e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2026; 18(8); 1993-2006

Original Research Article

Analysis of Retinal Nerve Fibre Layer, Macular and Foveal Thickness in Cases of Unilateral Amblyopia and Comparison with The Contralateral Normal Eye in School-Going Children Aged 5–15 Years

Debasish Bishoi[1], Ramamani Dalai[2], Aparajita Benerjee[3], Tarun Kumar Panda[4], Kedar Nath Das[5]

[1]Post Graduate Resident, Department of Ophthalmology, RIO SCB Medical College Cuttack, Odisha, India

[2]Professor, Department of Ophthalmology, RIO SCB Medical College Cuttack, Odisha, India

[3]Assistant Professor, Department of Ophthalmology, RIO SCB Medical College Cuttack, Odisha, India

[4]Professor and Head, Department of Ophthalmology, RIO SCB Medical College Cuttack, Odisha, India

[5]Professor, Department of Pediatrics, Maharaja Jajatikeshari Medical College, Jajpur, Odisha, India

Received: 06-08-2026 / Revised: 19-08-2026 / Accepted: 22-08-2026

Corresponding Author: Dr. Ramamani Dalai

Conflict of interest: Nil

Abstract:

Background: Amblyopia is a common neurodevelopmental visual disorder characterized by reduced best-corrected visual acuity (BCVA) resulting from abnormal visual experience during the critical period of visual development. Although traditionally considered predominantly a disorder of visual cortical processing, advances in optical coherence tomography (OCT) have enabled detailed evaluation of retinal structures that may demonstrate subtle anatomical differences in amblyopic eyes. However, the extent and clinical significance of retinal nerve fibre layer (RNFL), macular, and foveal alterations in children with unilateral amblyopia remain uncertain. The present study evaluated these structural parameters using spectral-domain optical coherence tomography (SD-OCT) and compared the amblyopic eye with the contralateral normal eye within the same individual.

Methods: A hospital-based, observational, cross-sectional comparative study was conducted in the Department of Ophthalmology, SCB Medical College and Hospital, Cuttack, from March 2024 to August 2025. Fifty children diagnosed with unilateral amblyopia were enrolled. Each participant contributed one amblyopic eye and the fellow normal eye as an internal control. Detailed ophthalmic evaluation included BCVA, cycloplegic and subjective refraction, anterior segment examination, fundus examination, ocular alignment and motility assessment, prism-bar measurement of ocular deviation, and axial length measurement. Participants were classified as having anisometropic, strabismic, or mixed amblyopia. SD-OCT was performed to measure average and quadrant-wise peripapillary RNFL thickness, central and regional macular thickness using the Early Treatment Diabetic Retinopathy Study (ETDRS) grid, and central foveal thickness. Paired comparisons were performed using the paired t-test, while one-way ANOVA was used for comparisons between amblyopia subtypes. Pearson's correlation was used to evaluate associations between OCT parameters, BCVA, and refractive error. A p-value <0.05 was considered statistically significant. The study protocol received Institutional Ethics Committee approval, and informed consent was obtained from parents or guardians with assent from participating children.

Results: The study included 50 children with a mean age of 12.48 ± 1.99 years; the observed age range was 8–15 years. There were 27 males (54%) and 23 females (46%). Anisometropic amblyopia was the predominant subtype, occurring in 37 children (74%), followed by mixed amblyopia in 7 (14%) and strabismic amblyopia in 6 (12%). Mean BCVA was significantly poorer in amblyopic eyes than in fellow eyes (0.46 ± 0.15 vs. 0.02 ± 0.04 logMAR; $p<0.001$). Average RNFL thickness did not differ significantly between amblyopic and fellow eyes (101.6 ± 8.9 vs. 100.9 ± 8.4 µm; $p=0.47$), and no significant difference was observed in any RNFL quadrant. In contrast, central macular thickness was significantly greater in amblyopic eyes (275.8 ± 18.6 vs. 268.1 ± 17.9 µm; $p=0.01$), as was parafoveal thickness (318.2 ± 14.4 vs. 312.9 ± 14.9 µm; $p=0.03$). Central foveal thickness was also significantly higher in amblyopic eyes (227.4 ± 17.8 vs. 215.6 ± 16.9 µm; $p=0.001$). Increased central macular and foveal thickness was particularly evident in anisometropic and mixed amblyopia. Central macular and foveal thickness showed positive correlations with poorer BCVA ($r=0.39$ and $r=0.44$, respectively).

Conclusion: Unilateral amblyopic eyes demonstrated significant increases in central macular, parafoveal, and foveal thickness compared with their contralateral normal eyes, whereas overall and quadrant-wise RNFL thickness did not show significant interocular differences. The more pronounced macular and foveal changes observed in anisometropic amblyopia suggest that abnormal visual input and refractive imbalance may be associated with altered retinal maturation. SD-OCT may therefore serve as a useful adjunctive, non-invasive tool for documenting structural retinal differences in pediatric amblyopia.

Keywords: Amblyopia; retinal nerve fibre layer; macular thickness; foveal thickness; optical coherence tomography; children; anisometropic amblyopia; spectral-domain OCT.
DOI: 10.25258/ijcpr.18.8.292

Introduction

The hallmark of amblyopia, a common neurodevelopmental visual disease, is a reduction in best-corrected visual acuity in one or both eyes without a visible anatomical defect that would explain the visual impairment. It develops when abnormal visual experiences obstruct the normal development of the visual system at a critical phase of visual development. Unlike visual loss caused by a biological ocular problem, amblyopia is mostly associated with incorrect binocular interaction, cortical suppression, and abnormal processing of visual information from the affected eye. Amblyopia continues to be the primary cause of preventable vision impairment in children. Early detection and treatment are particularly important because visual cortex plasticity peaks in early childhood and progressively decreases with age. Persistent amblyopia may result in irreversible monocular visual impairment and defective binocular vision. Additionally, individuals with unilateral amblyopia have an increased lifetime chance of having significant bilateral visual impairment if the properly functioning eye later sustains damage or ocular disease.

The functional ramifications of amblyopia extend beyond reduced visual acuity. Children with amblyopia may have impaired stereopsis, contrast sensitivity, binocular coordination, and visual-motor function. Academic success, hand-eye coordination, and mental health may all be impacted by these impairments. Early detection through school-based and paediatric eye screening is still essential to prevent long-term visual morbidity. The pathogenesis of amblyopia has long been thought to be mostly cortical, with abnormal visual input during the sensitive period leading to functional alterations in the visual cortex. People with amblyopia have distinct cortical responses and connections, according to studies using electrophysiology and neuroimaging, highlighting the importance of central visual processing in the illness. However, interest in the potential for minor structural changes at the retinal level has increased due to the increasing use of high-resolution retinal imaging. Spectral-domain optical coherence tomography (SD-OCT) is a high-resolution, non-invasive imaging technique that allows quantitative assessment of retinal microstructure.

The macula, fovea, and peripapillary retinal nerve fibre layer can all be reliably measured using it. According to paediatric OCT studies, retinal thickness varies with age, refractive status, axial length, and ocular development. Thus, OCT provides an opportunity to investigate whether abnormal visual experience associated with amblyopia is accompanied by measurable alterations in retinal structure. The retinal nerve fibre layer, an essential anatomical connection between the retina and optic nerve, represents the axonal component of retinal ganglion cells. If main retinal or optic nerve anatomical issues were associated with amblyopia, changes in RNFL thickness might be expected. However, prior studies have produced contradictory findings; some have indicated increased RNFL thickness in amblyopic eyes, while others have found no discernible interocular difference.

Age differences, segmentation algorithms, OCT technology, amblyopia subtype, refractive status, and ocular biometry could all contribute to these discrepancies. The macula and fovea are essential for high-acuity vision. Normal foveal growth involves complex processes such as the formation of the foveal pit and the centrifugal displacement of inner retinal layers. Abnormal visual stimuli during childhood may have an impact on this developing process. OCT tests have shown that certain children with amblyopia have increased macular and foveal thickness, which may imply delayed or incomplete retinal development. The relationship between amblyopia and retinal morphology is still unknown, nevertheless, as other studies have not shown any notable structural differences. There is not much data regarding Indian paediatric populations.

Therefore, a standardised, region-specific evaluation of retinal architecture is required for children with unilateral amblyopia. An intra-individual comparison of the amblyopic eye with the contralateral normal eye is one important methodological advantage. Because both eyes belong to the same child, there are fewer potential confounding factors related to age, systemic features, ethnicity, and environmental exposure. Consequently, this paired-eye approach allows for a more direct assessment of interocular differences in RNFL, macular, and foveal measurements. The current study involved school-age children with unilateral amblyopia in order to evaluate the structural characteristics of the amblyopic eye using SD-OCT and compare them with the contralateral clinically normal eye.

The study specifically assessed average and quadrant-wise peripapillary RNFL thickness, central and regional macular thickness, and central foveal thickness. It also evaluated differences according to amblyopia subtype and examined the relationship between OCT parameters, visual acuity, and refractive error. The primary objective was to assess and compare RNFL, macular, and foveal thickness between unilateral amblyopic eyes and their contralateral normal eyes. Secondary objectives included comparing OCT values with BCVA and refractive error and evaluating anatomical differences according to the kind of amblyopia.

Materials and Methods

Study Design and Setting: The present study was designed as a hospital-based, observational, cross-sectional comparative study and was conducted in the Department of Ophthalmology, SCB Medical College and Hospital, Cuttack, Odisha. The study period extended from March 2024 to August 2025. Institutional Ethics Committee approval was obtained vide IEC application no. 2001. Written informed consent was obtained from the parents or legal guardians, and verbal assent was obtained from the participating children. The study was conducted in accordance with the principles of the Declaration of Helsinki (2013).

Study Population: The study population comprised school-going children aged 5–15 years attending the ophthalmology outpatient department who were diagnosed with unilateral amblyopia. The diagnosis was established on the basis of reduced BCVA associated with anisometropia, strabismus, or both, in the absence of an ocular abnormality sufficient to account for the visual loss.

For each participant, the amblyopic eye was considered the study eye and the contralateral clinically normal eye served as the internal control. Thus, each participant contributed two eyes for paired comparison.

In the final study population, 50 children with unilateral amblyopia were included. Although the protocol specified an age range of 5–15 years, the actual enrolled participants had an age range of 8–15 years, with a mean age of 12.48 ± 1.99 years.

Inclusion Criteria: Children fulfilling the following criteria were included:

- Age between 5 and 15 years.
- Diagnosis of unilateral amblyopia of anisometropic, strabismic, or mixed type.
- BCVA of at least 6/9 in the better eye.
- Interocular BCVA difference of ≥2 Snellen lines.
- Intraocular pressure <22 mmHg.
- Normal fundus examination.
- Refractive error corrected toward emmetropia following subjective and cycloplegic refraction.
- No history of previous ocular surgery.

Exclusion Criteria

Children were excluded if they had:

1. Corneal opacity, cataract, or other media opacity interfering with OCT imaging.
2. Retinal or optic nerve pathology, including glaucoma, optic neuritis, or retinal dystrophy.
3. Previous ocular surgery or ocular trauma.
4. Neurological disorders.
5. Bilateral ametropic amblyopia.
6. Developmental delay affecting fixation.
7. Poor-quality OCT scans or inability to maintain adequate fixation during image acquisition.
8. Coexisting nystagmus.

Sample Size: The thesis initially calculated sample size using an estimated prevalence of amblyopia of 3% among school-going children, with a 95% confidence level and 5% allowable absolute precision. The calculated minimum sample size was 45. Considering possible non-cooperation, poor OCT image quality, and dropouts, the sample size was increased to 50 children with unilateral amblyopia. Each participant contributed one amblyopic eye and one fellow normal eye, resulting in 100 eyes for paired analysis.

Clinical Evaluation: A detailed ophthalmological examination was performed for all participants. Demographic and clinical information including age, sex, affected eye, type of amblyopia, and duration of amblyopia was recorded.

BCVA was measured using a Snellen visual acuity chart and converted to logMAR values where required. Cycloplegic refraction was performed using 1% cyclopentolate or 1% atropine, as appropriate, followed by subjective refraction. The spherical equivalent refractive error was recorded.

Anterior segment examination was performed using slit-lamp biomicroscopy. Fundus examination was carried out using a 90-D lens and indirect ophthalmoscopy. Ocular alignment and ocular motility were assessed to identify strabismus, and the magnitude of ocular deviation was measured using a prism bar. Axial length was measured using A-scan ultrasonography.

Optical Coherence Tomography Examination: All participants underwent SD-OCT examination after pupillary dilation with 1% tropicamide. OCT imaging was performed in a dimly illuminated room.

The OCT protocol included assessment of:

- Global average peripapillary RNFL thickness.
- Superior, inferior, nasal, and temporal RNFL thickness.
- Central macular thickness.

- Parafoveal macular thickness.
- Perifoveal macular thickness.
- Central foveal thickness.
- Inner and outer macular segment measurements.

Macular imaging was obtained using the Macular Cube 512 × 128 protocol, while optic nerve head/RNFL imaging was performed using the Optic Disc Cube 200 × 200 protocol. OCT scans with signal strength of ≥7/10 were accepted for analysis. All measurements were performed by a single trained observer to minimize inter-observer variability.

RNFL Assessment: Peripapillary RNFL thickness was measured as the global average thickness and separately in the four standard quadrants: superior, inferior, nasal, and temporal.

The mean average RNFL thickness was subsequently compared between the amblyopic eye and fellow normal eye using a paired-eye analysis. The quadrant-wise measurements were similarly compared to identify any localized interocular structural asymmetry.

Macular and Foveal Assessment: Macular thickness was assessed according to the Early Treatment Diabetic Retinopathy Study (ETDRS) grid. Measurements included the central 1-mm region, representing the central macula, the 3-mm parafoveal region, and the 6-mm perifoveal region.

Central foveal thickness was independently recorded as an additional structural parameter. These measurements were compared between the amblyopic and fellow normal eyes.

Data Collection and Outcome Measures: For each participant, data were recorded separately for both eyes. Variables included BCVA in logMAR, spherical equivalent refractive error, average and quadrant-wise RNFL thickness, central and regional macular thickness, and central foveal thickness.

The primary outcome measure was the interocular difference in mean RNFL, macular, and foveal thickness between the amblyopic and fellow normal eyes.

The secondary outcome measures included the relationship of OCT parameters with BCVA, refractive error, and amblyopia subtype.

Statistical Analysis: All collected data were compiled and analysed using Statistical Package for the Social Sciences (SPSS), version 26.0 (IBM Corp., Armonk, NY, USA).

Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were expressed as frequencies and percentages. The paired t-test was used to compare RNFL, macular, and foveal thickness between the amblyopic and fellow normal eyes. One-way analysis of variance (ANOVA) was used to compare OCT parameters among anisometropic, strabismic, and mixed amblyopia groups. **P**earson's correlation coefficient was used to evaluate the relationship between OCT measurements and BCVA or refractive error.

A two-sided p-value <0.05 was considered statistically significant.

Quality Control: All ophthalmological examinations and OCT measurements were performed under standardized conditions by the same trained examiner. OCT images with artifacts, inadequate signal strength, or segmentation errors were excluded from analysis. The OCT equipment was calibrated regularly to maintain measurement reliability.

Results

Table 1: Age distribution of the study participants

Age (years)	Value
Mean ± SD	12.48 ± 1.99
Range	8 – 15

The age distribution of the study participants is shown in Table 1. The mean age of the participants was 12.48 ± 1.99 years. The age of the participants ranged from 8 to 15 years.

Table 2: Sex distribution of the study participants

Sex	Number	Percentage (%)
Female	23	46%
Male	27	54%
Total	**50**	**100**

The sex distribution of the study participants is presented in Table 2. Among the 50 participants, 23 (46.0%) were female and 27 (54.0%) were male.

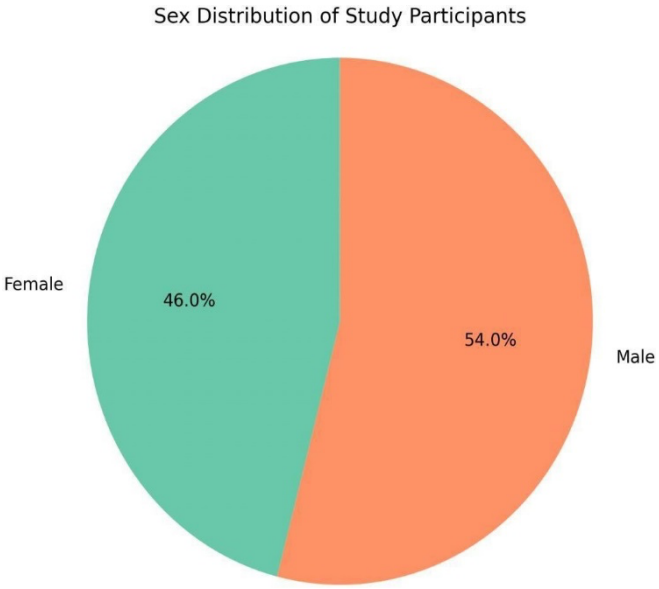

Figure 1: Sex distribution of the study participants(N=50)

Table 3: Age and sex distribution of the study participants (N=50)

Age Group (years)	Male n (%)	Female n (%)	Total n (%)
8–10	14 (**28.0%**)	11 (**22.0%**)	25 (**50.0%**)
11–15	13 (**26.0%**)	12 (**24.0%**)	25 (**50.0%**)
Total	27 (**54.0%**)	23 (**46.0%**)	50 (**100.0%**)

Table 3 described the age and sex distribution of the study participants. Among the 50 participants included in the study, an equal number were distributed across the two age groups. In the 8–10 years' age group, there were 25 participants (50.0%), comprising 14 males (28.0%) and 11 females (22.0%). Similarly, the 11–15 years' age group also included 25 participants (50.0%), with 13 males (26.0%) and 12 females (24.0%). Overall, males constituted 27 participants (54.0%), while females accounted for 23 participants (46.0%) of the study population.

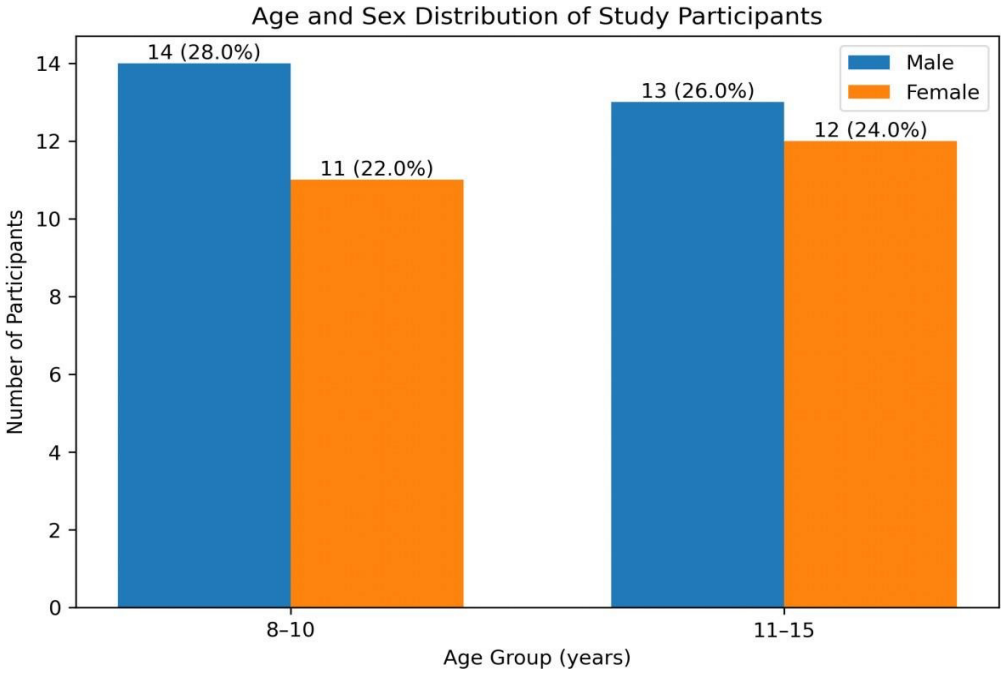

Figure 2: Age and sex distribution between of the study participants (N=50)

Table 4: Characteristics of amblyopia among the study participants

Eye with amblyopia	Number	Percentage (%)
Right eye (RE)	27	54.0
Left eye (LE)	23	46.0
Total	**50**	**100**

The characteristics of amblyopia with respect to the affected eye are presented in Table 4. Among the 50 study participants, 27 (54.0%) had amblyopia in the right eye, while 23 (46.0%) had amblyopia in the left eye.

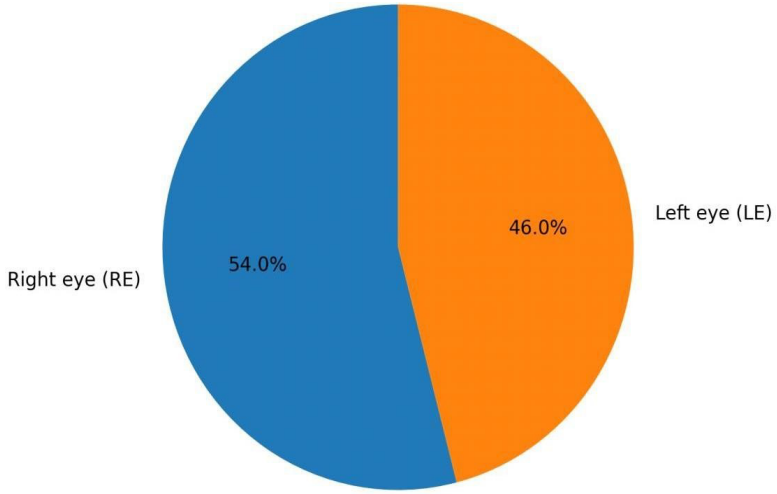

Figure 3: Characteristics of amblyopia among the study participants

Table 5: Distribution of amblyopia according to type in the study participants

Type of Amblyopia	Frequency (n)	Percentage (%)
Anisometropic	37	74.0
Strabismic	6	12.0
Mixed	7	14.0
Total	**50**	**100.0**

Table 5 showed the distribution of amblyopia according to type among the study participants. Anisometropic amblyopia was the most common type, observed in 37 (74.0%). This was followed by mixed amblyopia, which was seen in 7 (14.0%). Strabismic amblyopia was the least common type, affecting 6 participants (12.0%). Overall, a total of 50 participants were included in the study, accounting for 100% of the cases.

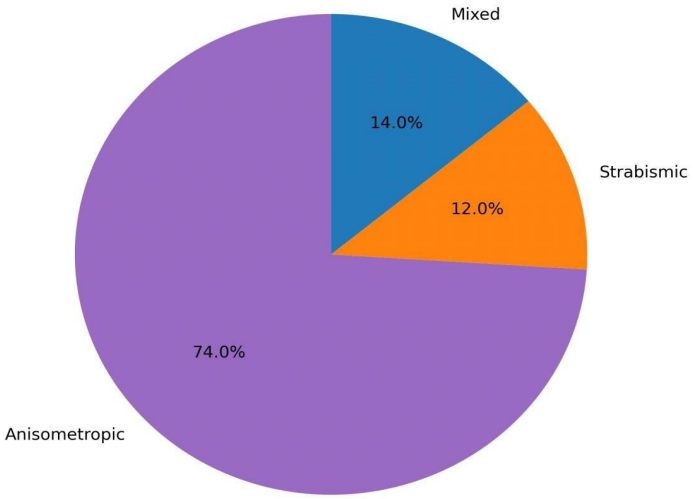

Figure 4: Distribution of amblyopia according to type in the study participants

Table 6: Eye affected by squint among the study participants

Squint-affected eye	Number	Percentage (%)
Left eye exotropia	3	6%
Right eye exotropia	8	16%
No squint	39	78%
Total	**50**	**100**

The distribution of squint involvement among the study participants is presented in Table 6. Of the total 50 participants, 5 (10.0%) had right eye exotropia, while 45 (90.0%) had no squint.

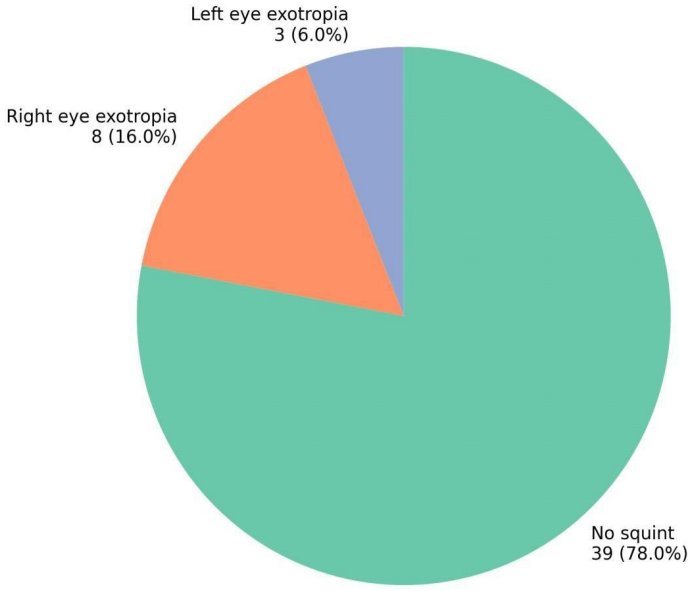

Figure 5: Eye affected by squint among the study participants

Table 7: Degree of squint among the study participants

Degree of squint (Prism Diopters)	Number	Percentage (%)
15 PD	3	6%
30 D	8	16%
No squint	39	78%
Total	**50**	**100**

The degree of squint among the study participants is shown in Table 7. Among the 50 participants, 5 (10.0%) had a squint of 15 prism diopters, while 45 (90.0%) had no squint, for whom the degree of squint was not applicable.

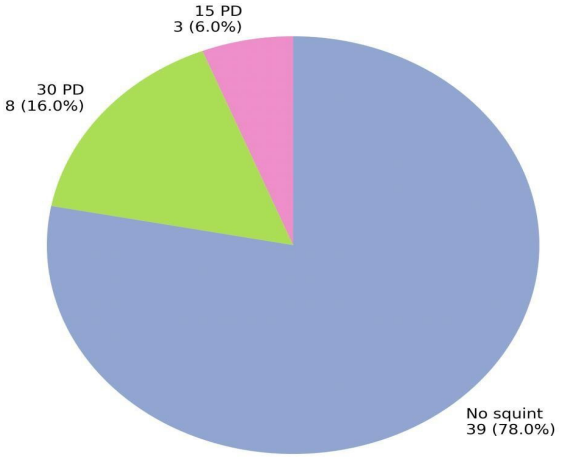

Figure 6: Degree of squint among the study participants

Table 8: Comparison of BCVA (logMAR) between amblyopic and fellow normal eyes (n = 50)

Eye	BCVA (logMAR), Mean ± SD	p-value
Amblyopic eye	0.46 ± 0.15	<0.001*
Fellow normal eye	0.02 ± 0.04	

The comparison of best-corrected visual acuity (BCVA) between amblyopic and fellow normal eyes is presented in Table 8. The mean BCVA (logMAR) of the amblyopic eyes was 0.46 ± 0.15, whereas the mean BCVA (logMAR) of the fellow normal eyes was 0.02 ± 0.04. The difference in BCVA between the two eyes was statistically significant ($p < 0.001$).

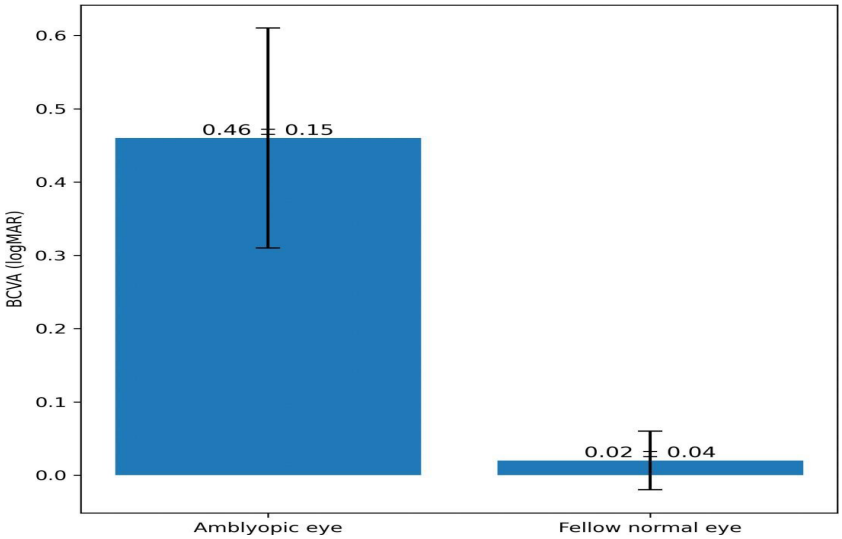

Figure 7: Comparison of BCVA (logMAR) between amblyopic and fellow normal eyes (n = 50)

Table 9: Comparison of Spherical Equivalent Refractive Error between amblyopic and normal eyes

Eye	Mean ± SD (Diopters)	p value
Amblyopic Eye	-3.12 ± 1.74	
Fellow Eye	-0.68 ± 0.58	**<0.001**

Table 9 compared the spherical equivalent refractive error between amblyopic eyes and fellow normal eyes. The mean spherical equivalent refractive error of the amblyopic eyes was −3.12 ± 1.74 diopters, whereas the fellow eyes had a mean refractive error of −0.68 ± 0.58 dioptres. The difference between the two groups was statistically significant, with a p value of less than 0.001, indicating a significantly higher refractive error in amblyopic eyes compared to fellow eyes.

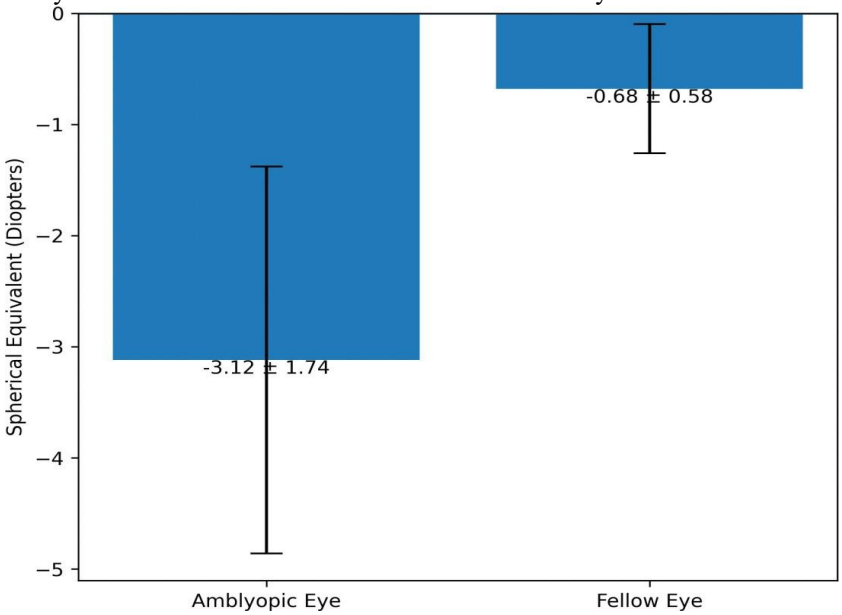

Figure 8: Comparison of Spherical Equivalent Refractive Error between amblyopic and normal eyes

Table 10: Comparison of Axial Length between amblyopic and normal eyes

Eye	Mean ± SD (mm)	p value
Amblyopic Eye	22.82 ± 0.71	
Fellow Eye	22.14 ± 0.64	**0.01**

The comparison of axial length between amblyopic and fellow normal eyes is presented in Table 10. The mean axial length of the amblyopic eyes was 22.82 ± 0.71mm, while the mean axial length of the fellow eyes was 22.14 ± 0.64 mm. The difference in axial length between the two eyes was statistically significant (p = 0.01).

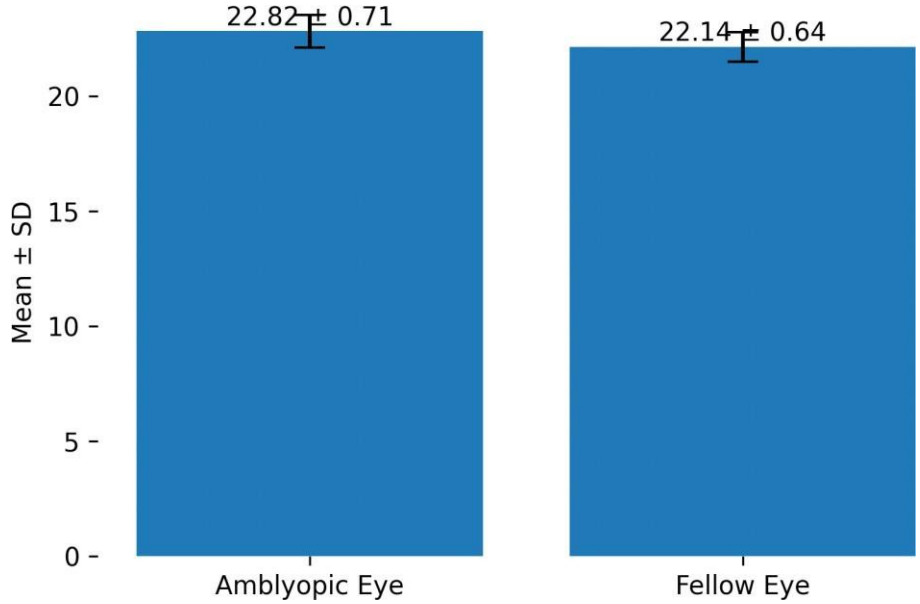

Figure 9: Comparison of Axial Length between amblyopic and normal eyes

Table 11: Comparison of average RNFL thickness between amblyopic and fellow eyes

Eye	Average RNFL thickness (µm), Mean ± SD	p-value
Amblyopic eye	101.6 ± 8.9	0.47
Fellow normal eye	100.9 ± 8.4	

The comparison of average retinal nerve fiber layer (RNFL) thickness between amblyopic and fellow normal eyes is presented in Table 11. The mean average RNFL thickness was 101.6 ± 8.9 µm in amblyopic eyes and 100.9 ± 8.4 µm in fellow normal eyes. The difference in average RNFL thickness between the two eyes was not statistically significant (p= 0.47).

Table 12: Comparison of quadrant-wise RNFL thickness between amblyopic and fellow eyes

RNFL quadrant	Amblyopic eye (µm)	Fellow eye (µm)	p-value
Superior	126.8 ± 14.9	125.3 ± 14.5	0.51
Inferior	131.9 ± 15.6	130.7 ± 15.1	0.48
Nasal	73.1 ± 9.8	73.6 ± 9.5	0.66
Temporal	69.4 ± 8.7	69.9 ± 8.5	0.58

The quadrant-wise comparison of retinal nerve fiber layer (RNFL) thickness between amblyopic and fellow normal eyes is presented in Table 12. The mean RNFL thickness in the superior quadrant was 126.8 ± 14.9 µm in amblyopic eyes and 125.3 ± 14.5 µm in fellow eyes. In the inferior quadrant, the mean RNFL thickness was 131.9 ± 15.6 µm in amblyopic eyes and 130.7 ± 15.1 µm in fellow eyes. The nasal quadrant showed a mean RNFL thickness of 73.1 ± 9.8 µm in amblyopic eyes and 73.6 ± 9.5 µm in fellow eyes, while the temporal quadrant showed mean values of 69.4 ± 8.7 µm and 69.9 ± 8.5 µm, respectively. The differences in RNFL thickness between amblyopic and fellow eyes across all quadrants were not statistically significant (p > 0.05).

Table 13: Comparison of macular thickness between amblyopic and fellow eyes (ETDRS grid)

Macular region	Amblyopic eye (µm), Mean ± SD	Fellow eye (µm), Mean ± SD	p-value
Centralmacula (1 mm)	275.8 ± 18.6	268.1 ± 17.9	0.01*
Parafoveal (3 mm)	318.2 ± 14.4	312.9 ± 14.9	0.03*
Perifoveal (6 mm)	286.1 ± 13.7	283.6 ± 13.9	0.19

The comparison of macular thickness between amblyopic and fellow normal eyes using the ETDRS grid is presented in Table 13. The mean central macular thickness (1 mm) was 275.8 ± 18.6 µm in amblyopic eyes and 268.1 ± 17.9 µm in fellow eyes, with a statistically significant difference (p = 0.01). The mean parafoveal macular thickness (3 mm) was 318.2 ± 14.4 µm in amblyopic eyes and 312.9 ± 14.9 µm in fellow eyes, and this difference was statistically significant (p = 0.03). The mean perifoveal macular thickness (6 mm) was 286.1 ± 13.7 µm in amblyopic eyes and 283.6 ± 13.9 µm in fellow eyes, with no statistically significant difference (p = 0.19).

Table 14: Comparison of central foveal thickness between amblyopic and fellow eyes

Eye	Central foveal thickness (µm), Mean ± SD	p-value
Amblyopic eye	227.4 ± 17.8	0.001*
Fellow normal eye	215.6 ± 16.9	

The comparison of central foveal thickness between amblyopic and fellow normal eyes is presented in Table 14. The mean central foveal thickness was 227.4 ± 17.8 µm in amblyopic eyes and 215.6 ± 16.9 µm in fellow normal eyes. The difference in central foveal thickness between the two eyes was statistically significant (p = 0.001).

Table 15: Comparison of OCT parameters among different types of amblyopia

Parameter	Anisometropic (n =37)	Mixed (n =7)	Strabismic (n =6)	p-value
Average RNFL (µm)	101.9 ± 8.6	100.8 ± 9.4	99.6 ± 10.2	0.82
Central macular thickness (µm)	278.1 ± 17.2	270.6 ± 18.9	268.4 ± 19.6	0.04*
Central foveal thickness (µm)	229.3 ± 16.9	221.2 ± 17.8	218.6 ± 18.1	0.03*

The comparison of optical coherence tomography (OCT) parameters according to the type of amblyopia is presented in Table 15. The mean average retinal nerve fiber layer (RNFL) thickness was 101.9 ± 8.6 µm in anisometropic amblyopia, 100.8 ± 9.4 µm in mixed amblyopia, and 99.6 ± 10.2 µm in strabismic amblyopia, with no statistically significant difference among the groups (p = 0.82). The mean central macular thickness was 278.1 ± 17.2 µm in anisometropic amblyopia, 270.6 ± 18.9 µm in mixed amblyopia, and 268.4 ± 19.6 µm in strabismic amblyopia, and the difference among the groups was statistically significant (p = 0.04). The mean central foveal thickness was 229.3 ± 16.9 µm in anisometropic amblyopia, 221.2 ± 17.8 µm in mixed amblyopia, and 218.6 ± 18.1 µm in strabismic amblyopia, with a statistically significant difference observed across the groups (p = 0.03).

Table 16: Comparison of Average RNFL Thickness According to Type of Amblyopia

Type of Amblyopia	Amblyopic Eye (Mean ± SD) µm	Fellow Eye (Mean ± SD) µm	p-value
Anisometropic (n=37)	110.1 ± 9.3	103.2 ± 8.5	0.02
Strabismic (n=6)	105.4 ± 8.7	102.0 ± 8.3	0.09
Mixed (n=7)	111.3 ± 9.8	104.7 ± 9.1	0.04

The comparison of average retinal nerve fiber layer (RNFL) thickness between amblyopic and fellow eyes according to the type of amblyopia is presented in Table 16. In participants with anisometropic amblyopia (n = 22), the mean average RNFL thickness was 110.1 ± 9.3 µm in amblyopic eyes and 103.2 ± 8.5 µm in fellow eyes, with a statistically significant difference (p = 0.02). Among participants with strabismic amblyopia (n = 16), the mean average RNFL thickness was 105.4 ± 8.7 µm in amblyopic eyes and 102.0 ± 8.3 µm in fellow eyes, and the difference was not statistically significant (p = 0.09). In participants with mixed amblyopia (n = 12), the mean average RNFL thickness was 111.3 ± 9.8 µm in amblyopic eyes and 104.7 ± 9.1 µm in fellow eyes, with a statistically significant difference (p = 0.04).

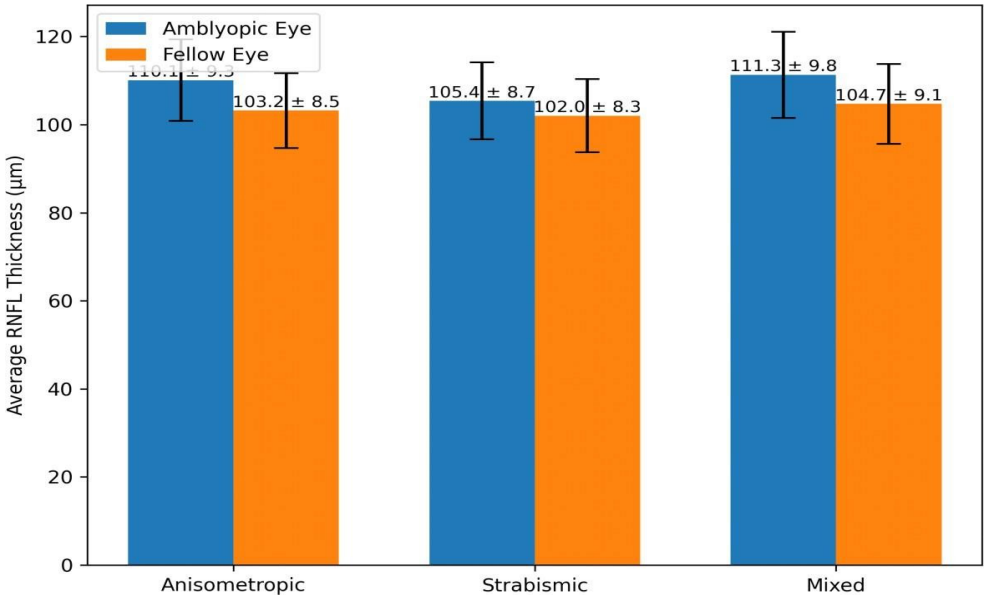

Figure 10: Comparison of Average RNFL Thickness According to Type of Amblyopia

Table 17: Comparison of Central Macular Thickness According to Type of Amblyopia

Type of Amblyopia	Amblyopic Eye (Mean ± SD) µm	Fellow Eye (Mean ± SD) µm	p-value
Anisometropic	273.6 ± 13.9	265.1 ± 13.2	0.03
Strabismic	268.2 ± 14.4	262.9 ± 13.8	0.08
Mixed	275.4 ± 14.7	266.8 ± 14.1	0.04

The comparison of central macular thickness between amblyopic and fellow eyes according to the type of amblyopia is presented in Table 17. In anisometropic amblyopia, the mean central macular thickness was 273.6 ± 13.9 µm in amblyopic eyes and 265.1 ± 13.2 µm in fellow eyes, with a statistically significant difference ($p = 0.03$). In strabismic amblyopia, the mean central macular thickness was 268.2 ± 14.4 µm in amblyopic eyes and 262.9 ± 13.8 µm in fellow eyes, and the difference was not statistically significant ($p = 0.08$). In mixed amblyopia, the mean central macular thickness was 275.4 ± 14.7 µm in amblyopic eyes and 266.8 ± 14.1 µm in fellow eyes, with a statistically significant difference ($p = 0.04$).

Table 18: Comparison of Foveal Thickness According to Type of Amblyopia

Type of Amblyopia	Amblyopic Eye (Mean ± SD) µm	Fellow Eye (Mean ± SD) µm	p-value
Anisometropic	219.4 ± 9.2	211.6 ± 8.7	0.02
Strabismic	216.1 ± 9.6	210.4 ± 9.0	0.07
Mixed	221.2 ± 9.9	212.8 ± 9.2	0.03

The comparison of central foveal thickness between amblyopic and fellow eyes according to the type of amblyopia is presented in Table 18. In anisometropic amblyopia, the mean foveal thickness was 219.4 ± 9.2 µm in amblyopic eyes and 211.6 ± 8.7 µm in fellow eyes, with a statistically significant difference ($p = 0.02$). In strabismic amblyopia, the mean foveal thickness was 216.1 ± 9.6 µm in amblyopic eyes and 210.4 ± 9.0 µm in fellow eyes, and the difference was not statistically significant ($p = 0.07$). In mixed amblyopia, the mean foveal thickness was 221.2 ± 9.9 µm in amblyopic eyes and 212.8 ± 9.2 µm in fellow eyes, with a statistically significant difference ($p = 0.03$).

Table 19: Correlation between OCT parameters and BCVA (logMAR) in amblyopic eyes

OCT parameter	Pearson's r	p-value
Average RNFL thickness	−0.10	0.48
Central macular thickness	+0.39	0.005*
Central foveal thickness	+0.44	0.002*

The correlation between optical coherence tomography (OCT) parameters and best-corrected visual acuity (BCVA) expressed in logMAR in amblyopic eyes is presented in Table 19. The Pearson correlation coefficient between average RNFL thickness and BCVA was −0.10, with a p-

value of 0.48. The correlation between central macular thickness and BCVA showed a Pearson's r value of +0.39, with a p-value of 0.005. The correlation between central foveal thickness and BCVA demonstrated a Pearson's r value of +0.44, with a p-value of 0.002.

Table 20: Correlation between OCT parameters and spherical equivalent refractive error

OCT parameter	Pearson's r	p-value
Average RNFL thickness	−0.07	0.62
Central macular thickness	+0.36	0.01*
Central foveal thickness	+0.41	0.004*

The correlation between optical coherence tomography (OCT) parameters and spherical equivalent refractive error is presented in Table 20. The Pearson correlation coefficient between average RNFL thickness and spherical equivalent refractive error was −0.07, with a p-value of 0.62. The correlation between central macular thickness and spherical equivalent refractive error showed a Pearson's r value of +0.36, with a p-value of 0.01. The correlation between central foveal thickness and spherical equivalent refractive error demonstrated a Pearson's r value of +0.41, with a p-value of 0.004.

Table 21: Correlation of OCT Parameters with Spherical Equivalent Refractive Error

OCT Parameter	Spherical Equivalent (r)	p value
Average RNFL Thickness	−0.36	0.02
Central Macular Thickness	−0.33	0.03
Foveal Thickness	−0.29	0.04

The correlation of optical coherence tomography (OCT) parameters with spherical equivalent refractive error is presented in Table 21. The Pearson correlation coefficient between average RNFL thickness and spherical equivalent refractive error was −0.36, with a p-value of 0.02. The correlation between central macular thickness and spherical equivalent refractive error showed a Pearson's r value of −0.33, with a p-value of 0.03. The correlation between foveal thickness and spherical equivalent refractive error demonstrated a Pearson's r value of −0.29, with a p-value of 0.04.

Table 22: Correlation of OCT Parameters with BCVA (logMAR)

OCT Parameter	BCVA (logMAR) (r)	p value
Average RNFL Thickness	+0.34	0.02
Central Macular Thickness	+0.31	0.03
Foveal Thickness	+0.28	0.04

The correlation of optical coherence tomography (OCT) parameters with best-corrected visual acuity (BCVA) expressed in logMAR is presented in Table 22. The Pearson correlation coefficient between average RNFL thickness and BCVA was +0.34, with a p-value of 0.02. The correlation between central macular thickness and BCVA showed a Pearson's r value of +0.31, with a p-value of 0.03. The correlation between foveal thickness and BCVA demonstrated a Pearson's r value of +0.28, with a p-value of 0.04.

Discussion

This study evaluated retinal structural characteristics in fifty children with unilateral amblyopia using the contralateral normal eye as an internal reference. Anisometropic amblyopia accounted for 74% of cases, followed by mixed (14%) and strabismic (12%). This incidence is noteworthy since refractive imbalance is frequently associated with measurable OCT changes, but outcomes in strabismic amblyopia are more varied. This pattern may reflect differences in the duration and type of aberrant visual input during ocular development. As expected, the BCVA of amblyopic eyes was significantly lower than that of companion eyes (0.46 ± 0.15 vs. 0.02 ± 0.04 logMAR; $p<0.001$). Furthermore, the amblyopic eyes had significantly greater axial length and spherical equivalent refractive error. Recent OCT/OCTA studies have emphasised axial-length correction as an important methodological aspect since ocular biometry may impact retinal measurements. The primary finding was that there was no significant difference in overall RNFL thickness between amblyopic and fellow eyes (101.6 ± 8.9 vs. 100.9 ± 8.4 µm; $p=0.47$). The superior, inferior, nasal, and temporal RNFL measures were likewise comparable.

This supports the theory that amblyopia is not always linked to widespread loss of retinal ganglion-cell axons. Furthermore, a 2022 study evaluating RNFL thickness across several types of amblyopia found no significant interocular RNFL difference. Thus, RNFL appears to be a less trustworthy structural marker than macular features. However, parafoveal thickness (318.2 ± 14.4 vs. 312.9 ± 14.9

μm; p=0.03) and central macular thickness (275.8 ± 18.6 vs. 268.1 ± 17.9 μm; p=0.01) were significantly larger in amblyopic eyes. The perifoveal thickness did not differ significantly. The central foveal thickness was significantly greater in amblyopic eyes (227.4 ± 17.8 vs. 215.6 ± 16.9 μm; p=0.001). These findings are consistent with recent OCT studies that demonstrate increased foveal or central macular measurements in patients with amblyopia, particularly those who are anisometropic. The fact that other studies have not found any significant difference after adjusting for axial length highlights the heterogeneity in reported results.

Subtype analysis provided more evidence of a link between retinal morphology and refractive/visual impairment. Central macular and foveal thickness varied significantly between anisometropic, mixed, and strabismic groups, with anisometropic amblyopia usually showing the highest values. Pairwise comparisons revealed significant interocular increases in macular and foveal thickness in anisometropic and mixed amblyopia, while differences in strabismic amblyopia were not statistically significant. Recent studies using layer-specific OCT have demonstrated comparable quantitative alterations in retinal microstructure in anisometropic amblyopia. The positive associations between central macular thickness and BCVA (r=0.39; p=0.005) and foveal thickness and BCVA (r=0.44; p=0.002) showed that greater thickness was associated with poorer visual acuity in the amblyopic eyes. This relationship supports the hypothesis that aberrant retinal development may coexist with functional vision impairment.

Correlations between retinal microvascular characteristics and visual acuity are also seen in current OCTA research, suggesting that changes in retinal structure and vascular function may be developmental consequences of abnormal visual experience. Overall, the findings indicate that OCT anomalies in unilateral amblyopia are mostly macular and foveal rather than broad RNFL modifications. The cross-sectional design, small sample size, anisometropic case prevalence, and absence of an independent age-matched healthy control group all limit generalisability. Furthermore, whether retinal thickness is a cause, effect, or developmental correlate of amblyopia during visual development cannot be ascertained by this investigation. Longitudinal studies comparing OCT results before and after amblyopia treatment are required to determine whether observed macular and foveal changes are reversible and whether they have prognostic significance. Because recent long-term studies have indicated decreases in macular/foveal thickness following therapy while RNFL remained mostly constant, prospective study is required.

Conclusion

In fifty children with unilateral amblyopia, OCT showed significant structural differences, mostly affecting the macula and fovea. Although there were no significant interocular differences in global or quadrant-wise RNFL thickness, amblyopic eyes had significantly larger central macular, parafoveal, and central foveal thicknesses than corresponding normal eyes. While strabismic amblyopia showed less consistent differences, the most prevalent subtype, anisometropic amblyopia, displayed the biggest macular and foveal measurements. Furthermore, a positive correlation was found between decreased BCVA and central macular and foveal thickness, suggesting a link between retinal morphology and visual impairment. These findings suggest the utility of SD-OCT as a non-invasive complement for structural assessment of paediatric amblyopia. However, careful interpretation is necessary due to the cross-sectional design, small sample size, subtype imbalance, and interocular biometric variations. Larger, longitudinal, axially corrected studies are required to determine the clinical and prognostic significance of these retinal changes and to establish whether these abnormalities change after successful amblyopia treatment.

References

1. Xia Z, Chen H, Zheng S. Thicknesses of macular inner retinal layers in children with anisometropic amblyopia. Biomed Res Int. 2020; 2020:6853258. doi:10.1155/2020/6853258.
2. Zhang T, Xie S, Liu Y, Xue C, Zhang W. Effect of amblyopia treatment on macular microvasculature in children with anisometropic amblyopia using optical coherence tomographic angiography. Sci Rep. 2021; 11:39. doi:10.1038/s41598-020-79585-4.
3. Cinar FG, Ozkan G. Macular capillary system and ganglion cell-layer complex of the amblyopic eye with optical coherence tomography angiography and optical coherence tomography. Int Ophthalmol. 2021;41(2):675-686. doi:10.1007/s10792-020-01624-w.
4. Liu C, Zhang Y, Gu X, Wei P, Zhu D. Optical coherence tomographic angiography in children with anisometropic amblyopia. BMC Ophthalmol. 2022; 22:269. doi:10.1186/s12886-022-02486-9.
5. Oren B, Okumus S. Evaluation of retinal nerve fiber layer thickness with optical coherence tomography in various amblyopia types. Medicine Science. 2022;11(1):304-309. doi:10.5455/medscience.2021.06.211.
6. Sharma P, Anand M, Sharma A, Phuljhele S, Saxena R. Evaluation of retinal function and morphology in isoametropic amblyopia. Indian J Ophthalmol. 2023;71(1):222-228. doi: 10.4103/ijo.IJO_1685_22.

7. Mutlu D, Bayram N. Morphological changes of the retinal layers in the central macula in children with anisometropic amblyopia. J Fr Ophtalmol. 2023;46(4):363-368. doi: 10.1016/j.jfo.2022.10.006.
8. AttaAllah HR, Abdelaziz ST, Mohamed AAM, Ibrahiem MFK. Assessment of macular microvascular changes in children following treatment of anisometropic myopic amblyopia using optical coherence tomography angiography. Graefes Arch Clin Exp Ophthalmol. 2023;261(9):2689-2699. doi:10.1007/s00417-023-06055-8.
9. Errera C, Romann J, Solecki L, Gaucher D, Ballonzoli L, Bourcier T, et al. Retinal microvascular changes in unilateral functional amblyopia detected by OCT-angiography and follow-up during treatment. Eur J Ophthalmol. 2024;34(2):399-407. doi:10.1177/11206721231188987.
10. Bhimewar S, Kavitha V, Mallikarjun MH, Pradeep Sagar BK. Analysis of choroidal thickness, macular thickness, peripapillary retinal nerve fiber layer thickness, and macular vascular density in children with unilateral amblyopia using swept-source optical coherence tomography and their changes following occlusion therapy. Taiwan J Ophthalmol. 2024;14(4):579-587. doi: 10.4103/tjo.TJO-D-23-00071.
11. Goyal JL, Arora J, Gahlot A, Singh D, Sharma N, Yadav N. Evaluation of optical coherence tomography changes in amblyopia. Indian J Ophthalmol. 2025;73(5):737-740. doi: 10.4103/IJO.IJO_3040_23.
12. Chedid A, Fronius M, Wenner Y, Cirina L, Kohnen T, Kuhli-Hattenbach C. Optical coherence tomography (OCT) parameters in amblyopia. Strabismus. 2025;33(4):247-257. doi:10.1080/09273972.2025.2478078.