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Evaluation of Fundus Changes in High Axial Myopia and Their Correlation with Axial Length of the Eye: A Cross-Sectional Study

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Abstract

Background: High axial myopia is a progressive refractive disorder associated with structural changes in the posterior segment of the eye. These fundus alterations can lead to significant visual impairment and are believed to correlate with increasing axial length.

Objective: To evaluate the spectrum of fundus changes in patients with high axial myopia and assess their correlation with axial length measurements.

Methods: A cross-sectional observational study was conducted on 150 eyes with high myopia (spherical equivalent ≥ −6.00 D and axial length ≥26.5 mm). Fundus changes were documented using dilated fundus examination and wide-field fundus photography. Axial length was measured with optical biometry. Correlations between axial length and specific fundus findings (peripapillary atrophy, chorioretinal atrophy, lacquer cracks, and posterior staphyloma) were statistically analyzed.

Results: The most common fundus finding was peripapillary atrophy (76.0%), followed by chorioretinal atrophy (58.7%) and posterior staphyloma (34.7%). A significant positive correlation was found between axial length and the severity of fundus changes ($p < 0.01$). Eyes with axial length ≥30 mm had a higher frequency of myopic maculopathy and staphyloma.

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Conclusion: Progressive axial elongation in high myopia is significantly associated with degenerative fundus changes. Axial length measurement can serve as a useful indicator for predicting structural ocular complications in myopic eyes and guiding follow-up protocols.

Introduction

High myopia, defined by a spherical equivalent refractive error of ≥−6.00 diopters and/or axial length ≥26.5 mm, is an important cause of irreversible visual impairment worldwide. Its global prevalence is rising sharply, particularly in East and Southeast Asia, where lifestyle changes and increasing near-work activities have contributed to its emergence as a major public health concern (1). While optical correction can compensate for refractive errors, the axial elongation that characterizes pathological myopia results in progressive and sometimes vision-threatening structural changes within the retina, choroid, and sclera.

Axial elongation leads to mechanical stretching and thinning of the ocular coats, especially at the posterior pole, predisposing the eye to a spectrum of fundus changes. These include peripapillary atrophy, diffuse and patchy chorioretinal atrophy, lacquer cracks, myopic macular degeneration, and posterior staphyloma (2). The extent and severity of these fundus alterations have been shown to correlate with increasing axial length, suggesting that axial length may be a surrogate biomarker for ocular complications in myopia (3).

Peripapillary atrophy (PPA) is one of the earliest and most frequent signs of myopic fundus changes and is thought to arise due to the mechanical strain around the optic nerve head as the eye elongates. Chorioretinal atrophy—either diffuse or patchy—represents progressive degeneration of the outer retinal layers and underlying choroid and is associated with poor visual prognosis. Lacquer cracks, indicative of ruptures in Bruch's membrane, are risk factors for choroidal neovascularization (CNV), a severe and vision-threatening complication of myopic maculopathy (4). Posterior staphyloma, defined as an outpouching of the weakened sclera, represents an advanced stage of axial elongation and is strongly linked with both retinal and choroidal thinning (5).

The **Meta-Analysis for Pathologic Myopia (META-PM)** classification system provides a standardized framework for grading myopic maculopathy and has facilitated epidemiologic comparisons across populations (6). However, the clinical progression of fundus changes

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varies, and there is a growing interest in identifying quantitative predictors—like axial length—that could help anticipate risk and guide follow-up intensity. Optical biometry, which provides accurate, non-invasive measurement of axial length, is now widely available and can be integrated into routine assessments of high myopia patients.

A number of cross-sectional and longitudinal studies have highlighted the link between axial length and myopic maculopathy. Fang et al. reported that the prevalence of chorioretinal atrophy and posterior staphyloma increased significantly in eyes with axial lengths over 30 mm (7). Similarly, Ohno-Matsui et al. demonstrated that excessive axial elongation is the most consistent structural change underlying degenerative changes in pathologic myopia (8).

Despite these advances, there remains a paucity of data from the Indian subcontinent, where myopia rates are also on the rise. A comprehensive evaluation of the types and frequencies of fundus changes in Indian patients with high axial myopia, and their association with axial length, would contribute valuable region-specific insights and inform monitoring strategies.

Therefore, the objective of this study was to evaluate fundus changes in eyes with high axial myopia using detailed fundus imaging and to determine the correlation between the axial length of the eye and the presence and severity of these changes. This research may help clinicians identify patients at higher risk for myopic complications and tailor surveillance accordingly.

Methods

Study Design and Setting

This was a **cross-sectional observational study** conducted in the Department of Ophthalmology at a tertiary care center in South India from January to December 2023. The study aimed to evaluate fundus changes in high axial myopia and correlate these findings with axial length measurements.

Study Population

A total of **150 eyes from 90 patients** diagnosed with high axial myopia were included. High axial myopia was defined as:

- **Spherical equivalent ≥ −6.00 diopters**, and/or

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- **Axial length ≥ 26.5 mm**

Inclusion Criteria

- Age ≥18 years
- Refractive error consistent with high myopia
- Axial length ≥26.5 mm
- Clear ocular media permitting adequate fundus visualization and OCT imaging

Exclusion Criteria

- History of intraocular surgery (excluding uncomplicated cataract surgery)
- Presence of diabetic or hypertensive retinopathy
- Ocular trauma or inflammatory eye disease
- Poor-quality imaging due to media opacity or poor fixation

Ocular Examination and Imaging

All patients underwent a comprehensive ophthalmologic examination including:

- Best corrected visual acuity (BCVA)
- Slit-lamp biomicroscopy
- Intraocular pressure measurement
- Dilated fundus examination using indirect ophthalmoscopy and +90D slit-lamp biomicroscopy

Fundus photography was performed using a wide-field digital fundus camera (Optos/Zeiss). **Axial length** was measured using **optical biometry** (IOL Master 700, Carl Zeiss Meditec).

Optical coherence tomography (OCT) was used in selected cases to evaluate macular morphology and detect early myopic maculopathy when suspected clinically.

Fundus Changes Documented

- Peripapillary atrophy (PPA)

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- Chorioretinal atrophy (diffuse/patchy)
- Lacquer cracks
- Posterior staphyloma
- Myopic traction maculopathy (if present)

The **Meta-Analysis for Pathologic Myopia (META-PM)** classification system was used to grade the severity of myopic maculopathy.

Data Categorization

Participants were grouped into three categories based on axial length:

- Group A: 26.5–28.9 mm
- Group B: 29.0–30.9 mm
- Group C: ≥31.0 mm

Fundus changes were analyzed and compared across these axial length groups.

Statistical Analysis

Data were entered and analyzed using **IBM SPSS Statistics version 26.0**. Continuous variables were expressed as mean ± standard deviation, and categorical variables as percentages. **Chi-square test** was used to assess associations between fundus changes and axial length categories. **Pearson's correlation coefficient** was calculated to assess the correlation between axial length and severity of fundus changes. A p-value of <0.05 was considered statistically significant. The study was approved by the Institutional Ethics Committee. Written informed consent was obtained from all participants. The study adhered to the tenets of the Declaration of Helsinki.

Results

A total of **150 eyes** from 90 patients with high axial myopia were included. The mean age was **43.5 ± 11.2 years**, and **60% were female**. The mean axial length was **29.3 ± 1.7 mm**, ranging from 26.6 to 33.2 mm. Fundus changes were systematically documented and analyzed in relation to axial length.

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Table 1: Demographic and Clinical Profile of Study Population

Parameter	Value
Mean age (years)	43.5 ± 11.2
Gender (M:F)	36 (40%) : 54 (60%)
Mean spherical equivalent	−8.9 ± 2.5 D
Mean axial length (mm)	29.3 ± 1.7
Axial length range (mm)	26.6 – 33.2

The majority of patients were middle-aged females with significant refractive error and axial elongation. The average axial length exceeded 29 mm, consistent with advanced myopic elongation and placing patients at risk for degenerative fundus changes.

Table 2: Distribution of Fundus Changes by Frequency

Fundus Finding	Number of Eyes (%)
Peripapillary atrophy	114 (76.0%)
Chorioretinal atrophy	88 (58.7%)
Posterior staphyloma	52 (34.7%)
Lacquer cracks	21 (14.0%)
Myopic traction maculopathy	9 (6.0%)

Peripapillary and chorioretinal atrophy were the most common fundus findings, observed in over half the eyes. Posterior staphyloma and lacquer cracks—both considered more advanced complications—were less frequent but notable, underscoring the structural vulnerability in highly myopic eyes.

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Table 3: Comparison of Fundus Changes Across Axial Length Groups

Fundus Finding	Group A (26.5–28.9 mm)	Group B (29–30.9 mm)	Group C (≥31 mm)	p-value
Peripapillary atrophy	34 (62.9%)	45 (78.9%)	35 (92.1%)	0.02
Chorioretinal atrophy	21 (38.8%)	37 (64.9%)	30 (78.9%)	<0.001
Posterior staphyloma	10 (18.5%)	20 (35.1%)	22 (57.9%)	<0.001
Lacquer cracks	3 (5.5%)	7 (12.3%)	11 (28.9%)	0.004

There was a statistically significant increase in the prevalence of all fundus changes with increasing axial length. Group C (axial length ≥31 mm) had the highest rates of posterior staphyloma and lacquer cracks, suggesting progressive structural degeneration in extreme axial elongation.

Table 4: Correlation Between Axial Length and Fundus Change Severity Score

Variable	r (Pearson correlation)	p-value
Axial length vs. fundus change severity score	0.68	<0.001

A strong positive correlation ($r = 0.68$, $p < 0.001$) was observed between axial length and cumulative severity score of fundus changes. This reinforces the hypothesis that as axial length increases, the likelihood and severity of degenerative fundus findings also escalate.

Discussion

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This cross-sectional study investigated the prevalence and pattern of fundus changes in eyes with high axial myopia and assessed the correlation of these changes with axial length. The results show a significant association between increasing axial length and the severity of degenerative changes at the posterior pole. The most common fundus alterations identified were peripapillary atrophy (76.0%), chorioretinal atrophy (58.7%), and posterior staphyloma (34.7%), all of which became more prevalent with greater axial elongation.

High axial myopia is a progressive condition marked not only by increased refractive error but also by anatomical changes in the retina, choroid, and sclera. These structural alterations are primarily driven by axial elongation, which is both a diagnostic and prognostic marker of pathological myopia. Numerous studies have confirmed the relationship between axial length and degenerative retinal findings, consistent with our observations (1).

Peripapillary atrophy (PPA), the most frequently observed finding in our cohort, was present in 76% of eyes. This is in agreement with previous studies where PPA has been reported in 60–80% of highly myopic eyes (9). PPA is thought to arise due to mechanical stretching of the sclera and choroid around the optic nerve head, and its extent has been shown to correlate with axial length. In our study, the frequency of PPA increased significantly across axial length groups—from 62.9% in Group A (26.5–28.9 mm) to 92.1% in Group C (≥31 mm) ($p = 0.02$).

Chorioretinal atrophy, a hallmark of myopic degeneration, was seen in 58.7% of cases. This is consistent with previous findings reported by Vongphanit et al., who demonstrated a significant rise in the prevalence of chorioretinal atrophy with longer axial lengths and advancing age (2). The relationship between choroidal thinning and progressive elongation has been well established using enhanced-depth imaging OCT, which shows choroidal atrophy as a consequence of scleral stretching and vascular compromise (10).

Posterior staphyloma, a critical indicator of pathological myopia, was noted in 34.7% of eyes, and its prevalence increased sharply with axial length—from 18.5% in Group A to 57.9% in Group C ($p < 0.001$). Curtin's classification describes posterior staphyloma as an outpouching of the weakened posterior sclera, associated with progressive atrophic changes and poor visual prognosis (5). Our data reinforce this structural association and emphasize the importance of axial length as a marker for staphyloma risk.

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Lacquer cracks were seen in 14% of eyes and were more prevalent in those with axial lengths ≥31 mm (28.9%). These findings are consistent with the work of Ohno-Matsui et al., who reported that lacquer cracks are often found in eyes with extremely elongated axial length and represent breaks in Bruch's membrane (6). These lesions are clinically significant due to their potential to develop into myopic choroidal neovascularization (CNV), a vision-threatening complication.

Our findings also align with those of Fang et al., who demonstrated a stepwise increase in fundus degenerative changes in eyes with increasing axial length. In their longitudinal study, chorioretinal atrophy and posterior staphyloma were most commonly seen in eyes with axial length >30 mm (7). Similarly, we found a significant positive correlation ($r = 0.68$, $p < 0.001$) between axial length and the severity of fundus changes, validating axial length as an objective predictor of structural deterioration.

Notably, myopic traction maculopathy was relatively uncommon in our sample (6%), likely due to the exclusion of symptomatic patients and the cross-sectional design. However, it is important to monitor these cases longitudinally, as the risk of traction-related changes, including foveoschisis and macular holes, increases with progressive elongation, especially in eyes with staphyloma (11).

Our study adds valuable regional data from South India, where limited literature exists on the structural manifestations of high axial myopia. The mean axial length in our cohort (29.3 mm) is slightly higher than in similar population-based studies, possibly reflecting a referral bias in a tertiary care setting. Nevertheless, the progressive trend in fundus pathology across increasing axial lengths mirrors findings from international cohorts, supporting the universality of this structural association.

The findings have important clinical implications. Regular documentation of axial length should be incorporated into routine evaluation of high myopia, not just for refractive purposes but also for predicting the risk of fundus complications. Patients with axial length ≥30 mm should be monitored more closely for early signs of myopic maculopathy, including lacquer cracks, staphyloma progression, and choroidal neovascularization. Wide-field imaging and OCT should be used liberally to detect early peripheral changes and subtle macular disruptions.

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Strengths of this study include a well-defined high myopia cohort, systematic documentation of fundus changes, and the use of objective axial length measurements through optical biometry. However, the study has some limitations. Being cross-sectional in nature, it does not provide information on the progression or rate of fundus changes over time. Additionally, advanced imaging modalities such as swept-source OCT or fundus autofluorescence were not used, which may have detected more subtle pathological changes.

Future research should focus on longitudinal follow-up of high myopes, particularly those with axial length >30 mm, to assess the progression of staphyloma, development of CNV, and vision outcomes. Genetic and environmental risk factors influencing the rate of axial elongation should also be explored, as they may inform preventive strategies.

Conclusion

In conclusion, this study reinforces the strong correlation between increasing axial length and the prevalence of fundus degenerative changes in high axial myopia. Structural abnormalities such as peripapillary atrophy, chorioretinal atrophy, and posterior staphyloma increase significantly with axial elongation. Axial length measurement serves not only as a refractive parameter but also as a critical predictor of pathological changes that can compromise vision. Incorporating axial length and fundus monitoring into standard care protocols will improve risk stratification and long-term visual outcomes for patients with high myopia.

Recommendations

Routine measurement of axial length should be incorporated into the standard evaluation of patients with high myopia to identify those at greater risk for degenerative fundus changes. Eyes with axial length ≥30 mm warrant closer monitoring using fundus photography and OCT to detect early signs of chorioretinal atrophy, lacquer cracks, or posterior staphyloma. Early identification of high-risk eyes can guide more frequent follow-up, timely intervention, and patient counseling to prevent vision-threatening complications. Future longitudinal studies are recommended to assess progression patterns and optimize surveillance strategies in this growing population.

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