:10.4103/2008-322X.183921
17. Yıldız Y, Gürdal C, Saraç Ö, Nacaroğlu ŞA, Takmaz T, Can İ. The Long Term Effects of Silicone Hydrogel Contact Lens Wearing on Corneal Morphology. TJO. 2012;42(2):91–6.
18. Liu Z, Pflugfelder SC. The effects of long-term contact lens wear on corneal thickness, curvature, and surface regularity 1 1The authors have no proprietary interest in any of the products or equipment mentioned in this article. Ophthalmology. 2000 Jan;107(1):105–11. DOI:10.1016/S0161-6420(99)00027-5
19. Ruiz-Montenegro J, Mafra CH, Wilson SE, Jumper JM, Klyce SD, Mendelson EN. Corneal Topographic Alterations in Normal Contact Lens Wearers. Ophthalmology. 1993 Jan;100(1):128–34. DOI:10.1016/S0161-6420(93)31704-5
20. Alba-Bueno F, Beltran-Masgoret À, Sanjuan C, Biarnés M, Marín J. Corneal shape changes induced by first and second generation silicone hydrogel contact lenses in daily wear. Contact Lens Anterior Eye. 2009 Apr;32(2):88–92. DOI:10.1016/j.clae.2008.11.002
21. Gonzalez-Meijome JM, Gonzalez-Perez J, Cervino A, Yebra-Pimentel E, Parafita MA. Changes in Corneal Structure with Continuous Wear of High-Dk Soft Contact Lenses: A Pilot Study. Optom Vis Sci. 2003 Jun;80(6):440–6. DOI:10.1097/00006324-200306000-00010
22. Nourouzi H, Rajavi J, Okhovatpour MA. Time to Resolution of Corneal Edema After Long-Term Contact Lens Wear. Am J Ophthalmol. 2006 Oct;142(4):671–3. DOI:10.1016/j.ajo.2006.04.061
23. Chalmers R, Long B, Dillehay S, Begley C. Improving Contact-Lens Related Dryness Symptoms with Silicone Hydrogel Lenses. Optom Vis Sci. 2008 Aug;85(8):778–84. DOI:10.1097/OPX.0b013e318181a90d
24. Sheng H, Bullimore MA. Factors Affecting Corneal Endothelial Morphology. Cornea. 2007 Jun;26(5):520–5. DOI:10.1097/ICO.0b013e318033a6da
25. Farrell RA, Hart RW. On the theory of the spatial organization of macromolecules in connective tissue. Bull Math Biophys. 1969 Dec;31(4):727–60. DOI:10.1007/BF02477784
26. Kettesy B, Vardai J, Berta A, Modis L, Kemeny-Beke A. A survey of corneal changes caused by daily wear silicone hydrogel contact lenses. J Innov Opt Health Sci. 2015 Nov 27;08(06):1550044. DOI:10.1142/S1793545815500443