Characteristics of the Macula in Amblyopic Eyes Assessed by Optical Coherence Tomography

Ophthalmol Pak. - Official Journal of College of Ophthalmology & Allied Vision Sciences

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ABSTRACT

Purpose: Amblyopia is a developmental condition characterized by reduced visual acuity (VA), typically resulting from abnormal visual experiences during the brain's critical periods of development. The condition is typically associated with factors such as strabismus, anisometropia, and visual deprivation. Despite the corrective treatments, children with amblyopia fail to get their perfect vision, raising the possibility of underlying retinal abnormalities. This study aims to investigate the thickness of the macular neuroretina in amblyopic and normal eyes using Optical Coherence Tomography (OCT).

Methodology: A prospective observational cross-sectional study was conducted involving children aged 7 to 15 years. After visual acuity, refraction, and slit-lamp examinations, participants underwent OCT imaging using the OCT 2000 system. Detailed measurements of macular thickness and other retinal structures were obtained and analyzed.

Result: Descriptive statistics showed that the right macular thickness (224–293 microns), left macular thickness (200–280 microns), and total macular thickness (224–293 microns). The correlation between age and macular thickness was strong for all measurements ($r = 0.903$ for right, $r = 0.927$ for the left, and $r = 0.903$ for total macular thickness). A significant difference was evaluated in region A0 between the better and amblyopic eyes ($P = 0.045$); no significant differences were noticed in other regions.

Conclusion: The findings suggest that amblyopia may selectively affect certain macular regions, particularly in the neuroretina.

Keywords: Amblyopia, Optical Coherence Tomography (OCT), Neuroretina, Strabismus, Anisometropia, Pediatric Vision, Macular Thickness.

How to cite this article: Haider M, Sattar U, Amjad M. Characteristics of the Macula in Amblyopic Eyes Assessed by Optical Coherence Tomography. Pak. 2016;16(1): 31-36.

DOI: https://doi.org/10.62276/OphthalmolPak.16.01.239

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Received: 16-02-2026
Accepted: 27-02-2026

INTRODUCTION

Amblyopia is a condition in which a person has decreased visual acuity in one or both eyes, even with the best possible correction, due to abnormal visual experiences during the development of the brain in a critical period of age. Usually, the researchers debated that have either the problem arises from the retina or the brain for many years. Although some of the early studies reported that the retina might be the main cause. Many studies on animals and tests on humans have shown that the retina works normally in people with amblyopia. This shows that the problem is more likely in the brain than the retina.[1] It is now believed that the issue is a brain, with a new emerging debate about which brain areas were involved. This review focuses on the location of the deficit, leaving other aspects for future discussion.[2] Amblyopia is a condition characterized by a unilateral or bilateral decrease in VA, usually resulting from abnormal visual experiences during the early developmental stages of the visual system. This condition commonly occurs when one eye receives improper or inadequate visual signals, despite the use of corrective lenses, leading to poor vision. Most common risk factors for amblyopia include strabismus (misalignment of the eyes), anisometropia (a significant difference in the refractive error between the two eyes), high refractive errors, and visual deprivation (such as from cataracts or other obstructions that affect vision).

Amblyopia is usually treated by blurring the stronger eye with the help of correcting vision problems with glasses or contact lenses, or using an eye patch and eye drops. The treatment options depend on severity factors like how severe the amblyopia is, the type of vision problem, eye alignment, the child's age when treatment starts, and how well they follow and comply with the treatment plan. Even with proper treatment, about 50% of children may not achieve a perfect 20/20 or 6/6 VA. This could be due to hidden problems in the retina, especially in the macula, that may affect how well the treatment works[3-10] In Chinese children aged 7–14 years, the normal thickness of the foveola (center), fovea (1 mm), and macula has been measured using OCT as 130 ± 17.4 μm, 153.8 ± 17.6 μm, and 176.7 ± 14.8 μm, respectively. The macula's superior and inferior regions were found to be thicker (157–159 μm) compared to the nasal and temporal regions (102–109 μm). [10,11]

A non-invasive imaging technique, Optical coherence tomography (OCT), is used that provides high-resolution (10-20 μm) cross-sectional images of the retina. It enables us to have a detailed visualization of retinal layers, allowing us for non-contact imaging in living individuals. This technique is commonly used in clinical settings to assess and monitor retinal conditions with precision. This study was conducted to assess whether the amblyopic neuroretina may have a changed macular thickness as compared to the normal.

METHODOLOGY

Ethical approval was obtained from the Ethical Review Committee of Al-Ehsan Eye Hospital, Lahore. For this prospective cross-sectional study, using the formula $n=e2Z2\times\sigma2$ and 95% confidence ($Z=1.96$), $p=0.5$, and a margin of error of ~17% the sample size was 33. Written informed consent was obtained from the parents. Patients aged 7 to 11 years were included. After visual acuity, refraction, and slit Lamp examination, the amblyopic patients underwent Ocular Coherence Tomography (OCT). The images were obtained with the OCT 2000 system (Carl Zeiss Meditec, Inc., Dublin, California, USA), which is equipped with software version 4.0. This advanced imaging technology provides us a detailed cross-sectional view of the retina, enabling accurate measurements of macular thickness and other retinal structures for analysis.

RESULTS

Table 1 represents the participants' ages, which ranged from 7 to 15 years with SD ±2.55). Right macular thickness varied between 224 and 293 microns (SD ±17.94), left macular thickness ranged from 200 to 280 microns (SD ± 17.99), and total

macular thickness ranged from 224 to 293 microns (SD ± 16.09). Table 2 shows that 57.58% of participants were male and 42.42% were female. The left eye was affected in 63.63% of cases, while the right was in 36.36%. Exotropia was observed in 51.52% and esotropia in 48.48% of cases. Table 3 shows the correlation between age and macular thickness, revealing strong positive correlations for right macular thickness (r = 0.903), left macular thickness (r = 0.927), and total macular thickness (r = 0.903). Table 4 details the macular neurosensory retina thickness in 33 cases. Differences between the better and amblyopic eyes were significant in region A0 (P = 0.045) but not in other regions, where P-values ranged from 0.071 to 0.965, indicating no statistically significant differences.

Table No. 01: Descriptive Statistics of the Quantitative Data

Variables	Maximum	Minimum	Standard Deviation
Age	15	7	±2.55
Right Macular Thickness	293	224	±17.94
Left Macular Thickness	280	200	±17.99
Total Macular Thickness	293	224	±16.09

Table No. 02: Descriptive Statistics of the Quantitative Data

Variable	Frequency (n)	Percentage (%)
Gender		
Male	**19**	**57.58%**
Female	**14**	**42.42%**
Eye Affected		
Left Eye	**21**	**63.63%**
Right Eye	**12**	**36.36%**
Condition		
Exotropia	**17**	**51.52%**
Esotropia	**16**	**48.48%**

Table No. 03: Shows the Correlation between age and Macular Thickness

Variable	Maximum	Minimum	Std Dev	Correlation with Age
Right Macular Thickness	293	224	±17.94	0.903
Left Macular Thickness	280	200	±17.99	0.927
Total Macular Thickness	293	224	±16.09	0.903

Table No. 04: Thickness of Macular Neurosensory Retina.

Macular Region	Better Eye (n=33)	Amblyopic Eye (n=33)	Difference (Better - Amblyopic)	P-value
A0	152.48±14.20	158.92±16.30	6.44±14.80	0.045
B0	181.32±12.50	184.40±13.10	3.08±8.20	0.071
A1	261.10±15.00	262.45±15.90	1.35±9.00	0.554
A2	259.10±14.80	261.80±15.90	2.70±11.00	0.45
A3	254.50±10.30	255.90±10.50	1.40±7.80	0.568
A4	263.10±11.80	262.20±13.00	-0.90±16.50	0.861
B1	259.10±15.20	263.30±9.60	4.20±9.40	0.114
B2	246.80±14.10	254.40±15.20	7.60±14.80	0.164
B3	220.10±11.00	219.90±12.80	-0.20±5.80	0.965
B4	227.10±12.30	229.50±9.10	2.40±8.50	0.357

DISCUSSION

This present study reported a positive correlation between age and macular thickness, with significant differences in region A0 (P = 0.045)

between better and amblyopic eyes. Most participants were male (57.58%), and the left eye was affected in 63.63% of cases. Exotropia (51.52%) and esotropia (48.48%) were nearly equally common in this study.

We observed that there is a significant difference in macular thickness between better and amblyopic eyes only in the A0 region (P = 0.045). In our study of participants aged 7–15 years, macular thickness showed strong correlations with age (r > 0.9). Significant differences were observed only in region A0 (P = 0.045). Exotropia (51.52%) and esotropia (48.48%) were nearly equally common, with the left eye affected in 63.63% of cases. However, a study by Kee et al. and Wang et al. found no significant differences in retinal thickness between amblyopic and non-amblyopic eyes, aligning with our findings.[13] This lower foveal thickness was possibly due to differences in race, examiners, or devices.[12]

Dickmann et al. found no significant differences in retinal nerve fiber layer thickness, macular thickness, or foveal volume between amblyopic and fellow eyes in unilateral amblyopia, consistent with our results. In our study, there is a strong positive correlation between age and macular thickness (r > 0.9). Significant differences appeared only in region A0 (P = 0.045), while other regions were not significant (P > 0.071). This aligns with the hypothesis that structural retinal changes may not be a primary factor in amblyopia, as macular and nerve fiber integrity appear preserved. Factors such as age, race, examiner technique, and device variations could influence differences across studies.[14]

Our study did not observe significant differences in macular thickness between amblyopic and fellow eyes, suggesting that structural differences may vary depending on the type of amblyopia and underlying conditions like myopia. This could explain the contrast in findings, as different causes of amblyopia (such as refractive errors) may lead to distinct retinal changes. Pang et al. reported that children with unilateral high myopia and amblyopia tend to have a thicker fovea but thinner inner and outer macular rings in the amblyopic eye compared to their fellow eye.[15]

Our study shows that changes in the macula, like thickness differences, may be linked to these vision problems. However, these changes can differ depending on the type of amblyopia and other related conditions. This highlights how complex the effects of amblyopia can be on retinal development, Similar to Liu and Wu's findings whose results in their study partly support recent research on retinal issues in amblyopia. Amblyopia is a condition that affects the development of vision, often causing problems with spatial vision and depth perception, especially in the fovea.[16]

Liu and Wu et al reported in their study, which supported the recent studies of the abnormalities in the retinal development that decrease the spatial vision, and stereopsis, which is almost related to the foveal functions of the retina. Ju et al also found that the macular impairments occurred only in the center of the macula, i.e., 6°area which causes dysfunction of the normal eye. Also, in our study, the same findings were Significant only in region A0 (P = 0.045). All these findings revealed that a specific region in the fovea is responsible for the development of amblyopia. The supported possibilities of this study supported our findings regarding the morphological changes in the macula in the amblyopic eye.[17,18]

The macula flava, which is responsible for sharp central vision, develops in two stages: differentiation during gestation and full development after birth. The fovea matures last, with cone cells in the foveola and foveal slope fully developing postnatally. During this process, some cell types, like rods and certain cones, are excluded from the fovea. Additionally, non-neuronal cells, such as microglial cells, move out of the foveal region. As cones form a dense layer, the foveola becomes specialized for high-acuity vision. Any disruption in this development can affect both the function and structure of the fovea, though the exact timing and causes of such impairments are still not

fully understood.[19-23] The general characteristics of the amblyopic eye are similar to those of the normal eye in the parafoveal and perifoveal regions measured by OCT. Although OCT measurements showed that the increased thickness in the amblyopic eye was found in the center of the fovea (neurosensory retinal layer) that is not correlated to the dioptric refractive power of eye. These changes in the macula may be attributed toward the formation of condition called amblyopia. [24]

CONCLUSION

The study indicates significant structural differences between the better and amblyopic eyes in region A0, but no significant differences were found in other macular regions, suggesting selective macular involvement in amblyopia.

Conflict Of Interest: None to declare

Ethical Approval: The study was approved by the Institutional Review Board / Ethical Review Board Reference No. AEWS/MS/HR Dated 27.06.2025 Al-Ehsan Welfare Eye Hospital Lahore.

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