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The Effect of Rigid Gas Permeable Contact Lenses on Visual Quality and Corneal Aberrations in The Keratoconus Patients

Keratokonus Hastalarında Sert Gaz Geçirgen Kontakt Lenslerin Görme Kalitesi ve Korneal Aberasyonlar Üzerine Etkileri

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ABSTRACT

Objectives: Aim was to investigate the effects of rigid gas permeable contact lenses (RGPCL) on visual quality and corneal aberrations in the patients with keratoconus and myopia.

Methods: Thirty-one eyes of 17 patients wearing RGPCL because of myopia (Group A) and 72 eyes of 47 patients who had keratoconus (Group B) were included in this study. Keratoconus patients were divided into four subgroups according to the Amsler-Krumeich classification. All patients underwent examination procedures, including visual acuity, contrast sensitivity and simulated keratometric value (sim K), surface asymmetric index (SAI), surface regularity index (SRI), predicted visual acuity (PVA) values measured with corneal topography; mean RMS values of spherical aberration, coma, trefoil, and total high order aberrations (THOA) measured with aberrometry, before and after RGPCL application.

Results: Mean best-corrected visual acuity values before lens use was 0.68 (±0.33) and afterwards 0.86 (±0.20) in Group A, 0.37 (±0.21) and 0.83 (±0.17) in Group B, respectively. During low contrast sensitivity measurement, nine letters were gained after wearing contact lenses in Group A, 18.7 letters in Group B. The change of topographic values after contact lens use was significant in both groups. The amount of change was more significant in Group B when compared to Group A ($p<0.05$). There was a significant difference in PVA values between Group B1 and Group B4 ($p<0.01$). After contact lens use, the change in spherical, coma, trefoil and THOA values were statistically significant in both groups. The mean decrease in aberration values was significantly higher in Group B comparing to Group A ($p<0.05$). The aberration values except THOA did not differ significantly among subgroups.

Conclusion: The topographic and aberrometry values decreased significantly in all eyes after RGPCL. The amount of decrease was significantly higher in keratoconus patients. Increase in visual acuity and contrast sensitivity was correlated with the decrease in higher aberrations, which points to the close relationship between them.

Keywords: Aberration; keratoconus; rigid gas permeable contact lens.

ÖZET

Amaç: Bu çalışmada amacımız, sert gaz geçirgen kontakt lenslerin keratokonus ve miyopi hastalarında görsel kalite ve kornea aberasyonları üzerindeki etkisini araştırmaktı.

Yöntem: Bu çalışmaya miyopi nedeniyle sert gaz geçiren kontakt lens kullanan 17 hastanın 30 gözü (A Grubu) ve keratokonuslu (B grubu) 47 hastanın 72 gözü dahil edildi. Keratokonus hastaları Amsler-Krumeich sınıflamasına göre dört alt gruba ayrıldı. Tüm hastalara görme keskinliği, kontrast duyarlılık ve simüle edilmiş keratometrik değer

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(sim K), yüzey asimetrik indeksi (SAI), yüzey düzenlilik indeksi (SRI), kornea topografisi ile ölçülen öngörülen keskinlik (PVA) değerleri dahil olmak üzere inceleme prosedürleri uygulandı; sert gaz geçirgen kontakt lens uygulamasından önce ve sonra, aberrometri ile ölçülen sferik aberasyon, koma, trefoil ve toplam yüksek dereceli aberasyonların (THOA) ortalama RMS değerlerine bakıldı.

Bulgular: Lens kullanımından önce düzeltilmiş en iyi görme keskinliği değerleri Grup A'da 0,68 (±0,33) ve Grup B'de ise 0,37 (±0,21), kullanımdan sonra ise 0,86 (±0,20), ve 0,83 (±0,17)idi. Düşük kontrast duyarlılık ölçümünde Grup A'da kontakt lens taktıktan sonra 9 harf, Grup B'de 18,7 harf kazanımı elde edildi. Kontakt lens kullanımından sonraki topografik değerlerde her iki grupta da anlamlı farklılıklar tespit edildi. Değişim miktarı Grup B'de Grup A'ya göre daha anlamlıydı (p<0,05). PVA değerlerinde Grup B1 ile Grup B4 arasında anlamlı fark vardı (p<0,01). Kontakt lens kullanımından sonra, her iki grupta da sferik, koma, trefoil ve toplam yüksek dereceli aberasyon değerlerindeki değişiklikler istatistiksel olarak anlamlı bulundu. Aberasyon değerlerindeki ortalama azalma, Grup B'de, Grup A'ya göre anlamlı derecede yüksekti (p<0,05). THOA dışındaki aberasyon değerlerinde alt gruplar arasında anlamlı farklılık yoktu. Kontrast duyarlılığı, görme keskinliği ve yüksek dereceli aberasyonlar arasında negatif bir korelasyon vardı.

Sonuç: Topografik ve aberrometrik değerler, RGP kontakt lenslerden sonra tüm gözlerde önemli ölçüde azalmıştır. Keratokonus hastalarında azalma miktarı anlamlı derecede yüksek bulundu. Görme keskinliği ve kontrast duyarlılığındaki artma, aralarındaki yakın ilişkiyi işaret eden yüksek aberasyonlardaki azalma ile bağlantılı olarak tespit edilmiştir.

Anahtar sözcükler: Aberasyon; keratokonus; sert kontakt lens.

Keratoconus is a condition with non-inflammatory, progressive thinning and steepening of the central or-and para central cornea. As keratoconus progresses, the corneal surface becomes more distorted and spectacle correction becomes unsuccessful. Eventually, keratoconus is primarily managed using rigid gas permeable (RGP) contact lenses.[1,2]

As the thinning and protrusion of the cornea begins, higher-order aberrations (HOA) become more evident. Bad night vision, glare, halos and monodiplopia are correlated with increased HOA resulting in degradation of the visual quality.[3,4] The corneal aberrations and stereoacuity induced by keratoconus are altered with RGP lenses by replacing the irregular, keratoconus corneal surface with the regular refractive surfaces of the RGP lens and a liquid tear-lens.[5,6]

These aberrations have been described as corneal wavefront aberrations and mathematically decomposed into a series of Zernike aberrations. The anterior cornea has been found to have most classical aberrations, including astigmatism, coma, trefoil, spherical aberration and much other high order aberration. Previous studies reported that corneal HOA increased in keratoconus patients when compared to control subjects.

We measured corneal wavefront aberrations in keratoconus eyes and eyes with refractive errors with and without RGP contact lenses. Our aim in this study was to investigate the effects of RGP contact lenses on visual quality and corneal aberrations on patients with keratoconus and myopia.

Methods

A hundred and three eyes of 64 patients who applied to the Fatih Sultan Mehmet Training and Research Hospital Eye Clinic contact lens section were included in this study. This research followed the tenets of the Declaration of Helsinki; informed consent was obtained from the subjects after explaining the nature and possible consequences of this study; and this research was approved by the institutional review board (IRB).

The patients who wore RGP contact lenses were divided into two groups: Group A (n=17) consisted of patients willing to use contact lenses for refractive reasons without any ocular disease and Group B (n=47) for Keratoconus. Keratoconus eyes were also divided into four subgroups as Group B1 to B4 according to Amsler- Krumeich classification. By that, Stage 1 patients consist Group B1, Stage 2 Group B2, Stage 3 Group B3 and Stage 4 of Amsler-Krumeich Group B4, respectively (Table 1. Amsler Krumeich Classification).

Conflex-air aspherical RGP lenses were used for patients in Group A (n=31) and Conflex-air aspherical RGP lenses (n=18) and Rose K multi-curve spherical RGP lenses (n=54) for Group B. Also, according to the Amsler-Krumeich classification, patients in Group B were divided into four subgroups; 14 eyes Grade 1 (Group B1), 29 eyes Grade 2 (Group B2), 10 eyes Grade 3 (Group B3) and 19 eyes Grade 4 (Group B4).

The inclusion criteria were no contraindications for RGP contact lens use, no ocular surface disease and no RGP intolerability. Patients who had any traumatic and infection

Table 1. Amsler–Krumeich classification

Stage 1	Eccentric steeping
	Myopia and Astigmatism <5.00D
	Mean Central K readings <48.00D
Stage 2	Myopia and Astigmatism from 5.00-8.00D
	Mean Central K readings <53.00D
	Absence of scarring, Minimum Corneal Thickness >400
Stage 3	Myopia and Astigmatism from 8.00-10.00D
	Mean Central K readings >53.00D
	Absence of scarring, Minimum Corneal Thickness from 300-400
Stage 4	Refraction not measurable
	Mean Central K readings >55.00D
	Central corneal scarring, Minimum Corneal Thickness 200M

based corneal scars and degenerative or distrofik corneal diseases, who underwent ocular surgery (except intracorneal ring implantation and cross-linking) were excluded from this study.

All patients underwent examination procedures before and after RGP contact lens fitting. Visual acuity was measured with Snellen acuity chart and contrast sensitivity with Bailey-Lowie charts in letters. Topographic and aberrometric measurements were analysed with Nidek Magellan Mapper (NIDEK®, Podova, Italy) placido disc corneal topograpy in a mesopic room without any mydriatic drops.

Simulated keratometric value (sim K), surface asymmetry index (SAI), surface regularity index (SRI), predicted visual acuity (PVA) values measured with corneal topographic analysis and mean RMS values of spherical aberration, coma, trefoil, and total high-order aberrations measured with aberrometry were noted.

We adopted different strategies when fitting RGP contact lenses; apical clearance fitting and three points touch technique. After fitting contact lenses, we waited for 20 minutes and we determined the best RGP contact lens by evaluating florescein pattern and movement and centralization of RGP contact lenses. The patients were informed about caring and wearing for RGP contact lenses.

Statistical Analysis

The data obtained were transferred to the computer environment and analyzed using the help of SPSS (Statistical Package for Social Sciences) 17.0 package program. Frequency (number), arithmetic mean±standard deviation, and median (1st quartile - 3rd quartile) were used to summarize the data. Compliance of continuous numerical data to normal distribution was determined by evaluating "An Sample Kolmogorov-Smirnov test" and "Coefficient of Variation" together. In variables with normal distribution; “Student's t-test in independent groups” was used for comparison of two groups, “One-Way Analysis of Variance (ANOVA) for comparing more than two groups and Tukey-HSD Test as the secondary test of this test, and “Student's t-test in dependent groups” was used for before and after comparison of a group. For variables that did not show normal distribution, "Mann-Whitney U test" was used for comparison of two groups, "Kruskal-Wallis test" for comparison of more than two groups, and the second test of this test was the Mann-Whitney U test with Bonferroni correction, and "Wilcoxon Signed Rank Test" was used for the comparison of one group before and after. In all analyzes, when $p<0.05$ (when $p<0.01$ in the Bonferroni correction) the difference was considered to be statistically significant.

Results

One hundred and three eyes of 64 patients were included in this study. Patients were divided into two groups: RGP contact lens applied for only refractive reasons (Group A) and keratoconus (Group B).

Seven eyes in Group B were applied collagen cross linking therapy, 1 eye had an intrastromal corneal ring and 1 eye was performed radial keratotomy before RGP contact lens fitting. There were corneal scars secondary to hydrops in two eyes of Group B.

The mean age of patients was 28.50±10.50 (14-67 yrs). While it was 35.97±12.45 in Group A, 24.70±6.91 in Group B ($p<0.05$).

When comparing spherical equivalents, it was -5.00±6.25 Diopters (D) in Group A and -5.20±4.26 D in Group B. There was no significant difference between groups. The mean spherical refractions in Group A was -3.72±D and -4.14±D in Group B, and cylindrical refractions were -3.61 D and -3.82 D, respectively.

Before contact lens fitting, the best-corrected visual acuity (BCVA) was 0.68±0.33 and afterwards 0.86±0.20 with Snellen in Group A. In Group B BCVA was 0.37±0.21 before lens use and 0.83±0.17 after lens fitting ($p<0.05$).

The mean increase in visual acuity was 0.15±0.18 in Group A and 0.45±0.21 in Group B. The increase in Group B was significantly higher than Group A statistically ($p<0.05$).

Among subgroups of Group B, the mean increase in visual acuity were 0.3; 0.4; 0,6 and 0.6 in Group B1, B2, B3, B4, respectively. The improvement of visual acuity in Group B1 was lower than Group B3 and B4, but there was no difference between other subgroups significantly.

Before contact lens fitting, the mean contrast sensitivity was 28.68±14.08 letters and 37.68±12.34 letters afterwards in Group A. In Group B, it was 12.41±10.63 letters and 31.11±8.54 letters, respectively.

When comparing both groups, the increase of letters in Group B was significantly higher than in Group A ($p<0.05$).

The topographic values including simK1, simK2, SAI, PVA and SRI were noted before lens use and afterwards. Before RGP lens fitting, the mean values were 47.24±2.57D; 41.24±10.26D; 0.63±0.51; 20/24 and 0.87±0.33 in Group A, respectively whereas these values in Group B were 54.63±6.35D; 49,80±5,01D; 2.85±1.57; 20/40 and 1.56±0.33 respectively. After RGP lens fitting, those values were 43,19±1,78D; 42.03±1.73D; 0.46±0.30; 20/16 and 0.37±0.29 in Group A and 45,50±2,13D; 44,96±2,10D; 0,43±0,14; 20/18 and 0.47±0,31 in Group B, respectively.

The change of sim K1, sim K2, SAI, SRI and PVA -which were topographic values- after contact lens use were found significant in both groups. When we compared both groups, the amount of change in Group B was more significant than Group A ($p<0.05$) (Table 2).

In subgroups of Group B, the mean decrease of simK1 values were statistically significant in all subgroups except Group B2 comparing with Group B3. When assessing the mean PVA values in subgroups, the difference was significant only in Group B1 comparing with Group B4 among all subgroups. None of the changes in SAI and SRI values were significant in all subgroups otherwise.

The mean RMS value of wavefront aberrations as spherical, coma, trefoil and total high order aberration (THOA) were also compared. Before RGP contact lens wearing these values were 0.52 μm; 0.42 μm; 0.34 μm and 1.13 μm in Group A and 1.41 μm; 1.49 μm; 0.66 μm and 4.43 μm in Group B respectively. After fitting RGP contact lens the mean RMS values were 0.27 μm; 0.20 μm; 0.15 μm and 0.54 μm in Group A and 0.22 μm; 0.41 μm; 0.17 and 0.76 μm in Group B as well.

When we compared both groups, before lens use and afterwards, values in Group B were statistically higher than Group A for all aberrometric measurements ($p<0.05$) (Fig. 1).

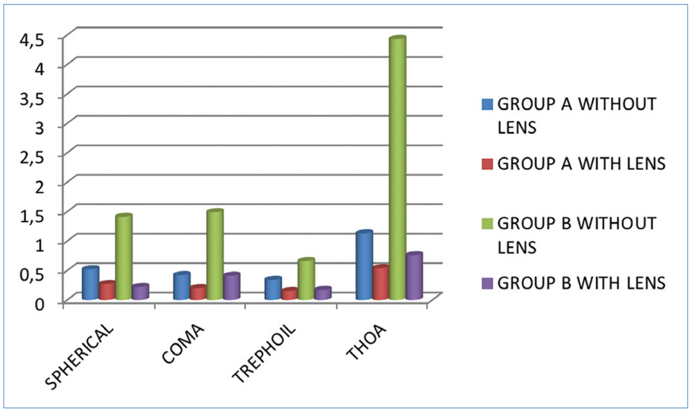

Figure 1. The Wavefront Aberrometry analysis among Groups with and without RGP contact lens.

Table 2. Mean topographic values in both groups with and without RGP contact lenses

	Group A(D)		p	Group B(D)		p
	without RGP	with RGP		without RGP	with RGP	
sim K1	47.24±2.57	43.19±1.78	0.001	54.63±6.35	45.50±2.13	0.001
sim K2	41.24±10.26	42.03±1.73	0.04	49.80±5.01	44.96±2.10	0.001
SAI	0.63±0.51	0.46±0.30	0.001	2.85±1.57	0.43±0.14	0.001
PVA	20/24	20/16	0.001	20/40	20/18	0.001
SRI	0.87±0.33	0.37±0.29	0.001	1.56±0.33	0.47±0.31	0.001

Table 3. The wavefront aberrations values of Group B subgroups

	Spherical (µm)	Coma (µm)	Trefoil (µm)	THOA (µm)
Group B1	0.6±0.81	0.84±0.47	0.43±0.24	1.98±0.98
Group B2	1.38±1.64	1.04±1.04	0.43±0.46	3.26±2.57
Group B3	1.38±1.00	1.48±2.37	0.37±0.26	4.00±3.06
Group B4	1.49±4.38	1.23±0.85	0.69±0.70	5.69±3.25
p	0.001	0.001	0.001	0.07

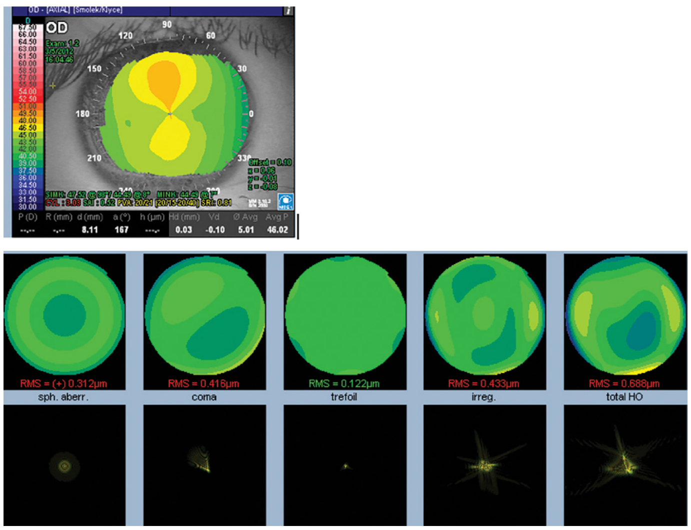

Figure 2. The corneal topographic and aberrometric values of a patient before RGP contact lens fitting in Group A.

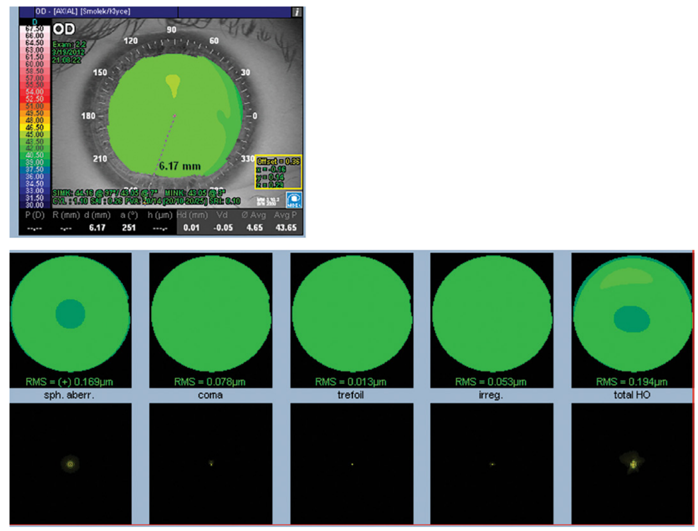

Figure 3. Topographic and aberrometric values of the same patient in Fig.1 after onflex-air 100 UV (base curve; 7.3 mm; diameter; 9.80 mm and power:-8.00D) f itting.

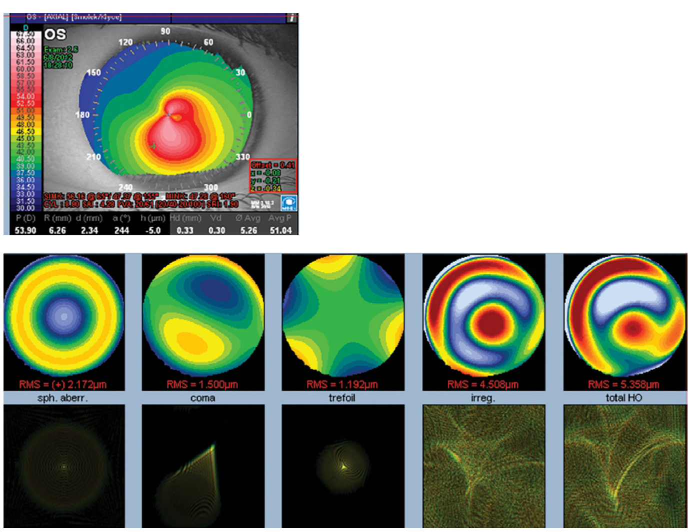

Figure 4. The corneal topographic and aberrometric values of a patient with keratoconus before RGP contact lens use.

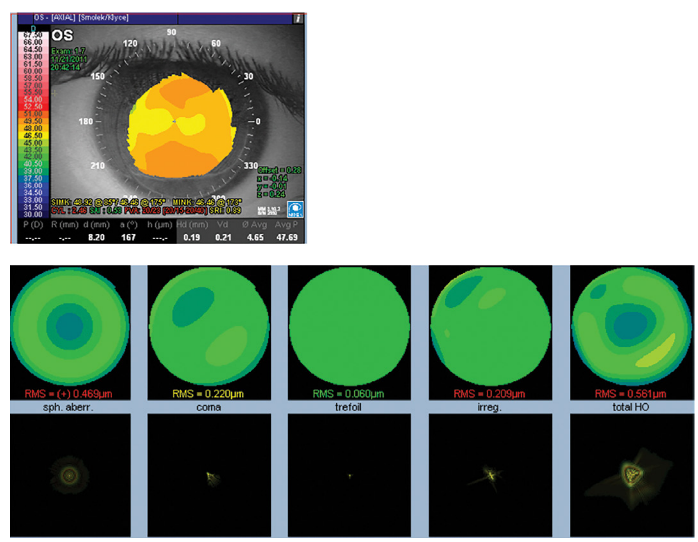

Figure 5. The corneal topographic and aberrometric values of the same patient in Fig. 3 with Rose-K RGP contact lens (base curve: 7.00 mm; diameter: 8,70 mm; power -4.50D).

While the amount of changes in total high order aberration values were significant between Group B1 and Group B4, other aberration values except total HOA did not differ significantly among subgroups (Table 3).

The mean base curve (BC) of RGP contact lenses was 7.67 mm, the mean diameter of RGP contact lenses was 8.98 mm, and the mean power of RGP contact lenses was -7.18 D (Fig. 2, 3).

(Rose- K: Base curve: 7.00 mm; diameter: 8.70 mm; power -4.50D,

(Conflex – Air: Base curve; 7.3 mm; diameter; 9.80 mm and power: -8.00D)

When we compared two different types of RGP contact lenses used in Group B, we observed no significant difference between the aberration decreases, except THOA (Fig. 4, 5).

Discussion

In keratoconus patients thinning of the cornea causes myopia and irregular astigmatism. Because of these reasons, visual acuity and visual quality decrease as keratoconus progresses.

Early diagnosis of keratoconus is very important to decide the best way of treatment for the patient. When it is about refractive surgery, it has a crucial effect on prognosis. Corneal topography is the gold standard method to determine corneas, which are a candidate for keratoconus. Many studies have reported abnormalities in corneal topography using videokeratoscopy or slit-scanning corneal topography.[7-9]

It has been reported in many studies that when optical correction of the keratoconus eyes with spectacles is failed, RGP contact lenses are a successful alternative way of treatment.[10-12] We also found significant increase in visual acuity with RGP contact lenses in both keratoconus and refractive groups compared to the spectacles. A recent study revealed novel information about correction with RGPs. Nilagiri et al. reported that their study showed an improvement in three-dimensional depth perception of subjects with bilateral and unilateral keratoconus with rigid gas-permeable (RGP) contact lens wear, relative to spectacles.[6]

Can et al.[11] found that the success of RGP contact lenses on improving visual acuity was higher in moderate and advanced keratoconus patients compared to mild keratoconus groups. In our study, the improvement of visual acuity in group B3 and B4 was significantly higher than in group B1. We suggest that the reason for this finding could be due to higher visual acuity in Group B1 before RGP contact lens fitting or RGP contact lenses could be more successful in advanced keratoconus patients with higher aberrations.

Visual quality is affected by many factors, such as age, pupil size, illumination and contrast sensitivity. These factors cause HOA creating glare, halo, bad night vision and monodiplopia.

In assessing visual performance, low contrast acuity is also valuable for evaluating visual quality besides high contrast visual acuity; for this reason, we used Bailey Lowie low contrast charts in our study.

We found that without RGP contact lens, the contrast sensitivity was lower in both groups than with RGP significantly. However, the increase of contrast sensitivity in subgroups did not differ statistically significant. We suggest thaRGP contact lenses show the same efficiency for contrast sensitivity in every stage of keratoconus. This finding was also compatible with the study which was suggested by Bi yang et al.[13]

Placido disc videokeratography is a valuable method to determine irregular astigmatism by measuring curvature and elevation of the cornea.[14] In our study, we found that as the stage of keratoconus increases, the topographic measurements of the cornea elevates as many previous studies mentioned, likewise.[15-19]

The amount of change in topographic values after RGP contact lens fitting was statistically higher in keratoconus eyes when we compared the two groups. The reason of this finding can be because the irregular corneal surface is replaced by the regular anterior surface of the contact lenses.

We measured wavefront aberrations in a mesopic room without using any mydriatic drops not to induce myopia and we thought that naturally dilated pupilla is better for determining visual performance. The previous studies also demonstrated that pupilla size is very important to detect ocular aberrations and related symptoms.[20-22] HOA are other factors that affect visual quality in keratoconus patients.[23-29] In our study, as the stages of keratoconus progresses, the HOA were more elevated.

Lagana et al.[30] reported that measuring ocular wavefront aberrations was a sensitive method to diagnose keratoconus in early stages. They suggested that the disadvantage of their study was their measurement of the total ocular aberrations with the aberrometry which they used. The advantage of our study is that we used Placido disc topography. Thus, we were able to measure only corneal aberrations changed with RGP contact lenses instead of total ocular aberrations.

Saad et al.[31] reported that coma and trefoil aberrations were significantly higher in suspected keratoconus patients than normal subjects. In an another study, comparing with spherical aberrations, coma aberrations were higher in early keratoconus patients.[32] Similar to Kazuno et al.,[25] we found that both spherical and coma aberrations were higher in keratoconus patients. Furthermore, Naderan et al.[33] suggested that ocular aberration, especially vertical and total coma and total high-order aberrations, were suitable parameters to discriminate keratoconus and forme fruste keratoconus from normal patients. This also indicates the importance of aberration differences in detecting asymptomatic keratoconus.[33]

Although aberrometric and topographic values decreased with RGP lenses in both groups, it was significantly larger in keratoconus patients compared to non keratoconus group.

The change in all values in advanced keratoconus was higher even though it was not statistically significant. This finding proves that in conditions with low visual performance resulting from larger aberrations like keratoconus, RGP contact lenses are more efficient to correct aberrations. RGP lenses were the pioneers in this area; scleral lenses, mini scleral lenses followed the same path and corrected the aberrations similarly.[34,35]

Conclusion

As a result, keratoconus patients have increased topographic and aberrometric values. The topographic and aberrometry values decreased significantly in all eyes after RGP contact lenses. Increase in visual acuity and contrast sensitivity with RGP contact lenses was correlated with the decrease in higher aberrations. This correlation points to the close relationship between HOA with visual acuity and contrast sensitivity. Large scale studies about the effects of new design contact lenses to decrease the high-order aberrations to improve vision should be carried on.

Disclosures

Ethics Committee Approval: This research followed the tenets of the Declaration of Helsinki; informed consent was obtained from the subjects after explaining the nature and possible consequences of this study; and this research was approved by the institutional review board (IRB).

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship Contributions: Concept – T.G.A.; Design – T.G.A.; Supervision – S.A.K.; Materials – Y.B.Ö.; Data collection &/or processing – T.G.A., T.Ş.; Analysis and/or interpretation – M.A.; Literature search – T.G.A.; Writing – T.G.A.; Critical review – S.A.K.

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