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Superficial Retinal Vessel Density and Ganglion Cell Complex Parameters in Myopic Children

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ABSTRACT

Background: Myopia is a major cause of visual impairment worldwide, with severe cases leading to blindness. Its progression, driven by genetic and environmental factors, involves axial elongation that induces retinal structural changes and reduced perfusion, potentially causing myopic chorioretinopathy. Optical coherence tomography angiography (OCTA) enables simultaneous assessment of retinal vascular and neural parameters, making it valuable for investigating the relationship between superficial retinal vessel density, ganglion cell complex thickness, and axial length in myopic children aged 7–16 years.

Objectives: This study aims to determine the correlation between ganglion cell complex (GCC) parameters and superficial retinal vessel density (SRVD), as well as their association with axial length, in myopic children using optical coherence tomography angiography (OCTA).

Methods: A total of 136 eyes were evaluated: 40 eyes from 20 emmetropic children (control group) and 96 eyes from 48 myopic children. Myopia was defined as spherical equivalent < −1.0 D; emmetropia as +0.5 to −0.5 D. Mean axial length (AL) was 24.58 mm in the myopic group vs. 22.88 mm in controls. Participants aged 7–18 years underwent ophthalmologic exams. GCC thickness and retinal vessel density were measured with SS-OCTA DRI Triton (Topcon, Tokyo), and axial length by ultrasound biometry.

Results: Control eyes had significantly higher total and parafoveal SRVD than myopic eyes. A significant correlation was observed between spherical equivalent, age, and SRVD in the myopic group, but not in the emmetropic group. The GCC layer was significantly thinner in high myopia compared to low/moderate myopia and emmetropia.

Conclusions: SS-OCTA revealed a strong relationship between AL, GCC thickness, and SRVD in myopic children, suggesting reduced perfusion and neural thinning in this population.

Keywords: Ganglion cell complex (GCC); myopia; optical coherence tomography angiography (OCTA); retinal vessel density.

BACKGROUND

Myopia is among the most prevalent causes of visual impairment globally, and in severe cases, it can lead to blindness.[1] The development of myopia involves a complex interplay of genetic and environmental factors that disrupt normal emmetropization.[2] A common feature across all types of myopia is axial elongation of the eyeball, which correlates with increases in refractive error and leads to structural changes, such as thinning and stretching of retinal tissue.[3,4]

Axial elongation is believed to cause narrowing of the retinal vessels and choriocapillaries, reducing circulation and contributing to degenerative retinal and choroidal changes, collectively known as myopic chorioretinopathy.[5,6] OCTA is a noninvasive imaging method that allows for detailed visualization of both vascular and neural structures in the retina, including quantitative assessment of vessel density.[5,7,8] Reduced retinal perfusion associated with increasing AL in myopia has been demonstrated in adult populations, but studies on pediatric patients are limited.

Myopia is often accompanied by thinning of the GCC and a decline in vascular density within both superficial and deep retinal plexuses.[9,10] Since OCTA can simultaneously assess vascular and neural parameters, it is a valuable tool for examining such changes.[11,12] This study focuses on exploring the correlation between SRVD and GCC thickness in myopic children and their relationship with AL. The incidence of myopia increases notably between ages 7–16,[13] a critical period for early detection and intervention.

METHODS

Study population

The study included 48 myopic children and 20 age-matched emmetropic volunteers recruited from two medical centers in Tbilisi, Georgia.

Inclusion criteria

- Age 7–18 years;
- Known refractive status;
- Clear ocular media;
- High-quality OCT and biometry data;
- Good general health.

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Exclusion criteria

- Glaucoma, prior ocular surgery, and inherited retinal diseases;
- Posterior segment pathologies (e.g., uveitis, tumors);
- Media opacities, strabismus, amblyopia;
- Systemic or neurological diseases;
- Lack of consent.

Study design

Participants were grouped by age:

- Group I: 7–12 years;
- Group II: 12–14 years;
- Group III: 14–18 years.

and by refractive error:

- Low myopia: −0.5 to −3.0 D;
- Moderate myopia: −3.5 to −6.0 D;
- High myopia: > −6.5 D.

Imaging procedure

Cycloplegia was induced with 1% cyclopentolate. Retinal imaging was performed using the DRI OCT Triton Plus (Topcon, Tokyo), a swept-source OCT with 1050 nm wavelength and 100,000 A-scans/s. GCC thickness was measured from the inner surface of the nerve fiber layer to the inner plexiform/inner nuclear boundary. Automated segmentation was used for accuracy.

A 3 × 3 mm scan centered on the fovea measured SRVD, including total, foveal, and parafoveal values. Parafoveal regions were further divided into temporal, superior, nasal, and inferior quadrants.

Statistical analysis

SPSS v24.0 was used for the statistical analysis of data. Normality was checked via the Kolmogorov–Smirnov test. Pearson correlation assessed associations between variables. Coefficient of variation (CV) and intraclass correlation coefficient (ICC) determined measurement consistency and repeatability.

RESULTS

GCC thickness

Superior GCC was thinner in myopic children (64.89 ± 2.60 µm) than in emmetropes (68.91 ± 2.72 µm; $p < 0.001$). Inferior GCC was 64.70 ± 2.86 µm vs. 70.41 ± 3.12 µm, respectively ($p < 0.001$). Total average GCC was significantly reduced in myopic eyes (64.98 ± 2.72 µm) compared to controls (70.20 ± 2.83 µm). There was a weak but significant inverse correlation between age and GCC thickness (Tab.1).

TABLE 1. Thickness measurements are in µm and presented as mean ± SD

Subfield	Layer	high myopic	moderate myopic	low myopic	emmetropic	P
Central fovea	Retina	231±22	231±22	232±23	232±23	0.17
	Ganglion cell layer	47±11	47±11	47±12	49±16	0.55
Parafoveal nasal	Retina	308±14	308±14	309±23	309±23	0.15
	Ganglion cell layer	92±6	93±6	93±10	93±11	0.6
Parafoveal temporal	Retina	244±63	291±16	293±22	293±20	0.6
	Ganglion cell layer	86±6	87±8	88±8	88±8	0.49
Parafoveal superior	Retina	306±20	306±20	312±16	312±19	0.05
	Ganglion cell layer	92±8	92±8	94±9	94±9	0.06
Parafoveal inferior	Retina	301± 18	301±18	304±20	298±22	0.13
	Ganglion cell layer	91± 9	91±9	92±10	92±10	0.04
Perifoveal nasal	Retina	285± 20	285±20	291±24	296±21	<.01
	Ganglion cell layer	72±8	73±8	73±8	74±8	<.01
Perifoveal temporal	Retina	260±16	160±16	265±19	268±17	<.01
	Ganglion cell layer	71±7	72±7	75±7	75±7	<.01
Perifoveal superior	Retina	272±13	272±13	280±17	281±20	<.01
	Ganglion cell layer	64±7	65±7	65±8	65±8	<.01
Perifoveal inferior	Retina	265±19	265±19	274±14	277±18	<.01
	Ganglion cell layer	63±7	64±7	69±9	69±9	<.01

Retinal vessel density

Control eyes had significantly higher SRVD in both the full macular and parafoveal areas. Table 2 presents detailed measurements.

Correlation analysis

AL correlated significantly with age, total SRVD, parafoveal SRVD, foveal SRVD, and GCC thickness across the whole cohort. In the myopic group, AL significantly correlated with age, total, and parafoveal SRVD. Additionally, SRVD parameters correlated with spherical equivalent in the myopic group but not in controls.

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TABLE 2. Comparison among the four studied groups regarding VD in different positions

	High myopic Mean±SD	Moderate myopic Mean±SD	Low myopic Mean±SD	Emmetropic Mean±SD	P
Central fovea	24.89±6.119	25.51±6.119	26.6±6.381	28.24±5.990	0.007
Parafoveal nasal	35.97±5.781	36.24±5.781	36.23±5.781	37.27±5.744	0.001
Parafoveal temporal	34.89±5.166	34.92±5.166	36.36±6.189	37.71±5.515	0.005
Parafoveal superior	36.78±4.193	37.24±4.193	37.98±5.084	39.58±5.223	0.01
Parafoveal inferior	38.0 ± 4.292	38.01±4.292	37.91±5.096	38.99±5.003	0.398
Perifovela nasal	39.61±4.318	39.62±4.318	40.4±3.630	39.64±4.728	0.001
Perifovel temporal	36.65±3.754	36.66±3.754	36.89±5.273	37.27±5.441	0.702
Perifoveal superior	40.08±4.309	40.1±4.309	40.90±4.127	40.91±4.318	0.324
Perifoveal inferior	41.70±3.517	41.72±3.517	42.33±4.079	41.46±5.216	0.208

DISCUSSION

Our study confirms that axial elongation in pediatric myopia is linked to both neural and vascular changes in the retina. Using SS-OCTA, we observed reduced SRVD and GCC thickness in myopic children compared to emmetropic peers.

These results align with previous studies in adults.[10-14] For instance, Read et al. found that parafoveal thickness decreases with increasing AL in children.[10] Fan et al. reported lower superficial and deep vessel density with axial elongation, similar to our findings.[16] Mosa et al. observed reduced perfusion in pathological myopia, particularly in macular and peripapillary regions.[17]

The mechanism by which myopia leads to reduced perfusion remains unclear. It's hypothesized that axial elongation alters the retinal vasculature's architecture, causing ischemic or hypoperfused areas, especially in high myopia.[15-18] Our findings extend this understanding to the pediatric population, showing that similar changes can be detected early using SS-OCTA.

While adult studies dominate the literature, several pediatric investigations have emerged. Lee et al. reported a mean macular GCC thickness of 71.6 µm in healthy Korean children, though differences in refractive error distribution and ethnicity limit comparison.[14] Cheng et al. provided normative SS-OCT data in Chinese children, revealing slightly higher GCC averages than our study.[19,20] Ethnic differences, as shown by population-based data, may explain such variability—Chinese adults had thicker GCLs than Indian counterparts by 3.3 µm.[20,21]

A meta-analysis of over 12,000 eyes demonstrated that high and intermediate myopia are associated with significant GCC thinning.[22] Although data for low myopia were scarce, our results suggest that even in early-stage myopia, reductions in SRVD and GCC thickness may begin.

Totan et al. found an average GCIPL thickness of 83.36 µm in Turkish children, while Goh et al. showed decreasing GCIPL thickness with increasing AL using SD-OCT.[23] These findings mirror our observations using SS-OCTA and support the trend of retinal thinning with elongation.

Our subgroup analysis reinforced that high myopia in children correlates with both reduced GCC thickness and lower macular perfusion. This underscores the progressive nature of these changes and the value of early OCTA assessment in myopic children.

CONCLUSIONS

This study demonstrated that myopic children have significantly reduced SRVD and thinner GCC compared to emmetropic peers. The reduction in vascular density and neural tissue correlates strongly with axial elongation. These findings highlight the utility of SS-OCTA for early detection of microvascular and structural retinal changes in pediatric myopia.

Importantly, our results suggest there may be a critical axial length threshold beyond which GCC thinning and perfusion deficits become prominent. Identifying this point could aid in risk stratification and inform early interventions. Continued monitoring of children with myopia is essential to understand the long-term consequences of these changes better and develop effective management strategies.

ETHICAL APPROVAL

This study was reviewed and approved by the Ethics Committee of Tbilisi State Medical University Zhvania Academic Clinics of Pediatrics and Caucasus Medical Centre (Protocol No. 07, dated 12 December 2022; Protocol No. 08, dated 13 December 2022). Written informed consent was obtained from the parents or legal guardians of all participating children, who were also informed about the study procedures.

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