ORIGINAL RESEARCH

Comparison of Binocular Vision Parameters in Patients With Irregular Corneas Corrected With Spectacles Versus Rigid Contact Lenses (RGP, Rose K, & Scleral Lenses)

Manish Kumar Sah, BOptom, MOptom, FIACLE
Assistant Professor,
Sharda School of Allied Health Science,
Sharda University, India

Monica Chaudhry, BSc, MSc, FIACLE
Director,
Monica Chaudhry Vision Institute Vision and Eye Care Clinic,
Gurugram, India

Zeeshan Akhtar, BOptom, MPhil
Assistant Professor,
Sushant University, India

Ruchika Sah, BOptom, MOptom
Consultant Optometrist,
Ramlal Golchha Eye Hospital Foundation,
Biratnagar, Nepal.

Abstract

INTRODUCTION
The purpose of our study was to compare binocular vision parameters between spectacles and rigid lenses among patients with irregular corneas.

METHODS
We evaluated all binocular vision parameters on two separate occasions in 30 patients with irregular corneas (22 with keratoconus, 3 with pellucid marginal degeneration, 2 with post-LASIK ectasia, and 3 post-graft) who wore contact lenses and single-vision spectacles. The average age of the patients was 26 ± 8.0 years. The binocular vision parameters measured in the study included near point of accommodation (NPA), accommodative facility, near negative and positive fusional vergence (NFV/PFV), distance negative fusional vergence (NFV), positive fusional vergence (PFV), vergence facility, near point of convergence (NPC), negative relative accommodation (NRA), positive relative accommodation (PRA), AC/A ratio, and stereoacuity.

RESULTS
A total of 60 subjects participated in the study: 30 with normal corneas in the age-matched control group and 30 with irregular corneas in the treatment group. When patients with irregular corneas switched from single-vision glasses to rigid contact lenses, their monocular and binocular logMAR distance and near visual acuity (VA), as well as stereoacuity, improved significantly ($P < 0.05$). The stereoacuity with spectacles was 400 ± 60 arcs sec, and with rigid contact lenses, it was 140 ± 30 arcs sec, which was statistically significant ($P < 0.05$). We found significant differences between the rigid contact lens group and the control group in distance visual acuity, near and distance horizontal phoria, positive relative accommodation (PRA), and stereopsis. PRA was higher with contact lenses (-7.22 ± 0.50 D) compared to controls (-4.03 ± 1.96 D, $P = 0.00$), and stereopsis was better in the control group (40 ± 0.00 arcs sec) than in the contact lens group (140 ± 30 arcs sec, $P = 0.00$).

CONCLUSION
Binocular and monocular logMAR visual acuity, near phoria, and stereopsis improved when switching from single-vision spectacles to rigid contact lenses in patients with irregular corneas. The use of rigid gas-permeable contact lenses is an effective treatment for improving visual performance and binocular vision in patients with irregular corneas, which can directly enhance daily activities and quality of life. However, all binocular vision parameters with rigid contact lenses in patients with irregular corneas remained poorer compared to those of age-matched normal control subjects with normal corneas.

KEYWORDS: Binocular vision parameters, irregular cornea, rigid contact lenses, spectacles, visual acuity, stereopsis

INTRODUCTION

Irregular corneas are characterized by changes in their shape, ranging from oblate to hyper-prolate, and all exhibit irregular astigmatism. There are several causes of irregular corneas, such as keratoconus, pellucid marginal degeneration (PMD), Terrien's marginal degeneration (TMD), keratoglobus, post-graft eye, and many others. A person with an irregular cornea experiences remarkable deterioration of visual performance and quality of vision due to an increase in higher-order aberrations that degrade both high-contrast and low-contrast visual acuity, reduce image sharpness, impair the ability to detect subtle details, and make tasks such as reading, navigation, driving, and object recognition more challenging.[1,2,3,4] Most irregular corneas are treated with rigid contact lenses because they create a tear lens between the lens and the cornea, which masks the corneal irregularity. Different types of rigid contact lenses, such as rigid gas permeable (RGP), ROSE K, and scleral lenses, are used to address various irregular corneas. There are also many optical correction modalities, including spherocylinder spectacles and special soft lenses for irregular corneas with high central thickness (0.35 mm or more). [5] Additionally, customized wavefront-correcting contact lenses can improve visual function. [6]

Because accommodation, like refraction, takes place at the primary principal plane, which is slightly over a millimeter behind the corneal apex, the amount of accommodation can be different for a contact lens wearer than for a spectacle wearer.[7] If there is a change in accommodation, there will then be a change in convergence, which leads to a change in fusional vergence.[8] Very few studies have examined binocular vision characteristics in irregular corneas.[9,10] However, a few have assessed binocular vision characteristics in keratoconus.[11] A significant proportion of keratoconus patients exhibit binocular vision abnormalities, and it has been shown that positive fusional vergence is higher in keratoconus, while negative fusional vergence is lower than in control groups with normal corneas.[12]

Patients with irregular corneas often have different visual acuity in each eye, resulting in different retinal images forming on the retina, known as aniseikonia. Lovasik's investigation found that aniseikonia and anisometropia reduce stereopsis.[13] Using rigid contact lenses can help minimize aniseikonia. Rigid lenses minimize wavefront aberration, resulting in improved stereoacuity in patients with keratoconus, as reported in previous investigations. [14] This leads to an improvement in retinal image quality, better vision, and improved depth perception and stereopsis. [15]

When ametropes are corrected with spectacle lenses, they do not experience the same visual conditions as emmetropes because spectacles are positioned 12 to 14 mm in front of the principal point. This distance results in prismatic effects when looking through the peripheral areas of the lens or when focusing on near vision, such as base-in prism for minus power and base-out prism for plus-powered spectacles.[16] However, when ametropes are corrected with contact lenses, the prismatic effect is usually negligible because the lenses are positioned 1.5 mm from the principal point and the central area of the lens is used. The prismatic effect decreases the need for convergence in myopes. When contact lenses are worn in place of spectacles, this effect is lost, and consequently, a greater convergence effort is required.[7] Therefore, the type of optical correction will determine the degree of accommodation and vergence required.[17] This study aimed to determine if there are any changes in binocular vision parameters in patients with irregular corneas corrected with spectacles versus rigid contact lenses.

METHODS

A total of 60 participants (n = 60) were included in the study, comprising 30 individuals in an age-matched control group with normal corneas and 30 patients with irregular corneas. The inclusion criteria were: age between 20 and 35 years, use of rigid contact lenses, and the presence of any type of irregular cornea (unilateral or bilateral). The exclusion criteria were: age over 35 years, use of soft contact lenses, anisometropia with contact lenses, anisometropic amblyopia, and a visual acuity difference of more than one line. The age-matched normal control group consisted of individuals who had not been diagnosed with or treated for any binocular vision problems, had no symptoms of asthenopia, and had no ocular pathology.

The study received approval from the institutional ethics committee. Patients were recruited from Silver Line Laboratories and the Monica Chaudhry Vision Institute, two private clinics in Delhi, India, that provide specialized contact lens services. Patients with irregular corneas were examined and included in the study if they met the inclusion criteria, forming the irregular cornea group. Similarly, patients with normal corneas who were using soft contact lenses and came for follow-up were assessed, and those meeting the inclusion criteria were included in the normal control group. We recorded demographic details and a complete ocular and systemic history for all participants. Each participant underwent a comprehensive optometric examination, including both objective and subjective refraction. Visual acuity (VA) was assessed for both near and distance vision at 33 cm and 6 metres, respectively, and was recorded in logMAR values. We performed corneal topography to evaluate corneal curvature. Following the initial examination, we selected appropriate trial lenses based on corneal curvature and other parameters such as refractive error and corneal diameter. We used a fluorescein pattern to assess lens fit under a slit lamp before finalizing the lens choice. Each participant wore their refractive correction in a basic trial frame for the measurement of spectacle correction, and then we performed binocular vision assessment on the contact lens trial day. We assessed binocular vision with the contact lenses on the dispensing day, using the patient's final lenses. In the age-matched normal control group, we evaluated patients wearing soft contact lenses who came for follow-up for lens fit and ocular health. We assessed binocular vision assessment while wearing the contact lenses only if the lens fit was ideal.

The binocular vision parameters assessed in the study were: AC/A ratio, stereo acuity, near point of accommodation (NPA), accommodative facility, near negative and positive fusional vergence (NFV/PFV), distance negative and positive fusional vergence, vergence facility, near point of convergence (NPC), and negative/positive relative accommodation (NRA/PRA).

- We evaluated stereoacuity using the Titmus fly test.
- We calculated relative accommodation values, both negative and positive, by placing lenses in front of the eyes (plus and minus lenses, respectively). We instructed the patient to keep the letters distinct and single and to report when they became muddled or doubled. We conducted the test at 40 cm.
- We measured both binocular and monocular near points of accommodation using the RAF Rule (Royal Air Force Rule), with one line above the best-corrected visual acuity used as the target. The first sustained blur was considered the end point for the near point of accommodation. We measured accommodative facility using a ±2.00 DS flipper, with an appropriate target size based on the near visual acuity at 40 cm.
- We evaluated the near point of convergence using the RAF Rule, with a single line on the RAF Rule used as the target. We recorded both break and recovery values, and we assessed vergence facility using 3 prism dioptres base-in and 12 prism dioptres base-out, with an appropriate target size based on the near visual acuity at 40 cm.
- We measured the AC/A ratio using the heterophoria method. For this method, we measured interpupillary distance and the amount of phoria at distance and near using a prism bar.
- For measuring fusional vergence, we used a prism bar. We measured both positive and negative fusional vergence for distance (at 6 metres) as well as near (at 33 cm). We recorded the breakpoint when increasing prism strength caused the individual to experience double vision, while we recorded the recovery point when the prism strength was reduced and the individual regained single vision.

We analysed the data using SPSS version 25. Since the variables in this study were not normally distributed, a nonparametric Wilcoxon signed-rank test and Mann–Whitney U test were used to compare within and between groups. We set statistical significance at $P < 0.05$.

RESULTS

Our study, included 30 participants with irregular corneas. We identified keratoconus as the cause in 22 subjects. Pellucid marginal degeneration was present in three subjects. Post-LASIK ectasia affected two subjects, and three subjects had corneal irregularities following a graft (Table 1). The mean corneal curvature in the right eye (OD) was 53.97 ± 7.38 DS, while in the left eye (OS), it was 53.60 ± 4.07 DS. Based on corneal curvature, all patients were fitted with rigid contact lenses, including RGP, Rose K, and scleral lenses. Among the subjects, eight individuals used RGP contact lenses, seven used Rose K lenses, and 15 used scleral lenses (Table 2).

In the irregular cornea group, the mean sphere power in the right eye was −4.30 ± 3.21 D, and in the left eye, it was −4.42 ± 3.51 D. The normal control group had a mean sphere power of −1.53 ± 0.79 D in the right eye and −1.34 ± 0.65 D in the left eye. In the right eye, the irregular cornea group had a mean cylinder power of −4.84±1.89 D, while the normal control group had a mean of −0.39±0.14 D. In the left eye, the irregular cornea group had a mean cylinder power of −5.03±2.19 D compared to −0.42±0.23 D in the control group. There was no statistically significant difference in spherical power, cylindrical power, and spherical equivalent between the right and left eyes in both the irregular cornea group and the normal control group (Table 3).

Table 1: *Cause of the Corneal Irregularity*

Condition	Total Number of Subjects
Keratoconus	22
Pellucid marginal degeneration	3
Post-LASIK ectasia	2
Post graft	3

Table 2: *Type of Lens Used*

Mode of Visual Correction	Total Number of Subjects
RGP contact lens	8
RoseK	7
Corneo-scleral lens	15

Table 3: *Refractive Error Parameters of Patients With Irregular Cornea Group And Normal Control Group*

Parameters	Irregular Cornea Group Mean ± SD	P-Value	Normal Control Group Mean ± SD	P-Value
Right eye sphere power (D)	−4.30 ± 3.21	0.534	−1.53 ± 0.79	0.432
Left eye sphere power (D)	−4.42 ± 3.51		−1.34 ± 0.65	
Right eye cylinder power (D)	−4.84 ± 1.89	0.619	−0.39 ± 0.14	0.941
Left eye cylinder power (D)	−5.03 ± 2.19		−0.42 ± 0.23	
Right eye SE power (D)	−6.72 ± 3.22	0.554	−1.72 ± 0.79	0.518
Left eye SE power (D)	−6.93 ± 3.41		−1.55 ± 0.63	

(SE: spherical equivalent, SD: standard deviation, P-value: for comparing the right and left eyes)

LogMAR visual acuity in the right eye and left eye of all subjects was worse with spectacles than with rigid contact lenses. For distance visual acuity (VA) in the right eye (OD), the mean logMAR VA was 0.30 ± 0.10 with spectacles, which significantly improved to 0.08 ± 0.08 with rigid contact lenses ($p < 0.05$). Similarly, for the left eye (OS), the mean logMAR distance VA improved from 0.34 ± 0.10 with spectacles to 0.064 ± 0.08 with rigid contact lenses ($p < 0.05$). We found statistically significant differences in LogMAR visual acuity in both the right and left eyes for both near and distance vision between spectacles and rigid contact lenses. Stereopsis improved significantly with contact lenses, with values of 400 ± 60 arc sec with spectacles and 140 ± 30 arc sec with contact lenses ($p < 0.05$). Since the stereoacuity variables were not normally distributed, we used interquartile ranges (IQR) and medians instead of mean and standard deviation (Table 4).

The near point of accommodation was 10.75 ± 1.05 cm (OD) and 10.25 ± 0.86 cm (OS) with spectacles and 10.25 ± 0.86 cm (OD) and 10.08 ± 0.66 cm (OS) with contact lenses. The differences in these measurements were not statistically significant. Vergence facility measured in cycles per minute (cpm) was 11.58 ± 1.08 cpm with spectacles and 11.50 ± 0.90 cpm with contact lenses, with no significant difference ($p = 0.885$). Negative relative accommodation was 2.64 ± 0.24 D with spectacles and 2.64 ± 2.62 D with contact lenses, with a p-value of 0.22. Positive relative accommodation was −7.39 ± 0.50 D with spectacles and −7.22 ± 0.50 D with contact lenses, with a p-value of 1.00. The distance cover test (Δ) was −7.17 ± 3.2$^{\Delta}$ with spectacles and −4.87 ± 3.22$^{\Delta}$ with contact lenses, with a p-value of 0.06. The near cover test (Δ) was −9.67 ± 3.17$^{\Delta}$ with spectacles and −7.40 ± 2.79$^{\Delta}$ with contact lenses, also with a p-value of 0.06 (Table 4).

We found no significant difference between rigid contact lenses and spectacles in near point of accommodation (NPA), accommodative facility, near negative and positive fusional vergence (NFV/PFV), distance negative and positive fusional vergence (PFV), vergence facility, near point of convergence (NPC), negative/positive relative accommodation (NRA/PRA), and AC/A ratio (Table 4).

Table 4: *Binocular System Parameters & Logmar Visual Acuity of Subject When Corrected With Spectacles And Rigid Contact Lens (median ± IQR taken with stereoacuity)*

Parameters	Spectacle (Mean ± SD)	Contact Lens (Mean ± SD)	P-Value
Distance VA (OD)	0.30 ± 0.10	0.08 ± 0.08	p<0.05
Distance VA (OS)	0.34 ± 0.10	0.06 ± 0.08	p<0.05
Near VA(OD)	0.13 ± 0.01	0.00	p<0.05
Near VA (OS)	0.12 ± 0.01	0.00	p<0.05
Near point of accommodation OD (cm)	10.75 ±1.05	10.25 ± 0.86	0.119
OS (cm)	10.25 ± 0.86	10.08 ± 0.66	0.557
OU (cm)	10.33 ± 0.49	9.92 ± 0.51	0.25
Accommodation facility OD (cpm)	11.67 ± 1.37	11.33 ± 0.98	0.234
OS (cpm)	11.17 ± 1.2	11.42 ± 0.90	0.55
OU(cpm)	11.75 ± 1.05	11.58 ± 0.99	0.52
Distance cover test ($^{\Delta}$)	−7.17 ± 3.2	−4.87 ± 3.22	0.06
Near cover test ($^{\Delta}$)	−9.67 ± 3.17	−7.40 ± 2.79	0.06
Near point of convergence (cm)	10.17 ± 1.64	9.33 ± 1.07	0.061
Ac/A ratio	5.31 ± 0.37	5.14 ± 0.57	0.53
Vergence facility(cpm)	11.58 ± 1.08	11.50 ± 0.90	0.885
Negative relative accommodation (D)	2.64 ± 0.24	2.64 ± 2.62	0.22
Positive relative accommodation (D)	−7.39 ± 0.50	−7.22 ± 0.50	1.00
Distance PFV (break) ($^{\Delta}$)	19.33 ± 2.96	22.08 ± 2.5	0.33
Distance PFV (recovery) ($^{\Delta}$)	14.33 ± 2.6	17.83 ± 1.8	0.24
Distance NFV (break) ($^{\Delta}$)	10.33 ± 1.87	11 ± 1.5	0.56
Distance NFV (recovery) ($^{\Delta}$)	7.83 ± 1.5	8.3 ± 1.87	0.84
Near NFV (break) ($^{\Delta}$)	18.00 ± 1.70	17.67 ± 1.87	0.79
Near NFV (recovery) ($^{\Delta}$)	15.00 ± 2.0	14.83 ± 1.58	0.67
Near PFV (break) ($^{\Delta}$)	22.58 ± 4.92	25.00 ± 3.69	0.15
Near PFV (recovery) ($^{\Delta}$)	16.50 ± 2.43	17.67 ± 3.98	0.26
Stereopsis (arcs second)	400 ± 60	140 ± 30	p<0.05

(VA–visual acuity, PFV–positive fusional vergence, NFV–negative fusional vergence, cpm–cycles per minute)

Table 5: *Binocular System Parameters & Logmar Visual Acuity of Subject When Corrected With Rigid Contact Lens & Control Subjects Under the Best-Corrected Conditions*

Parameters	Contact Lens (Mean ± SD)	Control (Mean ± SD)	P-Value
Distance VA (OD)	0.08 ± 0.08	0.00	p<0.05
Distance VA (OS)	0.06 ± 0.08	0.00	p<0.05
Near VA(OD)	0.00	0.00	1.00
Near VA (OS)	0.00	0.00	1.00
Near point of accommodation OD (cm)	10.25 ± 0.86	9.23 ± 1.90	0.23
OS (cm)	10.08 ± 0.66	9.12 ± 1.97	0.21
OU (cm)	9.92 ± 0.51	8.62 ± 1.72	0.12
Accommodation facility OD (cpm)	11.33 ± 0.98	12.50 ± 4.3	0.115
OS (cpm)	11.42 ± 0.90	12.32 ± 4.2	0.119
OU(cpm)	11.58 ± 0.99	12.00 ± 3.3	0.386
Distance cover test (Δ)	−4.87 ± 3.22	−0.27 ± 2.33	p<0.05
Near cover test (Δ)	−7.40 ± 2.79	−1.27 ± 3.54	p<0.05
Near point of convergence (cm)	9.33 ± 1.07	8.5 ± 3	0.60
Ac/A	5.14 ± 0.57	5.44 ± 1.09	0.23
Vergence. facility (cpm)	11.50 ± 0.90	12.97 ± 3.2	0.28
Negative relative accommodation (D)	2.64 ± 2.62	2.75 ± 0.88	0.37
Positive relative accommodation (D)	−7.22 ± 0.50	−4.03 ± 1.96	p<0.05
Distance PFV (break) (Δ)	22.08 ± 2.5	21.66 ± 1.0	0.377
Distance PFV (recovery) (Δ)	17.83 ± 1.8	18 ± 14	0.386
Distance NFV (break) (Δ)	11 ± 1.5	9 ± 3	0.665
Distance NFV (recovery) (Δ)	8.3 ± 1.87	7 ± 2	0.315
Near NFV (break) (Δ)	17.67 ± 1.87	12 ± 6	0.994
Near NFV (recovery) (Δ)	14.83 ± 1.58	10 ± 5	0.897
Near PFV (break) (Δ)	25.00 ± 3.69	24 ± 8	0.893
Near PFV (recovery) (Δ)	17.67 ± 3.98	18 ± 6	0.517
Stereopsis (arcs second)	140 ± 30	40 ± 0.00	p<0.05

(VA–visual acuity, PFV–positive fusional vergence, NFV–negative fusional vergence, cpm–cycles per minute)

However, when comparing the normal control group and the contact lens group, we found significant differences in distance visual acuity (VA), near and distance horizontal phoria, PRA, and stereopsis. The distance cover test (CT) was $-4.87 \pm 3.22^{\Delta}$ with contact lenses and $-0.27 \pm 2.33^{\Delta}$ with controls, showing a significant difference ($p = 0.00$). The near cover test (CT) was $-7.40 \pm 2.79^{\Delta}$ with contact lenses and $-1.27 \pm 3.54^{\Delta}$ with controls, also significantly different ($p = 0.00$). Negative relative accommodation (NRA) was 2.64 ± 2.62 D with contact lenses and 2.75 ± 0.88 D with controls, with no significant difference ($p = 0.37$). Positive relative accommodation (PRA) was significantly higher with contact lenses at −7.22 ± 0.50 D compared to −4.03 ± 1.96 D with controls ($p = 0.00$). Stereopsis was considerably good in the control group, with a mean of 40 ± 0.00 arc sec, compared to 140 ± 30 arc sec in the contact lens group ($p = 0.00$) (Table 5).

DISCUSSION

In this study, we measured the binocular parameters of patients with irregular corneas using both spectacles and rigid contact lenses. The study showed a significant improvement in LogMAR visual acuity and stereopsis from spectacles to rigid contact lenses in eyes with irregular corneas, which is consistent with previous literature.[14,18,19] We know that patients with irregular corneas have a higher amount of high- and low-order aberrations that spectacles do not correct.[18] When a rigid contact lens is placed in front of an irregular cornea, a tear lens is formed, which somewhat reduces these aberrations, resulting in improved visual acuity.[5,14,19] However, compared to the age-matched normal control group in our study, visual acuity was lower with rigid contact lenses.

In this study, we found that the median spectacle-corrected stereoacuity was 400 arc sec, which was poorer than with rigid contact lenses. When switching from single vision glasses to rigid contact lenses, stereoacuity showed a considerable improvement, enhancing performance even further.[14] The stereoacuity of control subjects (40 arc sec) was still significantly better than that with rigid contact lenses. The improvement in stereoacuity can be explained by several factors. With rigid contact lenses, there is a decrease in the degree of wavefront aberration in both eyes, leading to improved image quality on the retina in both eyes. This results in better binocular matching and a reduction in aniseikonia as well as improved accuracy in binocular vergence eye movements.[13,18,20,21] It has been demonstrated that RGP contact lenses in individuals with irregular corneas lessen the impact of interocular changes in higher-order aberrations, anisometropia, and aniseikonia, which should enhance depth perception.[14]

Theoretically, the accommodation demand and vergence demand are different between single vision soft lenses and single vision spectacles.[22] Since accommodation, like refraction, occurs at the primary principal plane, which is slightly over a millimetre behind the corneal apex, accommodation can be significantly different for a single vision contact lens wearer compared to a single vision spectacle wearer.[7] As accommodation changes, there will also be a change in convergence for near work, which leads to a change in fusional vergence.[8] In our study, we did not find a significant difference in the near point of accommodation. This contrasts with the results of several previous studies.[8,23,24] This could be explained by several factors. The population size was much smaller in our study, and most of the patients were neophytes, which may have limited their ability to adapt to changes in the near point of accommodation.[24] This variance becomes significant in presbyopic individuals and increases with refractive power.[7] Hunt et al.[25] found a significant change in accommodation because they used a dynamic method with the PowerRefractor. Compared to the age-matched normal control group in our study, the near point of accommodation was less with contact lenses, but there was no significant difference.

We observed a change in near phoria by 2.27$^{\Delta}$ towards convergence in rigid contact lens users compared to those using spectacles, but this was not statistically significant. According to Fulk et al.,[26] there is a difference in exophoria values for near phoria in contact lens wearers. However, Jiménez et al.[24] found a significant difference in near phoria between soft contact lenses and spectacles, with less exophoria observed with soft contact lenses compared to spectacles in myopes. We found a more exophoric value than the control group, which is clinically significant (Table 5).

The AC/A ratio should change in contact lens users due to increased esophoria, i.e., a decrease in exophoria found at near distances. In this study, the AC/A ratio remained the same between rigid contact lenses and spectacles because we did not allow for adaptation time.[24] Stone et al.[27] and Robertson et al.[17] had patients wear contact lenses for 30 minutes and found increased esophoria for near distances and more accommodative lag. They suggested that long-term use of contact lenses might lead to changes in accommodative convergence, accommodation, and the AC/A ratio. Jiménez et al.[24] and Stone et al.[27] also found no change in the AC/A ratio when individuals shifted from spectacles to contact lenses. Additionally, compared to the normal control group, there was no change in the AC/A ratio (Table 5).

The prismatic effect decreases the need for convergence in myopes. When contact lenses are worn instead of spectacles, the prismatic effect is lost, and consequently, a greater convergence effort is required.[7] We found no change in near point of convergence (NPC) between spectacles and contact lenses, as well as with the control group. However, a decrease in NPC value was observed compared to the control group. Jiménez et al.[24] also found no change in convergence. Hunt,[25] using a dynamic method to measure convergence, similarly found no significant change between spectacles and contact lenses. However, increased esophoria at near distances with contact lenses might suggest convergence excess.

No significant change in the value of negative relative accommodation (NRA) was reported between spectacles and rigid contact lenses, although higher NRA values were found with contact lenses. Jiménez et al.[24] found higher NRA values with soft contact lenses compared to spectacles, and the difference was statistically significant. We found no change in NRA with the control group.

We found no change in positive relative accommodation (PRA) when comparing spectacles and rigid contact lenses, but there was a significant difference when compared to the age-matched control group. Higher PRA values were observed with rigid contact lenses compared to the control group. Jiménez et al.[24] also found higher PRA values in patients using contact lenses and spectacles. Scheiman and Wick[28] stated that several factors determine the maximum PRA value, and the actual PRA value may be much greater. PRA values fluctuated according to refractive error, being highest in myopic individuals, who often accept greater minus power than required.[29] Phoria, amplitude of accommodation, and accommodation facility can influence the values of relative accommodation.[30,31]

For assessing a patient's binocular state, the quantity of fusional reserves is crucial. Patients with near esophoria correct the deviation using a portion of the negative fusional vergence. We found no significant difference in fusional vergence between contact lenses and spectacles, but we observed lower values of negative fusional vergence for near distances with contact lenses. Jiménez et al. [24] found a significant difference in negative fusional vergence for near distances between contact lenses and spectacles. There was no change in fusional vergence, whether positive or negative, with the control group.

CONCLUSION

Binocular and monocular logMAR visual acuity, near phoria, and stereopsis improved when switching from single-vision spectacles to rigid contact lenses in patients with irregular corneas. The use of rigid gas-permeable contact lenses is an effective treatment for improving visual performance and binocular vision in patients with irregular corneas, which can directly enhance daily activities and quality of life. However, all binocular vision parameters with rigid contact lenses in patients with irregular corneas remained poorer compared to those of age-matched normal control subjects with normal corneas. ●

DISCLOSURES

We want to sincerely thank Monica Chaudhry Vision Institute and Silver Line Laboratories for their essential assistance in treating patients with irregular corneas. Their cooperation and dedication to developing the discipline of optometry have been crucial to this study's success.

CORRESPONDING AUTHOR: Manish Kumar Sah - sahmanish52@gmail.com

The authors declare no conflict of interest

REFERENCES

1. Kamiya K, Hirohara Y, Mihashi T, Hiraoka T, Kaji Y, Oshika T. Progression of Pellucid Marginal Degeneration and Higher-Order Wavefront Aberration of the Cornea. *Jpn J Ophthalmol* 2003;47(5):523–5. doi:10.1016/s0021-5155(03)00126-6
2. Shneor E, Piñero DP, Doron R. Contrast Sensitivity and Higher-Order Aberrations in Keratoconus Subjects. *Sci Rep* 2021 Jun 21;11(1):12971. doi:10.1038/s41598-021-92396-5
3. Romero-Jiménez M, Flores-Rodríguez P. Utility of a Semi-Scleral Contact Lens Design in the Management of the Irregular Cornea. *Cont Lens Anterior Eye* 2013;36(3):146–50. doi:10.1016/j.clae.2012.12.006
4. Alió JL, Shabayek MH. Corneal Higher Order Aberrations: A Method to Grade Keratoconus. *J Refract Surg* 2006;22(6):539–45. doi:10.3928/1081-597X-20060601-05
5. Choi J, Wee WR, Lee JH, Kim MK. Changes of Ocular Higher Order Aberration in On- and Off-Eye of Rigid Gas Permeable Contact Lenses. *Optom Vis Sci* 2007; 84(1):42–51. doi:10.1097/01.opx.0000254036.45989.65
6. Westheimer G. The Relationship Between Accommodation and Accommodative Convergence. *Am J Optom Arch Am Acad Optom* 1955;32(4):206–12. doi:10.1097/00006324-195504000-00005
7. Fannin TE GT. *Clinical Optics.* 2nd ed. New York: Butterworth–Heinemann; 1997.
8. Hermann JS, Johnson R. The Accommodation Requirement in Myopia. A Comparison of Contact Lenses and Spectacles. *Arch Ophthalmol* 1966;76(1):47–51. doi:10.1001/archopht.1966.03850010049011
9. Antunes-Foschini RMS, Coutinho JVAL, Rocha EM, Bicas HEA. Oculomotor Status, Binocular Vision, and Stereoacuity in a Series of Keratoconus Subjects. *Invest Ophthalmol Vis Sci* 2018;59(5):1869–77. doi:10.1167/iovs.17-23484
10. Sherafat H, White JE, Pullum KW, Adams GG, Sloper JJ. Anomalies of Binocular Function in Patients With Longstanding Asymmetric Keratoconus. *Br J Ophthalmol* 2001;85(9)1057–60. doi:10.1136/bjo.85.9.1057
11. Barba-Gallardo LF, Jaramillo-Trejos LM, Agudelo-Guevara AM, Galicia-Durán AP, Casillas-Casillas E. Binocular Vision Parameters and Visual Performance in Bilateral Keratoconus Corrected With Spectacles Versus Rigid Gas-Permeable Contact Lenses. *J Optom* 2024;17(3):100514. doi:10.1016/j.optom.2024.100514
12. Dandapani SA, Padmanabhan P, Hussaindeen JR. Spectrum of Binocular Vision Anomalies in Keratoconus Subjects. *Optom Vis Sci* 2020;97(6):424–8. doi:10.1097/OPX.0000000000001517
13. Lovasik JV, Szymkiw M. Effects of Aniseikonia, Anisometropia, Accommodation, Retinal Illuminance, and Pupil Size on Stereopsis. *Invest Ophthalmol Vis Sci* 1985;26(5):741–50.
14. Nilagiri VK, Metlapally S, Kalaiselvan P, Schor CM, Bharadwaj SR. LogMAR and Stereoacuity in Keratoconus Corrected With Spectacles and Rigid Gas-Permeable Contact Lenses. *Optom Vis Sci* 2018;95(4):391–8. doi:10.1097/OPX.0000000000001205
15. Barba-Gallardo LF, Jaramillo-Trejos LM, Agudelo-Guevara AM, Galicia-Durán AP, Casillas-Casillas E. Binocular Vision Parameters and Visual Performance in Bilateral Keratoconus Corrected With Spectacles Versus Rigid Gas-Permeable Contact Lenses. J Optom. 2024;17(3):100514. doi:10.1016/j.optom.2024.100514
16. Bennett ES, Weissman BA. *Clinical Contact Lens Practice*. Philadelphia: Lippincott Williams & Wilkins; 2005.
17. Robertson DM, Ogle KN, Dyer JA. Influence of Contact Lenses on Accommodation: Theoretic Considerations and Clinical Study. *Am J Ophthalmol* 1967;64(5):860–71. doi:10.1016/0002-9394(67)92228-3
18. Gemoules G, Morris KM. Rigid Gas-Permeable Contact Lenses and Severe Higher-Order Aberrations in Postsurgical Corneas. *Eye Contact Lens* 2007;33(6 Pt 1):304–7. doi:10.1097/ICL.0b013e318033edde
19. Negishi K, Kumanomido T, Utsumi Y, Tsubota K. Effect of Higher-Order Aberrations on Visual Function in Keratoconic Eyes With a Rigid Gas Permeable Contact Lens. *Am J Ophthalmol* 2007;144(6):924–9. e1. doi: 10.1016/j.ajo.2007.08.004
20. Jinabhai A, Radhakrishnan H, O'Donnell C. Visual Acuity and Ocular Aberrations With Different Rigid Gas Permeable Lens Fittings in Keratoconus. *Eye Contact Lens* 2010;36(4):233–7. doi:10.1097/ICL.0b013e3181e52dd1
21. Bharadwaj SR, Sarkar S, Reddy J, Vadavalli PK. Optical Quality and Visual Performance After Relex SMILE, LASIK or PRK Refractive Surgery Procedures for Myopia. *Invest Ophthalmol Vis Sci* 2016;57(12)
22. Alpern M. Accommodation and Convergence With Contact Lenses. *Am J Optom Arch Am Acad Optom* 1949;26(9):379–87. doi:10.1097/00006324-194909000-00002
23. Carney LG, Woo GC. Comparison of Accommodation With Rigid and Flexible Contact Lenses. *Am J Optom Physiol Opt* 1977;54(9):595–7. doi:10.1097/00006324-197709000-00003
24. Jiménez R, Martínez-Almeida L, Salas C, Ortíz C. Contact Lenses vs Spectacles in Myopes: Is There Any Difference in Accommodative and Binocular Function? *Graefes Arch Clin Exp Ophthalmol* 2011;249(6):925–35. doi:10.1007/s00417-010-1570-z
25. Hunt OA, Wolffsohn JS, García-Resúa C. Ocular Motor Triad With Single Vision Contact Lenses Compared to Spectacle Lenses. *Cont Lens Anterior Eye* 2006;29(5):239–45. doi:10.1016/j.clae.2006.08.004
26. Fulk GW, Cyert LA, Parker DE, West RW. The Effect of Changing From Glasses to Soft Contact Lenses on Myopia Progression in Adolescents. *Ophthalmic Physiol Opt* 2003;23(1):71-77. doi:10.1046/j.1475-1313.2003.00094.x
27. Stone J. Near Vision Difficulties in Non-Presbyopic Corneal Lens Wearers. *Contact Lens* 1967;1(2):14-25.
28. Scheiman M, Wick B. *Diagnostic Testing: Clinical Management of Binocular Vision, Heterophoric, Accommodative and Eye Movement Disorders.* Philadelphia: Lippincott Williams & Wilkins; 2008:3-35.
29. Yekta A, Hashemi H, Khabazkhoob M, et al. The Distribution of Negative and Positive Relative Accommodation and Their Relationship With Binocular and Refractive Indices in a Young Population. *J Curr Ophthalmol* 2017 Jan 21;29(3):204–9. doi:10.1016/j.joco.2017.01.001
30. Kragha IK. Accommodative Vergence and Related Findings for a Nigerian Population. *Ophthalmic Physiol Opt*. 1985;5(4):435–9.
31. Buzzelli AR. Vergence Facility: Developmental Trends in a School Age Population. *Am J Optom Physiol Opt* 1986;63(5):351–5.