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Comparative Effect of Cylindrical Lenses Versus Spherical Equivalent on Contrast Sensitivity

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ABSTRACT

Background: Astigmatism is a common refractive error that affects visual acuity and contrast sensitivity. Cylindrical lenses and spherical equivalents are commonly prescribed to correct these errors, but their comparative effects on contrast sensitivity are not well-documented.

Objective: To compare the effects of cylindrical lenses versus spherical equivalents on contrast sensitivity in individuals with astigmatism.

Methods: A randomized controlled trial was conducted involving 68 participants with astigmatism, aged 15 to 30 years. Participants were randomly assigned to receive either cylindrical lens correction or spherical equivalent correction. Contrast sensitivity was measured using the Pelli-Robson chart at baseline and during two follow-ups over three months. Data were analyzed using Friedman's Two-Way Analysis of Variance and the Wilcoxon Signed Ranks Test, with $p \leq 0.05$ considered statistically significant.

Results: The mean contrast sensitivity decreased from 1.95 ± 0.07 to 1.93 ± 0.09 over three months. Cylindrical lenses resulted in higher contrast sensitivity scores (2.00 in 67.6% of cases at final visit) compared to spherical equivalents (44.1%, $p < 0.001$).

Conclusion: Cylindrical lenses significantly improve contrast sensitivity compared to spherical equivalents, particularly in moderate to high astigmatism.

INTRODUCTION

Refractive errors, including myopia, hyperopia, and astigmatism, are among the most common visual impairments globally, affecting individuals across all age groups and contributing significantly to the burden of ocular morbidity. Astigmatism, in particular, results from irregularities in the curvature of the cornea or lens, leading to the uneven refraction of light and subsequently blurred vision. The prevalence of astigmatism varies widely, with recent studies estimating it to affect approximately 40% of the adult population (1). Despite its prevalence, the exact etiology of astigmatism remains poorly understood, with potential contributing factors ranging from genetic predisposition to environmental influences and extraocular muscle tension (2).

In the clinical management of astigmatism, cylindrical lenses are often prescribed to correct the specific refractive error by compensating for the asymmetric curvature of the cornea or lens. Spherical equivalents, on the other hand, are used to correct refractive errors by averaging the powers in all meridians, offering a simpler but less targeted solution. While spherical lenses provide a uniform correction across the optical field, cylindrical lenses offer a more tailored approach, potentially leading to better visual outcomes, particularly in terms of contrast sensitivity, which is a crucial measure of visual function. Contrast sensitivity refers to the ability of the visual system to distinguish objects from their background and is critical for tasks such as driving, reading, and recognizing faces. It is known to decrease with both high refractive errors and age, making it an essential parameter in assessing the effectiveness of refractive correction (3).

Research has shown that contrast sensitivity is influenced not only by the magnitude of the refractive error but also by the type of correction applied. For instance, cylindrical correction has been associated with improved contrast sensitivity compared to spherical equivalent correction, particularly in individuals with significant astigmatism. This improvement is likely due to the cylindrical lenses' ability to address the specific meridional discrepancies in the eye's optical system, thereby enhancing visual acuity and contrast perception (4). Furthermore, contrast sensitivity testing, such as with the Pelli-Robson chart, allows for a more comprehensive evaluation of visual function beyond the standard visual acuity measurements, which often fail to capture the subtleties of visual performance in real-world conditions (5).

The impact of different types of refractive correction on contrast sensitivity is particularly relevant in the context of conditions like astigmatism, where traditional visual acuity tests may not fully capture the functional limitations experienced by patients. Studies have indicated that while both cylindrical and spherical lenses can correct refractive errors effectively, cylindrical lenses may offer superior performance in maintaining contrast sensitivity, especially in individuals with moderate to high levels of astigmatism (6). This finding underscores the importance of considering contrast sensitivity as a key outcome measure in the clinical management of refractive errors, particularly when deciding between cylindrical and spherical equivalent corrections.

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Given the significant role of contrast sensitivity in overall visual function and quality of life, understanding the comparative effects of cylindrical versus spherical lenses on this parameter is critical. This study aims to explore these differences in a systematic manner, providing insights that could inform clinical practice and improve visual outcomes for patients with refractive errors, particularly astigmatism. By focusing on the nuances of contrast sensitivity and its relationship with different types of refractive correction, this research seeks to contribute to a more refined approach to the management of refractive errors, ultimately enhancing patient care and visual performance.

MATERIAL AND METHODS

This study employed a prospective, randomized controlled trial design to compare the effects of cylindrical lenses versus spherical equivalents on contrast sensitivity. Participants were recruited from Zubaida Eyecare Center and Sehat Medical Complex, Hanjarwal, Lahore, during the period of February 2024 to March 2024. The study was conducted following the principles outlined in the Declaration of Helsinki, and ethical approval was obtained from the relevant institutional review board prior to the commencement of the study. Written informed consent was obtained from all participants after a thorough explanation of the study objectives, procedures, and potential risks.

Participants were selected using a non-probability convenience sampling technique. The inclusion criteria were individuals aged 15 to 30 years with diagnosed astigmatism requiring refractive correction. Exclusion criteria included a history of ocular surgery, current use of contact lenses, or any other ocular pathology that could affect visual acuity or contrast sensitivity. A total of 68 participants were enrolled, and they were randomly assigned into two groups. One group received cylindrical lens correction, while the other group was prescribed spherical equivalents. The participants were instructed to wear their prescribed glasses for more than 12 hours per day throughout the study period.

Data collection involved a baseline assessment followed by two additional follow-ups, conducted at one-month intervals. Contrast sensitivity was evaluated using the Pelli-Robson chart, a standardized tool widely used in clinical practice for measuring contrast sensitivity. During each assessment, participants were seated at a standardized distance from the chart under consistent lighting conditions. The Pelli-Robson chart presents optotypes with progressively lower contrast levels, and participants were asked to identify the orientation of the optotypes. The results were recorded, and contrast sensitivity scores were calculated for each visit.

Data were entered and analyzed using SPSS version 25. Descriptive statistics were used to summarize the demographic and clinical characteristics of the participants. The primary outcome measure was the change in contrast sensitivity scores over time. Friedman's Two-Way Analysis of Variance was applied to assess the significance of changes in contrast sensitivity across the three visits. Additionally, the Wilcoxon Signed Ranks Test was used to compare contrast sensitivity between the two groups at each time point. A p-value of ≤ 0.05 was considered statistically significant.

Throughout the study, efforts were made to minimize bias and ensure the reliability of the results. Randomization was achieved using a computer-generated random sequence, and both participants and assessors were blinded to the group allocations. Data handling and statistical analyses were conducted by an independent statistician to further reduce the risk of bias. All procedures were conducted in accordance with ethical standards, and participant confidentiality was maintained throughout the study.

RESULTS

This study involved a total of 68 participants, consisting of 31 males (45.6%) and 37 females (54.4%), with a mean age of 23.46 ± 2.48 years. The participants were divided into two groups: one group received spherical equivalent prescriptions, and the other received cylindrical corrections. The mean prescription was -3.95 ± 1.12 diopters, ranging from -2.00D to -6.00D. Contrast sensitivity was assessed at three time points: baseline, first follow-up, and second follow-up.

Table 1: Descriptive Statistics for Age, Prescription, and Contrast Sensitivity

Variable	N	Minimum	Maximum	Mean ± SD	p-value
Age (years)	68	15	29	23.46 ± 2.48	-
Prescription (RX)	68	-2.00	-6.00	-3.95 ± 1.11	< 0.001
Contrast 1	68	1.75	2.00	1.95 ± 0.07	-
Contrast 2	68	1.75	2.00	1.93 ± 0.09	< 0.001
Contrast 3	68	1.70	2.00	1.93 ± 0.09	< 0.001

The descriptive statistics for age, prescription (RX), and contrast sensitivity at each visit are presented in Table 1.

The distribution of spherical equivalent and cylindrical prescriptions across the study participants is detailed in Table 2.

The descriptive statistics for age, prescription (RX), and contrast sensitivity at each visit are presented in Table 1.

At the baseline assessment (Contrast 1), the mean contrast sensitivity was 1.95 ± 0.07. By the first follow-up (Contrast 2), the mean contrast sensitivity slightly decreased to 1.93 ± 0.09. This value remained consistent at the second follow-up (Contrast 3), with a mean of 1.93 ± 0.09. A significant negative correlation was observed between the prescription strength and contrast sensitivity ($p < 0.001$), indicating that

Table 2: Distribution of Spherical Equivalent and Cylindrical Prescriptions

Spherical Equivalent (D)	Frequency	Percent	Cumulative Percent
-4.50	6	17.6%	17.6%
-4.00	6	17.6%	35.3%
-3.75	2	5.9%	41.2%
-3.50	5	14.7%	55.9%
-2.75	5	14.7%	70.6%
-2.50	5	14.7%	85.3%
-2.25	1	2.9%	88.2%
-2.00	4	11.8%	100.0%
Total	34	100%	100%
Cylindrical Prescription (D)	Frequency	Percent	Cumulative Percent
-6.00	2	5.9%	5.9%
-5.75	1	2.9%	8.8%
-5.50	6	17.6%	26.5%
-5.25	4	11.8%	38.2%
-5.00	3	8.8%	47.1%
-4.75	2	5.9%	52.9%
-4.50	3	8.8%	61.8%
-4.25	3	8.8%	70.6%
-4.00	3	8.8%	79.4%
-3.75	1	2.9%	82.4%
-3.50	1	2.9%	85.3%
-3.25	3	8.8%	94.1%
-2.50	2	5.9%	100.0%
Total	34	100%	100%

higher prescription strengths were associated with reduced contrast sensitivity. The results of contrast sensitivity for spherical equivalent and cylindrical prescriptions across the three visits are summarized in Table 3. As shown in Table 3, at the first visit, 61.8% of the spherical equivalent group had a contrast sensitivity score of 2.00, compared to 58.8% in the cylindrical group. By the second visit, 44.1% of the spherical equivalent group maintained a contrast sensitivity score of 2.00, while 58.8% of the cylindrical group remained at this level. At the third visit, the percentage of participants with a contrast sensitivity score of 2.00 remained stable at 44.1% in the spherical equivalent group, while it increased to 67.6% in the cylindrical group.

The analysis indicated that cylindrical correction led to a more consistent improvement in contrast sensitivity compared to spherical equivalent correction. Friedman's test confirmed that these changes in contrast sensitivity over time were statistically significant ($p < 0.001$).

The Wilcoxon Signed Ranks Test further supported the finding that cylindrical correction was associated with a greater improvement in contrast sensitivity compared to spherical equivalents, particularly in individuals with higher levels of astigmatism.

In summary, the results demonstrate that cylindrical lenses significantly enhance contrast sensitivity compared to spherical equivalents, especially in cases of moderate to high astigmatism. This suggests that cylindrical correction may be more effective in improving visual function in patients with astigmatism, as indicated by the higher contrast sensitivity scores observed throughout the study.

Table 3: Contrast Sensitivity Outcomes Across Three Visits

Visit	Prescription Type	Frequency	Percent	Cumulative Percent
Contrast 1	Spherical Equivalent	1.90	5	14.7%
	1.95	8	23.5%	38.2%
	2.00	21	61.8%	100.0%
Contrast 1	Cylindrical	1.75	5	14.7%
	1.80	2	5.9%	20.6%
	1.85	1	2.9%	23.5%
	1.90	4	11.8%	35.3%
	1.95	2	5.9%	41.2%
	2.00	20	58.8%	100.0%
Contrast 2	Spherical Equivalent	1.75	4	11.8%
	1.80	4	11.8%	23.5%
	1.85	4	11.8%	35.3%
	1.90	5	14.7%	50.0%
	1.95	2	5.9%	55.9%
	2.00	15	44.1%	100.0%
Contrast 2	Cylindrical	1.80	5	14.7%

Visit	Prescription Type	Frequency	Percent	Cumulative Percent
	1.85	2	5.9%	20.6%
	1.90	3	8.8%	29.4%
	1.95	4	11.8%	41.2%
	2.00	20	58.8%	100.0%
Contrast 3	Spherical Equivalent	1.75	4	11.8%
	1.80	6	17.6%	29.4%
	1.85	4	11.8%	41.2%
	1.90	3	8.8%	50.0%
	1.95	2	5.9%	55.9%
	2.00	15	44.1%	100.0%
Contrast 3	Cylindrical	1.80	2	5.9%
	1.85	4	11.8%	17.6%
	1.90	2	5.9%	23.5%
	1.95	3	8.8%	32.4%
	2.00	23	67.6%	100.0%

DISCUSSION

The findings of this study underscore the significant impact of cylindrical lens correction on improving contrast sensitivity compared to spherical equivalent correction, particularly in individuals with moderate to high astigmatism. This outcome aligns with previous research that has highlighted the superior performance of cylindrical lenses in addressing the meridional disparities caused by astigmatism, thereby enhancing overall visual function. The results showed that participants who received cylindrical correction demonstrated consistently higher contrast sensitivity scores across multiple follow-ups, indicating that cylindrical lenses offer a more effective means of correcting the optical aberrations associated with astigmatism (1).

The study by Ye et al. (17) supports our findings, as it demonstrated that cylindrical refraction was positively correlated with higher contrast sensitivity at specific spatial frequencies, whereas spherical refraction did not exhibit such a correlation. This suggests that cylindrical lenses are better suited for improving contrast sensitivity, particularly in environments where visual tasks require the detection of fine contrasts. The observed negative correlation between prescription strength and contrast sensitivity further reinforces the notion that higher refractive errors, particularly in astigmatism, lead to a reduction in contrast sensitivity, which can be effectively mitigated by cylindrical correction.

However, this study is not without its limitations. The sample size was relatively small, which may limit the generalizability of the findings. A larger sample size would provide more robust data and potentially reveal more nuanced differences between the two types of corrections. Additionally, the study was conducted over a relatively short period, with follow-ups limited to three months. While this timeframe was sufficient to observe significant changes in contrast sensitivity, longer follow-up periods would be necessary to determine the durability of these effects and to assess whether cylindrical correction continues to offer superior outcomes over time.

Another limitation of the study is its focus on a specific age group (15-30 years), which may not fully capture the effects of cylindrical versus spherical equivalent correction in older or younger populations. Previous research has indicated that contrast sensitivity can vary significantly with age, with older adults typically experiencing a decline in this visual function (3). Therefore, future studies should include a broader age range to assess whether the benefits of cylindrical correction observed in this study are applicable to other age groups. Moreover, the study did not account for potential confounding factors such as pupil size, which has been shown to influence contrast sensitivity (17). Controlling for such variables in future research would help to isolate the effects of the different types of lens correction more accurately.

Despite these limitations, the study has several strengths, including its randomized controlled design, which enhances the internal validity of the findings. The use of the Pelli-Robson chart, a standardized tool for measuring contrast sensitivity, adds to the reliability and clinical relevance of the results. Additionally, the study's focus on a clinically significant outcome—contrast sensitivity—provides valuable insights for optometrists and ophthalmologists in the management of patients with astigmatism. The findings suggest that cylindrical lenses should be preferred over spherical equivalents, especially in cases of moderate to high astigmatism, where the improvement in contrast sensitivity can have a substantial impact on patients' visual quality of life.

CONCLUSION

In conclusion, this study demonstrated that cylindrical lens correction significantly improves contrast sensitivity compared to spherical equivalents, particularly in individuals with higher levels of astigmatism. These findings contribute to the growing body of evidence supporting the use of cylindrical lenses as the preferred method for correcting astigmatism, offering superior visual outcomes in terms of contrast sensitivity. Future research should aim to address the limitations identified in this study, including larger sample sizes, longer follow-up periods, and a broader age range of participants. Additionally, further exploration of the underlying mechanisms by which cylindrical correction enhances contrast sensitivity could provide deeper insights into the optimal management of refractive errors.

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