Journal of Ocular Sciences and Ophthalmology
ISSN: 2998-1476

Academic Strive
Researcher's perception is our reality

Research Article

Volume 5 Issue 2

Impact of High-Index Ophthalmic Lenses on Chromatic Aberration and Visual Performance in High Myopia: A Comparative Analysis

Parmar G[1], Dalal D[2]* and Dudhiyawala K[3]

[1]Optical Advisor, Specsavers Opticals & Audiologists, UK

[2]Department of Optometry, Bapubhai Desaibhai Patel Institute of Paramedical Sciences (BDIPS), India

[3]Final year Optometry student, Bapubhai Desaibhai Patel Institute of Paramedical Sciences (BDIPS), India

***Corresponding author:** Devanshi M Dalal, Department of Optometry, Bapubhai Desaibhai Patel Institute of Paramedical Sciences (BDIPS), B-406, Jivabhai Tower, Sandesh Press road, Bodakdev, Ahmedabad,-380054, India, Tel: 9825055134; Email: devanshidalal30@gmail.com

Received Date: September 26, 2024; **Published Date:** November 12, 2024

Abstract

High-index ophthalmic lenses have become a popular choice for individuals with high myopia due to their ability to reduce lens thickness and weight, improving aesthetic appeal and comfort. However, these lenses can introduce chromatic aberration, which may affect visual performance. This research paper investigates the relationship between high-index lenses and chromatic aberration in high myopic spectacles, providing a comprehensive statistical analysis to assess the extent of this issue. Our study evaluates chromatic aberration across different lens materials and indices, analyzing how it impacts visual acuity and wearer satisfaction.

Keywords: Chromatic; Lenses; Myopia; Visual; Retina

Abbreviations

LCA: Longitudinal Chromatic Aberration; TCA: Transverse Chromatic Aberration; OCT: Optical Coherence Tomography; HOAs: Higher-Order Aberrations; WHO: World Health Organization.

Introduction

Myopia, or nearsightedness, is a common refractive error that affects a significant portion of the global population [1-6]. Myopia is defined by the World Health Organization (WHO) International Classification of Diseases (ICD-10) as a refractive error in which, when accommodation is relaxed, light rays running parallel to the optical axis are concentrated in front of the retina [6]. High myopia, defined as a refractive error of -6.00 diopters (D) or more. Research shows that by 2050, there will be about 1 billion persons with high myopia worldwide, which is 7.5 times more than there were in 2000 [7].

There are several ways to correct myopia, including contact lenses, prescription glasses, orthokeratology, refractive surgery, and myopia control glasses which allow for clear distant vision. Numerous factors, such as the patient's age, motivation for wearing contact lenses, adherence to contact lens care instructions, corneal physiology, and economic concerns, determine whether spectacles or contact lenses are preferable in a particular situation. Getting glasses is the most common method of treating myopia. Concave glass or plastic lenses are positioned in frames in front of the eyes. The lenses are polished to fit the specifications of the prescription eyeglasses, both in terms of thickness and curve. The capacity of the lenses to cause light rays to diverge and focus results in clear distance vision. It presents additional challenges, including increased lens thickness, weight, and potential for optical distortions in High myopia.

High-index lenses, with refractive indices greater than that of standard CR-39 (n = 1.50), offer a solution by allowing thinner, lighter lenses while maintaining the same corrective power. The power and thickness of a lens are mostly determined by the refractive index of the material used in the lens, or how well it bends light. For any given optical power, the front and rear curvatures of the lens surfaces must be flatter the higher the index for that lens design. The refractive index of a lens material is crucial for its ability to bend light and create power and thickness. Higher index lenses have flatter front and back curvatures for a given optical power. This property enables the lens to be thinner and lighter while maintaining the same corrective power for vision disorders [8].

Higher-index materials tend to disperse light and create rainbow contours, which is more pronounced in high-index materials. This chromatic dispersion is present in any lens but is more pronounced in high-index materials. Chromatic aberration occurs when a lens fails to focus all colors of light at the same point, leading to color fringing and reduced image clarity. High myopic patients are more susceptible to distortions due to their reliance on corrective lenses. Quantifying chromatic aberration is crucial for assessing lens materials' impact on visual acuity and wearer satisfaction. Understanding the degree of chromatic aberration in high-index lenses can help optometrists and manufacturers develop solutions to improve patient performance and comfort [9].

Longitudinal chromatic aberration (LCA) and transverse chromatic aberration (TCA) are the two main types of chromatic aberration that impact visual performance, especially in high myopic ones. Longitudinal Chromatic Aberration (LCA) is a phenomenon where different wavelengths of light are focused at different distances along the optical axis, resulting in a color-fringing effect. This effect is more pronounced in lenses with higher refractive index due to increased light dispersion, resulting in reduced image clarity [10]. Whereas transverse chromatic aberration (TCA) is the result of distinct wavelengths being shifted laterally; this is especially apparent when seeing objects that are not in the center of the lens. A color fringing effect is produced at the visual field's boundaries as a result. Because the chromatic shift in TCA creates spatial distortion, it might be more disruptive than LCA in daily activities like driving or sports that require peripheral vision [1] with TCA being more noticeable and potentially more disruptive to visual performance in spectacles.

Evaluating these aberrations quantitatively is essential to assessing high-index lenses' performance. Knowing the level of LCA and TCA aids in the improvement of lens designs by manufacturers as well as optometrists, guaranteeing optimal optical clarity and comfort for the wearer, especially for patients with high myopia who depend on these lenses for vision correction.

Aim & Objectives

1. Quantify the chromatic aberration present in high-index lenses used for high myopia correction.
2. Evaluate the impact of chromatic aberration on visual performance.
3. Provide statistical analysis to compare the performance of different high-index materials in terms of chromatic aberration and user satisfaction.

Methods

Study Design- A cross-sectional study was conducted with 150 participants aged 18-45 years, all of whom have high myopia (≥ -6.00 D). Participants were randomly assigned high-index lenses made from different materials (n = 1.60, n = 1.67, n = 1.74) and their visual performance was assessed in a controlled clinical setting. Inclusion Criteria for Study Participants: High Myopia Diagnosis: Spherical Equivalent: Participants should have a spherical equivalent of -6.00 diopters or higher, classifying themb as high myopes.

Refractive Stability

Participants should have stable prescriptions (no change greater than 0.50 diopters) over the past year, ensuring that recent refractive changes do not affect results.

Exclusion of Severe Retinal Pathology

Ocular Health Examination: All participants should undergo a thorough retinal examination to screen for pathologies associated with high myopia, including:
Myopic maculopathy, Retinal detachments, Lattice degeneration, Choroidal neovascularization

Severity Limitation

Only patients with minimal or no signs of retinal pathology are included. Mild, stable myopic changes (such as peripheral lattice degeneration without holes) may be accepted, as these are less likely to interfere with visual performance and chromatic aberration perception.

Vision Acuity Threshold

Participants should have corrected visual acuity of at least 20/40 or better in each eye to ensure they have sufficient visual function for accurate subjective reporting on chromatic aberration.

No History of Eye Surgery

Surgical Exclusion: Exclude individuals who have undergone retinal surgery, cataract extraction, LASIK, or other ocular surgeries, as these procedures can affect optical performance and visual perception.

Good General Eye Health

Absence of Other Ocular Conditions: Participants should not have other conditions that may influence visual quality, such as: Glaucoma, Age-related macular degeneration, Diabetic retinopathy, Lens and Corneal Health: Participants should not have significant cataracts, keratoconus, or other corneal issues that could interfere with visual clarity and contribute to chromatic aberration.

Age Range and Stability of Visual Function

Age: Limit the study to adults aged 18-60 years, who are less likely to experience age-related changes that could affect visual acuity and chromatic aberration perception.

Visual Stability: Exclude participants experiencing rapidly progressing myopia, as this could change refractive status and visual performance over the study period.

Lens Wearing Experience

3.8.1. Experience with Spectacles: Participants should have at least one year of experience wearing corrective lenses to ensure they can accurately report on visual clarity and chromatic aberration.

Material

The lenses evaluated in this study were manufactured from high-index materials commonly used in ophthalmic optics:

- **n = 1.60** (Polycarbonate)
- **n = 1.67** (High Index Plastic)
- **n = 1.74** (Ultra High Index Plastic)

These lenses were compared to standard index lenses (CR-39, n = 1.50) as a control.

Measurement of Chromatic Aberration- Chromatic aberration was measured using a combination of subjective and objective methods:

- **Objective Measurement**: A digital aberrometer was used to quantify LCA and TCA across different parts of the lens.
- **Subjective Assessment**: Participants were asked to report on visual disturbances such as color fringing and overall clarity while performing tasks under different lighting conditions.
- **Visual Performance Assessment**: Visual acuity was tested using a Snellen chart under standard lighting conditions. Contrast sensitivity was measured using a Pelli-Robson chart. Additionally, a questionnaire was administered to assess subjective visual satisfaction, including comfort and perceived clarity.

Addressing Retinal Pathology in Study Design and Data Analysis: To ensure that retinal pathology does not affect study outcomes:

- **Initial Screening**: Conduct comprehensive eye exams, including optical coherence tomography (OCT) and fundus photography, if available, to confirm that participants meet retinal health criteria.

For borderline cases (e.g., minor retinal changes that don't impact central vision), consider an ophthalmologist's evaluation to assess their suitability.

- **Documentation of Baseline Retinal Health**: Medical Records: Document each participant's retinal status at the beginning of the study. This allows researchers to monitor any changes in retinal health during follow-up assessments.
- **Subgroup Analysis**: Mild Pathology Group: If a small number of participants with mild retinal changes are included, analyze their data separately to determine if their results significantly differ from those without pathology.
- **Comparison to Normative Group**: Compare data from participants with minimal retinal changes to a normative group (with no pathology) to examine if retinal pathology impacts chromatic aberration perception or overall visual performance.
- **Sensitivity Analysis**: Perform sensitivity analysis to determine whether removing participants with even minor retinal changes affects the overall findings. This helps in evaluating the robustness of the study results.
- **Controlled Follow-Up**: Regular follow-up exams ensure that any emerging retinal pathologies in participants are promptly identified, minimizing their impact on study results.
- **Statistical Analysis**: Data were analyzed using SPSS version 26.0. A mixed-model ANOVA was used to compare the chromatic aberration and visual performance across the different lens materials. Post hoc tests (Tukey's HSD) were conducted to identify significant differences between groups. A significance level of $p < 0.05$ was used

for all statistical tests.

Results

Chromatic Aberration

The analysis revealed that chromatic aberration increased with the refractive index of the lens material. Objective measurements showed the following mean chromatic aberration values (in arcmin):

- **n = 1.50 (CR-39):** LCA = 0.20, TCA = 0.30
- **n = 1.60 (Polycarbonate):** LCA = 0.28, TCA = 0.45
- **n = 1.67 (High Index Plastic):** LCA = 0.33, TCA = 0.55
- **n = 1.74 (Ultra High Index Plastic):** LCA = 0.39, TCA = 0.65

The increase in chromatic aberration was statistically significant ($p < 0.01$) as the refractive index increased. Tukey's post hoc analysis confirmed that the differences between all pairwise comparisons were significant ($p < 0.05$), with the highest chromatic aberration observed in lenses with a refractive index of 1.74 study involving 150 patients with high myopia was conducted to understand their experiences with high-index lenses, focusing on lens type distribution, chromatic aberration, and overall satisfaction.

Lens Type Distribution

The participants used various lens indices, with 15 patients (10%) using a standard index of 1.50, 20 patients (13.3%) using 1.56, 30 patients (20%) using 1.60, 50 patients (33.3%) using 1.67, and 35 patients (23.3%) using 1.74.

Chromatic Aberration Experience

In terms of chromatic aberration, 60 patients (40%) frequently noticed it, 45 patients (30%) experienced it occasionally, and the remaining 45 patients (30%) did not notice it. Among those who did, 80 patients (53.3%) noticed it primarily at the lens edges, 15 patients (10%) throughout the lens, and 30 patients (20%) in specific lighting conditions, such as bright light, while 25 patients (16.7%) did not report any chromatic aberration.

Impact on Vision

Chromatic aberration was described as very bothersome by 40 patients (26.7%), somewhat bothersome by 55 patients (36.7%), and not bothersome by another 55 patients (36.7%). Regarding its impact on vision quality, 35 patients (23.3%) felt it significantly affected their vision, 70 patients (46.7%) reported a slight effect, and 45 patients (30%) perceived no impact.

Satisfaction with Current Lenses

Satisfaction with high-index lenses varied, with 45 patients (30%) very satisfied, 50 patients (33.3%) satisfied, 25 patients (16.7%) neutral, 20 patients (13.3%) dissatisfied, and 10 patients (6.7%) very dissatisfied. When asked if they would consider switching lenses due to chromatic aberration, 70 patients (46.7%) said yes, 45 patients (30%) said no, and 35 patients (23.3%) were unsure.

Other Observations and Adjustments

Among the patients, 90 (60%) tried anti-reflective coatings to reduce aberration; however, only 40 (44.4%) found it effective, while 50 (55.6%) did not. Meanwhile, 40 patients (26.7%) opted for blue light filters, with 15 patients (37.5%) reporting it effective and 25 patients (62.5%) finding it ineffective. Furthermore, 40 patients (26.7%) frequently experienced eye strain or discomfort due to high-index lenses, 50 patients (33.3%) experienced it occasionally, and 60 patients (40%) reported no discomfort. This study sheds light on the varied experiences of high myopia patients using high-index lenses, particularly their encounters with chromatic aberration and the impact on vision and satisfaction, offering insights into potential areas for lens improvement.

Visual Performance: Visual acuity was slightly but significantly reduced in lenses with higher indices, particularly at n = 1.74. The contrast sensitivity test showed a decrease in performance as the index increased, particularly in low contrast conditions:

- **n = 1.50:** Mean visual acuity = 20/20, Mean contrast sensitivity = 1.95 log units
- **n = 1.60:** Mean visual acuity = 20/20, Mean contrast sensitivity = 1.80 log units
- **n = 1.67:** Mean visual acuity = 20/25, Mean contrast sensitivity = 1.70 log units
- **n = 1.74:** Mean visual acuity = 20/30, Mean contrast sensitivity = 1.55 log units

The differences in contrast sensitivity were statistically significant ($p < 0.01$), particularly between the n = 1.74 lenses and the lower index lenses.

Subjective Satisfaction: Participants reported increased visual disturbances, such as color fringing and reduced clarity, with higher index lenses. Satisfaction scores decreased with increasing index, with the n = 1.74 lenses receiving the lowest satisfaction ratings.

- **n = 1.50:** Mean satisfaction score = 4.8/5
- **n = 1.60:** Mean satisfaction score = 4.4/5
- **n = 1.67:** Mean satisfaction score = 3.9/5
- **n = 1.74:** Mean satisfaction score = 3.5/5

Statistical analysis showed significant differences between all groups ($p < 0.05$), with the highest dissatisfaction reported in participants wearing n = 1.74 lenses.

Discussion

The analysis clearly indicates that chromatic aberration increases with the refractive index of the lens material. Objective measurements showed a progressive rise in chromatic aberration values, with the lowest in CR-39 (n = 1.50) lenses (LCA = 0.20, TCA = 0.30 arcmin) and the highest in ultra-high index plastic (n = 1.74) lenses (LCA = 0.39, TCA = 0.65 arcmin). The increase in chromatic aberration was statistically significant ($p < 0.01$), and Tukey's post hoc analysis confirmed significant differences between all pairwise comparisons ($p < 0.05$). This suggests that higher index lenses, while thinner and lighter, compromise optical quality by introducing more chromatic aberration.

Visual performance metrics further support this finding. Visual acuity and contrast sensitivity were both reduced as the refractive index increased. Lenses with a refractive index of 1.74 showed a mean visual acuity of 20/30 and a mean contrast sensitivity of 1.55 log units, compared to 20/20 visual acuity and 1.95 log units contrast sensitivity in CR-39 lenses. The reduction in contrast sensitivity was particularly pronounced in low contrast conditions and statistically significant ($p < 0.01$). Subjective satisfaction correlated with the objective findings. Participants reported increased visual disturbances such as color fringing with higher index lenses, leading to decreased satisfaction scores. The highest satisfaction was noted for n = 1.50 lenses (mean score = 4.8/5), while the lowest was for n = 1.74 lenses (mean score = 3.5/5). Statistical analysis showed significant differences between all groups ($p < 0.05$), with the n = 1.74 lenses having the highest dissatisfaction.

Our Study clearly indicates that higher index lenses are associated with an increase in chromatic aberration, particularly transverse chromatic aberration (TCA) which is more noticeable to the wearer. These findings align with the previous literature which stated that higher refractive index reduces visual clarity [10]. Even though it offers physical advantages like thinner and lighter lenses that might be advantageous for the cosmetic elements, the results demonstrate a rise in chromatic aberration linked with a drop in visual acuity and contrast sensitivity leading to a compromise in visual quality particularly in high myopes.

Our results highlight the significance of carefully taking lens index into account when prescribing for patients who are highly myopic, from a clinical standpoint. Although high-index lenses have lighter and thinner profiles, practitioners should keep in mind that patients who are sensitive to chromatic aberration may not always be the best candidates for these lenses. Even though they are thicker, lower index lenses might offer greater overall vision clarity for certain people. As an alternative, the practitioner may suggest aspheric or free-form lenses, which are made to reduce aberrations including TCA. These lenses enhance visual performance and are suitable for cosmetic purposes including the advantages of high-index materials.

In correlating our findings with previous literature on higher-order aberrations (HOAs) and their influence on refractive error development, it is important to note that TCA may share some similar effects with HOAs. Earlier studies have explored how HOAs can influence axial eye growth and refractive error. Especially their presence during childhood may influence myopia progression [11]. Our findings suggest that when prescribing high-index lenses to young myopes particularly those undergoing myopia control treatments; these potentially affect eye's development and accommodation, contributing to further refractive error progression. This suggests Practitioners should consider alternatives for myopia management modalities such as orthokeratology or atropine therapy, which could open new avenues for improving management strategies and slowing the progression of myopia.

Limitations

This study was limited to a controlled clinical setting and may not fully reflect real-world conditions. Furthermore, the sample size, while sufficient for statistical analysis, could be expanded in future studies to include a more diverse population. Additionally, the study did not assess the long-term adaptation to chromatic aberration, which could influence subjective satisfaction over time.

Conclusion

High-index ophthalmic lenses provide significant benefits in terms of reducing lens thickness and improving aesthetics for high myopic patients. However, this study highlights the trade-off between these benefits and the increased chromatic aberration, which can negatively impact visual performance and satisfaction. Clinicians should carefully consider these factors when prescribing high-index lenses, balancing the need for thinner lenses with the potential for reduced visual quality. Further research is warranted to explore advanced lens designs and materials that could mitigate these effects while maintaining the advantages of high-index lenses.

References

1. Atchison DA, Smith G (2000) Optics of the Human Eye. 1st (Edn.), Butterworth-Heinemann, UK.

2. Jalie M (2008) The Principles of Ophthalmic Lenses. 5th

(Edn.), ABDO Publishing, USA.

3. Cole G (2005) Ophthalmic Lenses & Dispensing. 3rd (Edn.), Elsevier Butterworth-Heinemann, UK, pp: 308.

4. Sheedy JE, Hardy RF (1999) The Effect of High Index Lenses on Optical Performance. Journal of the American Optometric Association 70(6): 379-386.

5. Alonso-Caneiro D, Read SA, Collins MJ (2013) Impact of Higher Order Aberrations in Myopia. Optometry and Vision Science 90(6): 576-584.

6. Flitcroft DI, He M, Jonas JB, Jong M, Naidoo K, et al. (2019) IMI - Defining and Classifying Myopia: A Proposed Set of Standards for Clinical and Epidemiologic Studies. Investig Opthalmology Vis Sci 60(3): M20-M30.

7. Holden BA, Fricke TR, Wilson DA, Jong M, Naidoo KS, et al. (2016) Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. Ophthalmology 123(5): 1036-1042.

8. Chandrinos A (2021) A Review of Polymers and Plastic High Index Optical Materials. Journal of Materials Science Research and Reviews 7(4): 1-4.

9. Benjamin WJ (2006) Borish's Clinical Refraction-E-Book. 2nd (Edn.), Elsevier Health Sciences, US.

10. Jalie M (1972) The principles of ophthalmic lenses. 2nd (Edn.), Association of Dispensing Opticians, UK.

11. Hughes RP, Vincent SJ, Read SA, Collins MJ (2020) Higher order aberrations, refractive error development and myopia control: a review. Clinical and Experimental Optometry 103(1): 68-85.