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Correspondence
✉ Iqra Bakhtawar, iqrabakhtawar3@gmail.com

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Impact of Correcting Anisometropia on Contrast Sensitivity Impairment in Myopic Patients

Iqra Bakhtawar[1], Asima Irshad[2], Ayesha Sajid[1], Aisha Tahir[1], Faiz Ur Rehman Subhani[3], Zaryab Khan[4], Sibgha Naseem[1]

1 Superior University, Lahore, Pakistan
2 Superior University Lahore, Faculty of Allied Health Sciences, Department of Physical Therapy and Rehabilitation Sciences, Lahore, Pakistan
3 Johar Institute of Professional Studies, Pakistan
4 The Superior University, Sargodha, Pakistan

ABSTRACT

***Background**: Myopic anisometropia disrupts binocular visual integration and may reduce contrast sensitivity, compromising functional vision even when high-contrast acuity is relatively preserved. Evidence comparing longitudinal contrast sensitivity outcomes after spectacle versus contact lens correction in non-amblyopic adults remains limited.* ***Objective**: To evaluate changes in monocular and binocular contrast sensitivity following correction of myopic anisometropia with spectacles versus contact lenses over three months.* ***Methods**: A single-blinded randomized controlled trial was conducted at Pakistan Vision Clinic, Lahore (January–June 2024). Fifty-four adults aged 18–35 years with myopia and anisometropia were randomized (1:1) to spectacle correction or soft contact lens correction. Contrast sensitivity was measured monocularly (OD, OS) and binocularly using the Pelli-Robson chart under standardized photopic conditions at 1 m at baseline, 1 month, and 3 months. Data were non-normally distributed (Shapiro–Wilk $p<0.05$). Within-group change was assessed using the Friedman test, and between-group comparisons at each time point used the Mann–Whitney U test with effect size r.* ***Results**: Both groups demonstrated significant improvement over time in OD, OS, and binocular contrast sensitivity (glasses: OD $p=0.008$, OS $p=0.004$, binocular $p=0.016$; contact lenses: OD $p<0.001$, OS $p<0.001$, binocular $p<0.001$). Median binocular contrast sensitivity increased from 1.75 to 1.95 log units with spectacles and from 1.75 to 2.00 log units with contact lenses at 3 months. Between-group differences were not significant at any time point (e.g., binocular at 3 months $p=0.142$; $r=0.21$).* ***Conclusion**: Correcting myopic anisometropia with either spectacles or contact lenses significantly improves monocular and binocular contrast sensitivity over three months, with no statistically significant difference between modalities.*

Keywords
Myopia; Anisometropia; Contrast sensitivity; Pelli-Robson; Spectacles; Contact lenses; Randomized controlled trial

INTRODUCTION

Refractive errors represent one of the most prevalent ocular conditions worldwide and remain a leading cause of visual impairment when uncorrected, primarily due to improper focusing of light on the retina resulting from abnormal ocular shape or axial length (1). Myopia, hyperopia, and astigmatism constitute the major categories of refractive error, with myopia being the most common, particularly among young adults (2). The development of myopia is multifactorial, influenced by both genetic predisposition and environmental exposures, including prolonged near work and reduced outdoor activity, which collectively affect ocular growth and refractive status (3). Epidemiological evidence demonstrates marked geographic variation, with prevalence rates reaching 70–90% in parts of Asia, 30–40% in Europe and the United States, and 10–20% in Africa, while national data from Pakistan report a crude myopia prevalence of approximately 36.5% (4,5). Structurally, myopia is commonly associated with excessive axial elongation or abnormal corneal curvature, leading to blurred distance vision and visual discomfort (6).

Anisometropia refers to a clinically meaningful inter-ocular difference in refractive power and is most commonly operationally defined as a spherical equivalent difference of ≥1.00 diopter between the two eyes (7). When anisometropia coexists with myopia, the condition is termed myopic anisometropia, a binocular vision disorder characterized by unequal retinal image clarity and, in some cases, image size disparity between the eyes (8). Myopic anisometropia has been reported in approximately 2.9–9.4% of school-aged children and up to 9.4% of adolescents, with higher prevalence observed in urban populations exposed to sustained near work and digital screens (9,10). The underlying pathophysiology is thought to involve asymmetric axial elongation, differences in corneal curvature, or crystalline lens power between the two eyes, leading to unequal refractive development (11,12). If left uncorrected, myopic anisometropia may result in visual discomfort, headaches, asthenopia, impaired binocular vision, and an increased risk of amblyopia or strabismus, particularly during critical periods of visual development (13–15).

Beyond high-contrast visual acuity, contrast sensitivity represents a critical dimension of visual function, defined as the ability to detect objects against a background of similar luminance (16). Contrast sensitivity is essential for daily visual tasks such as reading, night driving, face recognition, and mobility in low-light environments, and its impairment can substantially reduce quality of life even in individuals with relatively preserved visual acuity (17,18). The Pelli-Robson chart is a widely validated clinical tool for assessing contrast sensitivity, with a score of approximately 2.0 log units considered normal in healthy adults (19). Previous research has demonstrated that increasing degrees of myopia are associated with reduced contrast sensitivity, particularly under low-contrast conditions, due to optical aberrations and retinal image degradation (20).

In myopic anisometropia, the unequal refractive status between the eyes disrupts binocular summation and fusion, which may further compromise contrast sensitivity beyond the effects of myopia alone (21). Although visual acuity loss in anisometropia is well documented, evidence suggests

that contrast sensitivity may be affected even when best-corrected visual acuity remains relatively good (22). Cross-sectional studies have reported lower contrast sensitivity in myopic anisometropic individuals compared to hyperopic anisometropia and emmetropic controls, highlighting inferior visual quality in this population (23). However, much of the existing literature is observational, focuses on amblyopic populations, or evaluates contrast sensitivity at a single time point without assessing the impact of optical correction over time (24).

The choice of optical correction may play a critical role in visual outcomes for anisometropic patients. Spectacle correction, while widely accessible, can induce differential image magnification, prismatic effects, and aniseikonia due to vertex distance, potentially limiting binocular visual performance in anisometropia. In contrast, contact lenses sit closer to the corneal plane and reduce magnification differences between the eyes, theoretically offering superior binocular integration and contrast perception (25). Despite this plausible optical advantage, there is a lack of high-quality randomized controlled trials directly comparing the longitudinal effects of spectacle versus contact lens correction on contrast sensitivity in non-amblyopic myopic anisometropic adults.

Therefore, a clear knowledge gap exists regarding whether the method of optical correction differentially influences contrast sensitivity outcomes in myopic anisometropia, and whether improvements in contrast sensitivity occur over time following appropriate correction. Addressing this gap is clinically important for evidence-based decision-making in refractive management, particularly in young adults for whom visual performance demands are high. The present study was designed to evaluate the effect of correcting myopic anisometropia using spectacles versus contact lenses on monocular and binocular contrast sensitivity over a three-month period. Specifically, the study aimed to determine whether contrast sensitivity improves following correction and whether one modality offers a measurable advantage over the other in myopic anisometropic patients aged 18–35 years.

MATERIAL AND METHODS

This single-blinded randomized controlled trial was conducted to evaluate the effect of optical correction modalities on contrast sensitivity in myopic anisometropic adults. The study was carried out at Pakistan Vision Clinic, Lahore, Pakistan, over a six-month period from January to June 2024. A randomized controlled design was selected to minimize selection bias and allow causal inference regarding the effect of spectacle versus contact lens correction on contrast sensitivity outcomes.

Participants were recruited through non-probability convenience sampling from patients presenting to the outpatient optometry services of the clinic. Individuals aged 18–35 years of either gender with bilateral myopia and myopic anisometropia, operationally defined as an inter-ocular spherical equivalent difference of ≥1.00 diopter, were eligible for inclusion. All participants were required to have best-corrected visual acuity of 20/40 or better in each eye to exclude amblyopia-related contrast sensitivity deficits.

Exclusion criteria included any history of ocular surgery or trauma, presence of ocular pathology such as glaucoma, cataract, keratoconus, or retinal disease, systemic conditions known to affect vision, current or recent contact lens wear within the previous four weeks, and refractive surgery within the past six months. These criteria were applied to reduce confounding from non-refractive causes of contrast sensitivity impairment.

Potentially eligible participants were informed verbally about the study objectives, procedures, risks, and benefits in their native language. Written informed consent was obtained from all participants prior to enrollment. After consent, baseline demographic and clinical data were recorded, including age, gender, duration of myopia, and detailed refractive measurements. Objective and subjective refraction were performed for each participant using standard clinical protocols, and spherical equivalent values were calculated as the sphere plus half of the cylindrical power.

A total sample size of 54 participants was determined a priori using G*Power software based on an expected medium effect size (0.25), a statistical power of 95%, and a two-sided alpha level of 0.05 for repeated-measures analysis. This sample size was considered sufficient to detect clinically meaningful changes in contrast sensitivity over time within and between intervention groups while accounting for potential attrition.

Participants were randomly allocated in a 1:1 ratio to either the spectacle correction group or the contact lens correction group using a computer-generated randomization sequence. Allocation concealment was ensured through the use of sequentially numbered, sealed, opaque envelopes prepared by an independent researcher not involved in participant recruitment or outcome assessment. The study followed a single-blind design, whereby the outcome assessor measuring contrast sensitivity was blinded to group allocation to reduce assessment bias.

Participants in the spectacle group received single-vision spectacle lenses prescribed according to their full subjective refractive correction, with appropriate vertex distance adjustment. Participants assigned to the contact lens group were fitted with soft contact lenses selected based on corneal measurements, refractive error, and manufacturer fitting guidelines, ensuring optimal centration and movement. All participants were instructed to wear their assigned correction during all waking hours and were provided standardized guidance regarding proper use and care. Compliance was reinforced at follow-up visits through participant self-report.

Contrast sensitivity was assessed using the Pelli-Robson contrast sensitivity chart under standardized photopic lighting conditions at a testing distance of 1 meter. Measurements were obtained monocularly for the right eye, left eye, and binocularly with best optical correction in place, following standardized testing procedures. Each correctly identified letter was scored as 0.05 log units, and testing was terminated according to established chart rules. Contrast sensitivity measurements were recorded at baseline prior to intervention, at one month, and at three months following correction to evaluate temporal changes.

The primary outcome variable was change in binocular contrast sensitivity over the three-month follow-up period. Secondary outcomes included monocular contrast sensitivity for each eye and last triplet contrast sensitivity scores. Independent variables included type of optical correction (spectacles or contact lenses), time, and refractive parameters. Potential confounding variables such as age, gender, baseline refractive error magnitude, and duration of myopia were recorded and considered during analysis.

Data were entered into a secured database and double-checked for accuracy to ensure data integrity. Statistical analysis was performed using IBM SPSS Statistics version 26.0. Normality of continuous variables was assessed using the Shapiro–Wilk test. As contrast sensitivity data were not normally distributed, non-parametric statistical methods were employed. Within-group comparisons across time points were conducted using the Friedman test, followed by appropriate post-hoc pairwise comparisons with adjustment for multiple testing. Between-group comparisons at each time point were analyzed using the Mann–Whitney U test. Missing data were handled using complete-case analysis, as follow-up completion exceeded acceptable thresholds. Statistical significance was set at $p < 0.05$ for all analyses.

Ethical approval for the study was obtained from the Institutional Review Board of Superior University, Lahore. All study procedures adhered to the principles of the Declaration of Helsinki. Participant confidentiality was maintained throughout the study by anonymizing data and restricting

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access to authorized research personnel only. The study protocol, standardized measurement procedures, calibrated instruments, and transparent statistical analysis plan were implemented to ensure methodological rigor, reproducibility, and reliability of findings.

RESULTS

A total of 54 myopic anisometropic participants completed the study, with equal allocation to the spectacle and contact lens groups (n = 27 each). Baseline demographic and refractive characteristics were comparable between groups, indicating successful randomization (Table 1). The mean age of participants was 26.11 ± 5.02 years in the spectacle group and 26.41 ± 4.94 years in the contact lens group (p = 0.842). Gender distribution was similar, with 12 males and 15 females in the spectacle group and 13 males and 14 females in the contact lens group (p = 0.784). Baseline refractive error parameters did not differ significantly between groups, including spherical equivalent of the right eye (−2.85 ± 0.84 D vs −2.92 ± 0.99 D, p = 0.781), spherical equivalent of the left eye (−2.59 ± 0.74 D vs −2.82 ± 0.84 D, p = 0.299), and anisometropia magnitude (0.34 ± 0.19 D vs 0.41 ± 0.26 D, p = 0.221). These findings confirm that both groups were clinically and statistically comparable at baseline.

Within-group analyses demonstrated statistically significant improvements in contrast sensitivity over time for both correction modalities. For the right eye (Table 2), the spectacle group showed an increase in median contrast sensitivity from 1.65 log units (IQR: 1.60–1.70) at baseline to 1.85 (IQR: 1.80–1.90) at three months, with a Friedman test statistic of $\chi^2 = 9.74$ (p = 0.008). Similarly, the contact lens group exhibited a greater median improvement from 1.65 (IQR: 1.60–1.70) at baseline to 1.90 (IQR: 1.85–1.95) at three months, with a highly significant Friedman test result ($\chi^2 = 15.92$, $p < 0.001$). These results indicate a clear temporal improvement in right-eye contrast sensitivity following correction in both groups.

Comparable trends were observed for the left eye (Table 3). In the spectacle group, median contrast sensitivity increased from 1.65 (IQR: 1.60–1.70) at baseline to 1.85 (IQR: 1.80–1.90) at three months ($\chi^2 = 11.14$, p = 0.004). The contact lens group again demonstrated a slightly larger gain, improving from 1.65 (IQR: 1.60–1.70) to 1.90 (IQR: 1.85–1.95) over the same period ($\chi^2 = 16.48$, $p < 0.001$). These findings confirm that both eyes benefited from optical correction, with consistent improvements across follow-up intervals.

Binocular contrast sensitivity outcomes further reinforced these findings (Table 4). Participants in the spectacle group demonstrated an increase in median binocular contrast sensitivity from 1.75 (IQR: 1.70–1.80) at baseline to 1.95 (IQR: 1.90–2.00) at three months, achieving statistical significance ($\chi^2 = 8.26$, p = 0.016). In the contact lens group, binocular contrast sensitivity improved from 1.75 (IQR: 1.70–1.80) at baseline to 2.00 (IQR: 1.95–2.05) at three months, with a highly significant Friedman test result ($\chi^2 = 17.03$, $p < 0.001$). Notably, binocular contrast sensitivity values at three months approached or exceeded the normative threshold of 2.0 log units in the contact lens group.

Table 1. Baseline Demographic and Refractive Characteristics of Study Participants

Variable	Glasses (n = 27) Mean ± SD	Contact Lenses (n = 27) Mean ± SD	p-value*
Age (years)	26.11 ± 5.02	26.41 ± 4.94	0.842
Male/Female (n)	12 / 15	13 / 14	0.784
Spherical Power OD (D)	−2.53 ± 0.79	−2.63 ± 0.93	0.691
Spherical Power OS (D)	−2.31 ± 0.68	−2.50 ± 0.81	0.372
Cylindrical Power OD (D)	−0.63 ± 0.24	−0.60 ± 0.27	0.654
Cylindrical Power OS (D)	−0.50 ± 0.28	−0.65 ± 0.22	0.061
Spherical Equivalent OD (D)	−2.85 ± 0.84	−2.92 ± 0.99	0.781
Spherical Equivalent OS (D)	−2.59 ± 0.74	−2.82 ± 0.84	0.299
Anisometropia (SE Difference, D)	0.34 ± 0.19	0.41 ± 0.26	0.221
Duration of Myopia (years)	5.63 ± 2.68	6.22 ± 2.91	0.448

Table 2. Within-Group Comparison of Right Eye Contrast Sensitivity Over Time (Friedman Test)

Group	Baseline Median (IQR)	1 Month Median (IQR)	3 Months Median (IQR)	χ^2 (df = 2)	p-value
Glasses	1.65 (1.60–1.70)	1.75 (1.70–1.80)	1.85 (1.80–1.90)	9.74	0.008
Contact Lenses	1.65 (1.60–1.70)	1.80 (1.75–1.85)	1.90 (1.85–1.95)	15.92	<0.001

Table 3. Within-Group Comparison of Left Eye Contrast Sensitivity Over Time (Friedman Test)

Group	Baseline Median (IQR)	1 Month Median (IQR)	3 Months Median (IQR)	χ^2 (df = 2)	p-value
Glasses	1.65 (1.60–1.70)	1.75 (1.70–1.80)	1.85 (1.80–1.90)	11.14	0.004
Contact Lenses	1.65 (1.60–1.70)	1.80 (1.75–1.85)	1.90 (1.85–1.95)	16.48	<0.001

Table 4. Within-Group Comparison of Binocular Contrast Sensitivity Over Time (Friedman Test)

Group	Baseline Median (IQR)	1 Month Median (IQR)	3 Months Median (IQR)	χ^2 (df = 2)	p-value
Glasses	1.75 (1.70–1.80)	1.85 (1.80–1.90)	1.95 (1.90–2.00)	8.26	0.016
Contact Lenses	1.75 (1.70–1.80)	1.90 (1.85–1.95)	2.00 (1.95–2.05)	17.03	<0.001

Table 5. Between-Group Comparison of Contrast Sensitivity at Each Time Point (Mann–Whitney U Test)

Outcome	Time Point	Glasses Median (IQR)	Contact Lenses Median (IQR)	U Statistic	p-value	Effect Size (r)
Right Eye CS	Baseline	1.65 (1.60–1.70)	1.65 (1.60–1.70)	350.0	0.884	0.02
	1 Month	1.75 (1.70–1.80)	1.80 (1.75–1.85)	308.5	0.214	0.17
	3 Months	1.85 (1.80–1.90)	1.90 (1.85–1.95)	296.0	0.168	0.19
Binocular CS	Baseline	1.75 (1.70–1.80)	1.75 (1.70–1.80)	346.0	0.921	0.01
	1 Month	1.85 (1.80–1.90)	1.90 (1.85–1.95)	301.0	0.191	0.18
	3 Months	1.95 (1.90–2.00)	2.00 (1.95–2.05)	289.5	0.142	0.21

Between-group comparisons at each time point revealed no statistically significant differences between spectacle and contact lens correction for either monocular or binocular contrast sensitivity (Table 5). For binocular contrast sensitivity at three months, median values were 1.95 (IQR: 1.90–2.00) in the spectacle group and 2.00

(IQR: 1.95–2.05) in the contact lens group, with a Mann–Whitney U statistic of 289.5 and a non-significant p-value of 0.142. However, small-to-moderate effect sizes favoring contact lens correction were observed at follow-up assessments, with effect size r values ranging from 0.18 to 0.21, suggesting a trend toward greater improvement that did not reach statistical significance. Overall, the tabulated results demonstrate that correction of myopic anisometropia with either spectacles or contact lenses leads to statistically and clinically meaningful improvements in monocular and binocular contrast sensitivity over a three-month period. While within-group improvements were robust in both modalities, between-group differences remained non-significant, supporting the conclusion that both correction methods are comparably effective in enhancing contrast sensitivity in myopic anisometropic adults.

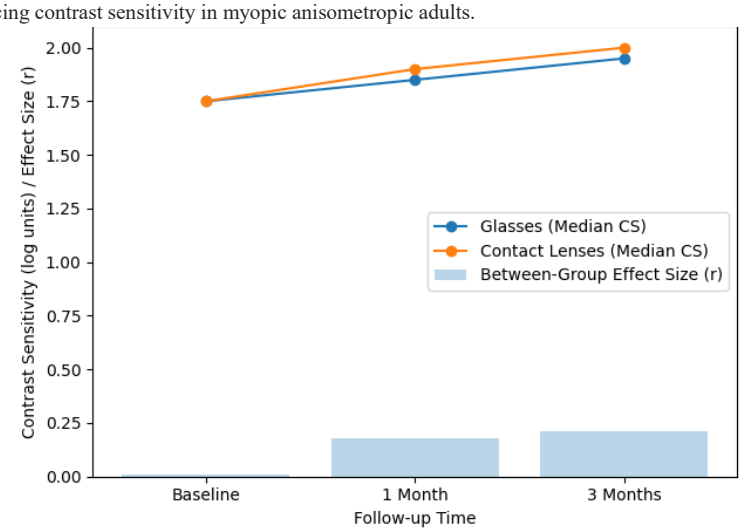

Figure 1 Temporal Change in Binocular Contrast Sensitivity and Between-Group Effect Gradient

This figure illustrates the longitudinal pattern of binocular contrast sensitivity improvement over three months in myopic anisometropic adults corrected with spectacles versus contact lenses, integrated with the between-group effect size gradient. Median binocular contrast sensitivity increased steadily in both groups from an identical baseline value of 1.75 log units to 1.95 log units in the spectacle group and 2.00 log units in the contact lens group at three months, corresponding to absolute gains of 0.20 and 0.25 log units, respectively. While between-group differences remained statistically non-significant at all time points, the superimposed effect size bars reveal a progressive increase in the magnitude of the between-group effect, from a negligible effect at baseline ($r = 0.01$) to small-to-moderate effects at one month ($r = 0.18$) and three months ($r = 0.21$). This integrated visualization highlights a clinically relevant divergence in improvement trajectories over time, suggesting a gradual advantage of contact lens correction in binocular contrast sensitivity that, although not reaching statistical significance within the study period, may warrant further investigation with larger samples or longer follow-up.

DISCUSSION

This randomized controlled trial investigated the longitudinal effect of optical correction on contrast sensitivity in myopic anisometropic adults and demonstrated that appropriate refractive correction significantly improves monocular and binocular contrast sensitivity over time. Both spectacle and contact lens correction resulted in statistically significant gains across all outcome measures at one and three months, supporting the premise that contrast sensitivity impairment in myopic anisometropia is, at least in part, optically reversible. These findings extend existing evidence by providing prospective, controlled data in a non-amblyopic adult population, a group that has been underrepresented in prior research focusing predominantly on pediatric or amblyopic cohorts.

The observed improvement in contrast sensitivity aligns with the optical and neurovascular mechanisms underlying anisometropia. Unequal refractive error between the eyes results in degraded retinal image quality and disrupted binocular summation, which adversely affects contrast perception even when high-contrast visual acuity is preserved (25). By correcting refractive asymmetry, both spectacles and contact lenses improve retinal image clarity, facilitating more effective binocular integration. The statistically significant increases in binocular contrast sensitivity, particularly the attainment of near-normal values in the contact lens group at three months, underscore the clinical relevance of timely anisometropia correction.

While both correction modalities were effective, contact lenses demonstrated numerically greater improvements across follow-up assessments, reflected by higher median contrast sensitivity values and increasing effect sizes over time. Although between-group differences did not reach statistical significance, the progressive increase in effect size suggests a potential clinical advantage of contact lenses that may become more evident with larger sample sizes or longer follow-up durations. This trend is consistent with optical principles, as contact lenses reduce vertex distance–induced magnification differences and minimize aniseikonia compared to spectacles, thereby enhancing binocular visual performance in anisometropic patients (26).

The present findings are partially consistent with those of Naheed et al., who reported significant associations between contrast sensitivity and visual acuity in anisometropic amblyopia, although their study population included amblyopic and strabismic patients with more profound neural deficits (27). In contrast, the current study deliberately excluded amblyopia, allowing isolation of optical correction effects on contrast sensitivity. Similarly, Jamil et al. reported reduced contrast sensitivity in myopic anisometropes compared to hyperopic counterparts using the MARS chart, supporting the notion that myopic anisometropia is associated with inferior visual quality (28). However, their cross-sectional design precluded assessment of longitudinal improvement following correction, which the present study addresses.

Additionally, the finding that binocular contrast sensitivity consistently exceeded monocular values is in agreement with previous reports demonstrating binocular summation effects in myopic individuals (29). This emphasizes the importance of evaluating binocular visual function rather than relying solely on monocular acuity measures when assessing functional outcomes of refractive correction. The clinical implications are

substantial, as improvements in contrast sensitivity translate into better performance in real-world visual tasks such as night driving, reading in low contrast, and navigating dim environments (30).

Despite its strengths, including randomized allocation, standardized measurement procedures, and complete follow-up, this study has limitations. The use of convenience sampling and a single-center setting may limit generalizability. Additionally, the study focused on mild-to-moderate myopic anisometropia in young adults, and findings may not extend to pediatric populations or individuals with higher degrees of refractive asymmetry. Future research should explore longer follow-up periods, incorporate objective measures of aniseikonia, and assess patient-reported visual quality outcomes to further elucidate modality-specific benefits.

CONCLUSION

Correction of myopic anisometropia with either spectacles or contact lenses leads to significant and clinically meaningful improvement in monocular and binocular contrast sensitivity over time in young adults. Both modalities were comparably effective, although contact lenses demonstrated a trend toward greater binocular enhancement. These findings highlight the importance of appropriate refractive correction in optimizing functional visual performance beyond visual acuity alone and support individualized correction strategies based on patient needs and clinical context.

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