Molecular Vision 2026; 32:343-352 <http://www.molvis.org/molvis/v32/343>
Received 7 November 2025 | Accepted 10 August 2026 | Published 12 August 2026

© 2026 Molecular Vision

Regional variation in choroidal and retinal thickness by refractive status in Mongolian adolescents from Ejin as measured by swept-source optical coherence tomography

Yan Zhao, Juan Liang, Yan Gao

Glaucoma & Cataract Department, Taiyuan Aier Eye Hospital, Taiyuan City, Shanxi Province, China

Purpose: To examine how differing refractive statuses of myopia, emmetropia, and hyperopia relate to choroidal and retinal thickness in adolescents from Ejin, Inner Mongolia, China.
Methods: We performed a cross-sectional study in 1,021 participants of varying refractive statuses in Ejin. Each study participant underwent comprehensive ophthalmic examinations consisting of optometry, axial length measurement, and swept-source optical coherence tomography (SS-OCT). Choroidal and retinal thickness were compared across the refractive statuses.
Results: The average central foveal choroidal thickness was 245 ± 52 µm. The choroid was significantly thinner for myopes (222 ± 60 µm) compared with emmetropes (255 ± 47 µm) and hyperopes (272 ± 51 µm). The central foveal retinal thickness was not significantly different among the groups. Central foveal choroidal thickness was positively correlated with refractive error ($r = 0.65$, $p = 0.02$) and negatively correlated with axial length ($r = –0.50$, $p < 0.01$). Central foveal retinal thickness was positively correlated with intraocular pressure ($r = 0.53$, $p = 0.02$). Axial length was negatively correlated with the total retinal thickness ($r = –0.40$, $p < 0.01$), ganglion cell layer ($r = –0.38$, $p < 0.01$), and inner nuclear layer ($r = –0.51$, $p < 0.01$). No significant relationships were found between central foveal retinal and choroidal thickness for any refractive group.
Conclusions: Myopic adolescents in Ejin had significantly thinner choroids than emmetropic and hyperopic peers, independent of age or sex. These findings provide preliminary normative data for Mongolian adolescents and highlight potential ethnic variations in ocular morphology.

Refractive error is increasingly being recognized as a significant public health issue worldwide. Some estimates have suggested that approximately one-third of the world's population could have a refractive error associated with myopia as early as 2020 [1]. The choroid is one of the important structural layers contributing to the ability of an eye to emmetropize by facilitating remodeling of the scleral extracellular matrix to allow for axial elongation [2,3]. For this reason, the ocular structure and function of the choroid and retina have become an area of tremendous research interest in optometry and ophthalmology.

Changes to the retinal and choroidal morphology of myopic eyes have been widely studied in children and adults [4-10]. Nonetheless, there exist documented anatomic differences between ethnic groups when it comes to ocular dimensions. For example, it has been reported that the axial length of Mongolians was shorter than that of Han Chinese individuals [11]. Furthermore, few segmentation studies have investigated retinal layer structure, and only one has been conducted in a specific cohort of 80 individuals [12].

Correspondence to: Juan Liang, Glaucoma & Cataract Department, Taiyuan Aier Eye Hospital, Taiyuan City, Shanxi Province, 030024 China; Phone: 18834823443; email: gaoy_sx@163.com

Ejin, located in Inner Mongolia, China, has been inhabited by local Mongolians exclusively for the past 400 years. Because of this, the population has migrated to the area little, and the contact between this population and all other nearby populations has been historically limited to an extent that the genetic homogeneity has remained intact. Thus, Ejin is a unique opportunity for population-based ocular research in relation to specific ethnic Mongolians.

This cross-sectional investigation utilizes swept-source optical coherence tomography (SS-OCT) to evaluate choroidal and retinal morphology. SS-OCT quantifies the amplitude and phase of back-scattered light from ocular tissues using a longer-wavelength swept light source, with benefits over spectral-domain OCT, including improved resolution, increased imaging depth, wider field of view, and faster scan times [13]. More recently, advancements have been made to improve SS-OCT imaging for greater choroidal assessment, quantitative measurements, and cross-population evaluation, resulting in potentially better normative data across a wider range of ethnicities [14-18].

Additionally, ethnic differences in ocular anatomy (e.g., differences in choroidal thickness, axial length, and prevalence of myopia) have been described across ethnic groups,

highlighting the need for reference values that are population based [19].

For this purpose, the Ejin population becomes a cohort that is genetically stable (i.e., limited migration) and environmentally stable, which allows for fewer confounding variables regarding migration, dietary exposure, and lifestyle to study the population directly relative to biology of ocular structural variability and provide normative baseline measurements that could be compared to future investigations of Han Chinese or other ethnicities in terms of ocular anatomic structure.

While previous studies have discussed differences in ocular parameters (e.g., axial length and refractive changes during development) among Mongolian and Han Chinese, few studies have assessed the differences in the thickness of retina and choroid between the cohorts of Mongolian and Han Chinese. Historical studies from Han cohorts have reported mean subfoveal choroidal thickness values averaging between ~280 and 310 µm among adolescents [14,15], which is demonstrated to be higher than the averages reported in the adolescent cohort of Mongolians in our study. This suggests a possible ethnic or genetic association with choroidal morphology.

Simultaneously, our study focuses on a cohort of Mongolian adolescents, a population characterized by relative genetic homogeneity and geographic isolation. This provides a valuable opportunity to establish normative baseline data for ocular parameters in this specific group. Such population-based data may facilitate future investigations into ethnic and regional differences in ocular anatomy. It should be noted, however, that the findings from this cohort are not directly representative of Han Chinese or other populations.

Although we do not directly compare the data with those of Han Chinese cohorts in this cross-sectional study, in this research, we provide normative choroidal and retinal thickness values in Mongolian adolescents, which could serve as a reference for future cross-ethnic investigations for assessment of ethnic comparisons.

This research uses SS-OCT to examine how retinal and choroidal thickness differ among refractive groups in Ejin adolescents. This will allow inquiry into ocular layer structural variability among refractive groups based on normative evaluations in this distinct population.

METHODS

Study design and ethics approval: The current cross-sectional study was conducted at a single institution and was approved by the Ethics Committee of the Taiyuan Aier Eye Hospital (approval number: EYETYYY-20250206–3). All procedures were in accordance with the Declaration of Helsinki guidelines for clinical research. Written informed consent was obtained from all patients or family members where the patient was a minor.

Participant recruitment and eligibility criteria: Potential participants were recruited through cluster sampling in selected communities in Ejin, Inner Mongolia, China. In March 2025, only participants of Mongolian ethnicity were screened for eligibility. Eligible participants had to self-identify as ethnic Mongolians and provide informed consent. Recruitment focused on children and adolescents aged 9 to 18 years, based on the aim of evaluating ocular growth throughout the school-age years. Participants were excluded from the study based on a self-reported history of intraocular surgery or ocular pathology that would likely interfere with measurement accuracy, including epiretinal membranes, macular edema, glaucoma, and advanced cataracts. For the 12 participants with reduced visual acuity (<20/25), additional screening excluded strabismus, anisometropia, and any amblyogenic ocular pathologies to ensure that reduced acuity could not be attributed to secondary reasons. Participants unwilling or unable to provide written consent or verbal assent were excluded.

Demographic and clinical data collection: Demographic data, including age and gender, were recorded through government-issued identification cards. Anthropometric data, including height, weight, chest circumference, waist circumference, and hip circumference, were taken by trained personnel. Body mass index (BMI) was computed using the following formula: weight (kg)/height $(m)^2$. Background medical history of previous diagnoses of hypertension, metabolic disease, and eye disease/surgery was recorded using a structured questionnaire administered on site. BMI and height were collected because previous studies suggest a potential association between body size and ocular parameters, including axial length and retinal morphology.

Ophthalmologic examinations: All participants underwent a complete ophthalmologic evaluation by a board-certified ophthalmologist. This evaluation consisted of slit-lamp biomicroscopy, best-corrected visual acuity with a retro-illuminated Early Treatment of Diabetic Retinopathy Study chart at 4 m, an objective refraction with a desktop auto-refractor (KR-8900; Topcon, Tokyo, Japan), dilated fundus examination, and noncontact tonometry (CT-80A; Topcon, Japan). Cycloplegic refraction was performed after instillation of 1% cyclopentolate hydrochloride (two drops, 5 min apart). Measurements were performed 30 min after the final instillation to ensure complete cycloplegia. Refractive status was summarized using spherical equivalent refraction (SER);

myopia was defined as SER ≤−0.50 diopters and hyperopia as SER ≥+0.50 diopters. Intraocular pressure was obtained with a noncontact tonometer, and the average of three contiguous measurements was recorded. Axial length was measured using a noncontact optical biometer (IOLMaster 500; Carl Zeiss Meditec, Jena, Germany).

Imaging and measurement procedures: High-resolution photography of the retina and choroid was taken with SS-OCT (DRI OCT Triton; Topcon). The imaging device consisted of a light source at 1,050 nm, with a lateral resolution of 10 µm and a depth resolution of 8 µm (three-dimensions: MACULA mode). Macular scans were acquired using the three-dimensional macular scan protocol, consisting of 25 parallel B-scans covering a 12-mm × 9-mm area centered on the fovea. The horizontal (12 mm) and vertical (9 mm) scan dimensions correspond to the temporal–nasal and superior–inferior directions, respectively. Each B-scan was obtained with four repeated scans at the same location using the automatic real-time averaging function to reduce noise and improve image clarity. To minimize diurnal variation, all images were taken by the same technician at the same time between 9:00 and 11:00 AM. To account for transverse magnification effects related to axial length, axial length values were entered into the OCT system before image acquisition for myopic and hyperopic participants, allowing automatic scaling adjustment by the device. For emmetropic participants, the default axial length setting (24 mm) of the OCT system was used without individualized input. Choroidal thickness was defined from Bruch's membrane to the choroid–scleral interface (Figure 1A); retinal thickness was defined from the internal limiting membrane to the interface of the photoreceptor outer segments and retinal pigment epithelium (Figure 1B). The built-in automated segmentation algorithm of the OCT software was used to determine choroidal thickness, but when boundaries were incorrectly identified, an observer trained and familiar with the anatomy corrected the digital delineation. To ensure consistent metrics when mapping the retina and the choroid, the Early Treatment of Diabetic Retinopathy Study grid was consistently applied to each tomographic image. The macula was divided into concentric circles centered on the fovea with radii of 500 µm, 1,000 µm, and 2,000 µm. Retinal and choroidal thicknesses were measured at the fovea and at corresponding points along the superior, inferior, nasal, and temporal meridians at each radius (Figure 2). Retinal layer segmentation was performed using the built-in automated algorithm, allowing extraction of individual layers, including the ganglion cell layer (GCL), inner nuclear layer (INL), and outer nuclear layer (ONL), as defined by the OCT software based on their respective anatomic boundaries. Thickness measurements of these layers were obtained at the fovea and at corresponding nasal and temporal points within the first parafoveal circle. For repeatability, a subsample of 50 participants had two scans performed 30 min apart on the same day. Intraclass correlation coefficients were calculated for all subfield metrics, with values between 0.91 and 0.95, determined to be of high reliability. Any image with a signal strength <60 was rejected and had to be repeated.

Statistical analysis: All statistical analyses were completed using SPSS software v. 23.0 (SPSS, Inc., Chicago, IL, USA). Data entry was conducted by two separate researchers, and any disagreements were discussed and resolved. Data were entered only for the right eye to avoid analyzing intereye correlations. Continuous variables were presented as mean ± standard deviation, while categorical variables were presented as frequencies and percentages.

The Kolmogorov–Smirnov test was used to assess the normality of the continuous variables. Independent samples *t* tests were performed on male versus female participants, while one-way analysis of variance (ANOVA) was used to assess the refractive groups. Categorical variables were analyzed using chi-square tests. Repeated-measures ANOVA with contrast analysis (multivariate ANOVA) was used to compare choroidal and retinal thickness across regions within the same eye, while stepwise multiple regression analysis examined the independent predictors of central foveal choroidal and retinal thickness. Finally, Pearson's correlation coefficients were used to quantify associations between refractive status, axial length, intraocular pressure, and layer thicknesses. Holm–Bonferroni sequential correction was applied to control type I error when multiple comparisons were made across various subfields. Analysis does not adjust for transverse magnification from axial length, and this is acknowledged as a limitation of our study. A two-tailed *p* value of less than or equal to 0.05 was regarded as statistically significant.

Clarified multivariate ANOVA terminology: Repeated-measures ANOVA was used to compare within-eye subfield differences; one-way ANOVA compared groups across refractive statuses.

RESULTS

Participant characteristics: Of the 1,021 participants enrolled in the research, 27 were removed due to insufficient image quality in the response-mode SS-OCT, making it impossible to assess the participants' retinal or choroidal thickness accurately. This resulted in a study cohort of 994 participants with an overall data inclusion of 97.35%. There were

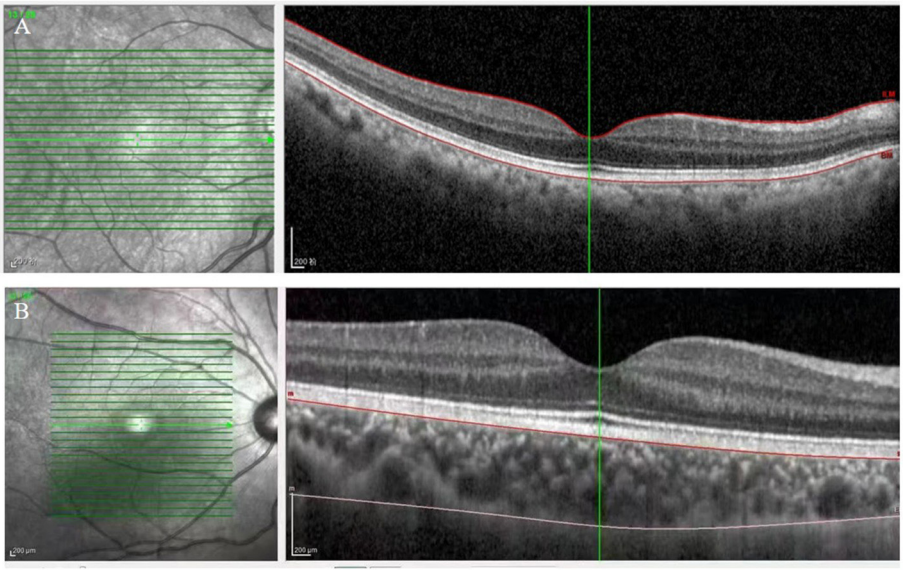


Figure 1. Representative SS-OCT image of the macula depicts a vertical cross-sectional image of the macula taken using swept-source optical coherence tomography (SS-OCT). **A**. Choroidal thickness is measured from Bruch's membrane to the choroid–scleral interface. **B**. The retinal layers are displayed from the internal limiting membrane to the outer segment–retinal pigment epithelium interface of the photoreceptor layer.

no statistically significant differences in age or sex between included and excluded participants ($p > 0.05$).

Of the 994 participants, 427 were male and 567 were female, corresponding to a male-to-female ratio of 0.75 (427/567). The mean age was 15.59 ± 2.58 years, ranging from 9 to 18 years of age. Most participants had a best-corrected visual acuity level of 20/20. Only 12 participants had vision worse than 20/25 (corrected), which indicates some degree of amblyopia. Intraocular pressure ranged from 9.3 to 22.1 mm Hg, with a mean of 13.17 ± 3.16 mm Hg. Axial lengths were measured from 21.79 to 26.22 mm, with a group mean of 23.76 ± 0.88 mm. Myopes had greater axial lengths than emmetropes ($p = 0.016$; not significant after Bonferroni correction), while hyperopes had shorter axial lengths than emmetropes ($p < 0.001$; significant after correction). Measurements comparing the three refractive groups for age, sex, BMI, axial length, intraocular pressure, and refractive error are summarized in Table 1.

Repeatability and thickness overview: The test–retest correlation coefficients for all subfield thickness values (0.91–0.95) indicated reliability of the results. The mean ± SD central foveal choroidal thickness for all participants was 245.0 ±

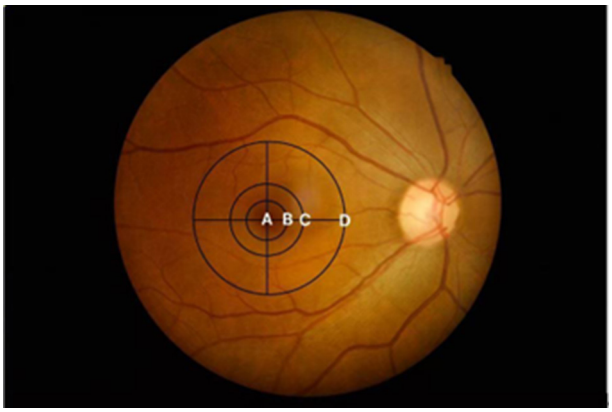


Figure 2. The Early Treatment of Diabetic Retinopathy Study grid is used for retinal and choroidal thickness measurements. The macula is divided into three concentric circles centered on the fovea with radii of 500 µm (inner), 1,000 µm (middle), and 2,000 µm (outer). The grid is further divided into four quadrants: superior, inferior, nasal, and temporal. Thickness measurements were obtained at specific locations along these meridians, as indicated by points A, B, C, and D, corresponding to the fovea and the three concentric radii.

Table 1. General characteristics of the 994 participants and comparison among refractive groups.

Parameter	Total (n=994)	Myopes (n=381)	Emmetropes (n=455)	Hyperopes (n=158)	P
Age,y	15.59±2.58	15.94±3.03	15.81±2.19	14.65±2.60	0.33
Male (%)	427 (42.59)	159 (41.73)	205 (45.05)	63 (39.87)	<0.01
BMI a, kg/m2	17.13±2.03	18.05±2.05	17.01±1.41	16.76±1.81	0.017
Axial length, mm	23.76±0.88	25.13±0.83	23.51±0.88	22.81±0.91	<0.01
Intraocular pressure, mmHg	13.17±3.16	13.20±3.11	13.43±2.93	13.06±3.22	0.13
Refractive error, D	−1.74±1.33	−3.29±1.13	−0.13±0.41	1.37±0.61	<0.01

a BMI: Body mass index, Mean ± SD, N (Proportion)

52 µm. We found the average choroidal thickness was the lowest in the myopes group (222 ± 60 µm), followed by the emmetropes group (255 ± 47 µm) and then the hyperopes group (272 ± 51 µm). The differences in choroidal thickness among the myopes, emmetropes, and hyperopes groups were statistically significant, $p < 0.01$. The differences in choroidal thickness remained statistically significant after Bonferroni correction. However, we did not find any statistically significant differences between refractive groups in central foveal total retinal thickness (Table 2). Furthermore, we did not find any statistically significant differences among refractive groups in GCL, INL, or ONL thicknesses within the first 500-µm radius of the parafoveal region (Table 3). Lastly, we did not find a statistically significant relationship of age to either central foveal choroidal thickness ($p = 0.39$) or retinal thickness ($p = 0.24$).

Topographic distribution of thickness: The thickest choroid in the first parafoveal circle was in the temporal quadrant, and the thickest retina was in the nasal quadrant. After adjusting for multiple comparisons, however, choroidal thickness differences were statistically significant between emmetropes and both myopes and hyperopes in the first parafoveal circle (adjusted $p < 0.05$), while the difference in retinal thickness was less pronounced, and many statistically significant differences were no longer significant after adjustment, particularly for smaller subfields.

In the second and third parafoveal circles, the thickest choroid was still in the temporal quadrant. Group differences for choroidal thickness for myopes, emmetropes, and hyperopes were also statistically significant across most quadrants (adjusted $p < 0.05$); differences between groups for retinal thickness were less robust in parafoveal circles 2 and 3: in some quadrants (temporal and superior), differences were statistically significant after correction. Please see Table 2 for full details.

Correlation analysis: The associations between various factors and central foveal choroidal thickness were analyzed. Central foveal choroidal thickness was positively correlated with refractive diopter values ($r = 0.65$, $p = 0.02$; significant after adjustment, Figure 3A) and negatively correlated with axial length ($r = −0.50$, $p < 0.01$; significant after adjustment, Figure 3B). No other factors showed statistically significant associations with central foveal choroidal thickness.

Central foveal retinal thickness was positively correlated with intraocular pressure ($r = 0.56$, $p = 0.02$; borderline significant after adjustment, Figure 3C) and refractive diopter values ($r = 0.27$, $p = 0.02$; significant after adjustment, Figure 3D). Positive correlations were also observed between central foveal retinal thickness and GCL thickness ($r = 0.31$, $p = 0.02$; significant after adjustment, Figure 3D), as well as INL thickness ($r = 0.39$, $p < 0.01$; borderline significant after adjustment, Figure 3D). After adjustment for multiple comparisons, the correlation between central foveal choroidal thickness and axial length remained statistically significant, whereas the correlation between central foveal retinal thickness and INL thickness was borderline significant.

Finally, no significant correlation was found between central foveal retinal and choroidal thickness within any refractive group (myopes, $p = 0.73$; emmetropes, $p = 0.59$; hyperopes, $p = 0.62$; Figure 3E).

DISCUSSION

The study demonstrated a relationship between refractive error and choroidal thickness, with greater refractive diopters associated with greater choroidal thickness. Choroidal

Table 2. Thickness of choroid and retina in myopes, emmetropes, and hyperopes.

Subfield	Layer	Total	Myopes	Emmetropes	Hyperopes	p
Central fovea	Choroid	245±52	222±60	255±47	272±51	<0.01
	Retina	229±22	231±23	227±21	230±22	0.29
Parafoveal radius 500µm nasal	Choroid	226±55	210±51	231±53	250±59	<0.01
	Retina	309±17	310±19	309±16	307±16	0.31
Parafoveal radius 500µm Temporal	Choroid	270±59	251±57	279±63	294±57	<0.01
	Retina	290±21	290±19	291±20	289±22	0.56
Parafoveal radius 500µm Superior	Choroid	251±50	231±50	255±49	276±51	<0.01
	Retina	297±19	296±17	293±20	301±20	0.07
Parafoveal radius 500µm Inferior	Choroid	257±51	239±50	255±48	270±52	<0.01
	Retina	300±14	297±11	301±17	301±13	0.34
Parafoveal radius 1000µm nasal	Choroid	192±49	166±47	193±50	211±50	<0.01
	Retina	296±22	288±19	293±23	307±22	0.03
Parafoveal radius 1000µm Temporal	Choroid	275±51	256±53	278±50	290±51	<0.01
	Retina	268±14	262±15	268±15	275±11	<0.01
Parafoveal radius 1000µm Superior	Choroid	252±50	230±52	255±47	270±50	<0.01
	Retina	270±12	265±13	271±10	277±12	<0.01
Parafoveal radius 1000µm Inferior	Choroid	242±51	230±51	243±50	255±50	<0.01
	Retina	273±11	263±10	272±11	282±13	<0.01
Parafoveal radius 2000µm nasal	Choroid	188±49	170±50	189±50	202±47	0.03
	Retina	284±18	284±17	284±19	285±18	0.39
Parafoveal radius 2000µm Temporal	Choroid	271±47	251±46	276±48	282±46	<0.01
	Retina	273±19	277±20	262±17	276±21	<0.01
Parafoveal radius 2000µm Superior	Choroid	248±46	222±45	253±46	266±48	<0.01
	Retina	275±21	266±21	273±22	285±21	<0.01
Parafoveal radius 2000µm Inferior	Choroid	244±49	232±49	247±47	250±52	<0.01
	Retina	266±16	257±19	263±17	275±13	0.03

Table 3. Thickness of ganglion cell layer (GCL), inner nuclear layer (INL), and outer nuclear layer (ONL) in myopes, emmetropes, and hyperopes.

Subfield	Layer	Total	Myopes	Emmetropes	Hyperopes	p
Fovea	GCL	16.55±3.42	16.57±4.11	16.55±2.31	16.55±2.68	0.28
	INL	18.25±3.65	18.21±3.59	18.23±3.65	18.27±3.71	0.36
	ONL	91.30±8.64	91.31±8.97	91.30±7.65	91.29±8.36	0.58
Parafoveal radius 500µm nasal	GCL	19.44±3.62	19.44±3.60	19.45±3.63	19.44±3.62	0.52
	INL	24.07±3.62	22.06±3.88	24.52±3.17	25.44±3.46	0.03
	ONL	90.83±8.62	90.47±8.61	90.85±8.55	91.03±8.74	0.27
Parafoveal radius 500µm Temporal	GCL	18.19±3.32	18.17±3.43	18.20±3.29	18.20±3.28	0.38
	INL	23.14±3.10	21.03±3.07	23.16±3.16	24.58±3.05	0.03
	ONL	89.71±8.83	89.69±9.01	89.68±8.71	89.72±8.53	0.47

GCL: ganglion cell layer; INL: inner nuclear layer; ONL: outer nuclear layer

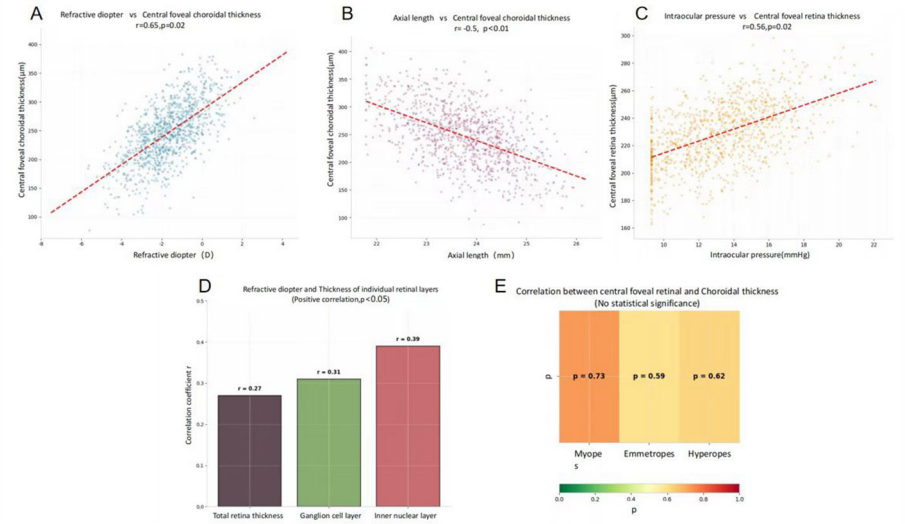


Figure 3. Correlation analyses of central foveal choroidal and retinal thickness with ocular parameters. **A**. Positive correlation between refractive diopter and central foveal choroidal thickness ($r = 0.65$, $p = 0.02$). **B**. Negative correlation between axial length and central foveal choroidal thickness ($r = -0.50$, $p < 0.01$). **C**. Positive correlation between intraocular pressure and central foveal retinal thickness ($r = 0.56$, $p = 0.02$). **D**. Positive correlations between refractive diopter and retinal layer thicknesses, including total retinal thickness ($r = 0.27$), ganglion cell layer ($r = 0.31$), and inner nuclear layer ($r = 0.39$; all $p < 0.05$). **E**. No significant correlation between central foveal retinal and choroidal thickness across refractive groups (myopes, $p = 0.73$; emmetropes, $p = 0.59$; hyperopes, $p = 0.62$).

thickness was significantly reduced in myopic participants, who had a thinner choroid than other reported measures, particularly in the 500-µm central parafoveal region, where total retinal thickness (GCL + INL + ONL) remained similar across refractive groups. Our findings suggest that choroidal thickness is more sensitive than retinal thickness to refractive variation in relation to refractive error and axial length [3,14,20-22].

While we did not make individual magnification corrections in the emmetropes group, previous validation studies show that these corrections only lead to small absolute changes (<3%) [23], without altering intergroup trends in refractive-related choroidal differences. In our study, central average foveal choroidal thickness was significantly related to both axial length and refractive error, while the central retinal thickness was associated with intraocular pressure. The remaining demographic factors of age, sex, and BMI were not associated with choroidal or retinal thickness, supporting literature that posits that axial length and refractive error are dependent on a sensitive choroid, while central retinal morphology may be intact [21,22,24-26].

Overall, the observed average central foveal choroidal thickness for all refractive groups in our study was lower than in prior studies of any refractive group, particularly in Caucasian study populations [14]. The average subfoveal choroidal thickness reported for Australian Caucasian individuals aged 10 to 15 years was 304 µm (myopes, SD 48 µm) and 360 µm (nonmyopes, SD 52 µm) [15]. In the sample we assessed, the averages were 222 µm (myopic), 255 µm (emmetropic), and 272 µm (hyperopic). The overlap of the standard deviations indicates average thickness may vary; however, the differences can likely be explained by some ethnic variations. Within any of the normal cohorts reported, ethnic differences were observed where Asian populations tended to have thinner choroids than Caucasian, Hispanic, and African American cohorts [16,17].

Importantly, when we compare to reports that outline average measurements from adolescents of Han Chinese descent, our cohort, being of Mongolian descent, experienced slightly thinner choroidal thickness (Han average subfoveal thickness ~280–310 µm) [18]. This indicates a likely regional or relationship association influenced by genetics or environment, albeit mildly. Further, the distribution of both choroidal and retinal thickness across quadrants appeared to be consistent with all previous population studies, where the temporal quadrant thickness was greater than the nasal quadrant thickness [19-22,24,25].

There does not appear to be any significant correlation between the central foveal retinal and choroidal thickness data presented here, which is in line with other studies [24-29]. As for retinal thickness, there are limited data, and correlations to refractive error are primarily observed in the parafoveal

areas (1,000 and 2,000 µm). Again, this supports the hypothesis that retinal thickness can vary widely in other areas as axial elongation occurs, while foveal cases retaining central retinal thickness data follow suit in stability, as confirmed in this study [28-33].

To summarize, we provide normative data from an adolescent cohort of Mongolian descent, who may be underrepresented in the literature regarding ocular imaging. This study examines our findings regarding differences among Han Chinese adolescents, comparisons with cohorts across the globe, and the influence of ethnic and geographical variations on ocular biometric configurations.

LIMITATIONS: While this research contributes significantly, there are limitations to be aware of. First, participants in this investigation were all from Ejin Banner, a Mongolian population that is relatively isolated, as there is little flux of people between populations and high ancestral continuity. Due to this, our findings would be less likely to generalize beyond an ethnic group and geography. Second, during the data collection period, we observed a statistically significant difference in BMI status between myopes and hyperopes. While previous studies demonstrated a relationship between body size and ocular parameters, given the conflicting interests, we cannot ascertain whether BMI influences refractive development in this cohort. Third, in this study, cycloplegia was used to accurately account for the measurements we made, but we could not entirely eradicate the possibility of residual accommodation influencing the results. Fourth, transverse magnification was not adjusted for emmetropic eyes, which were scanned using the default axial length setting (24 mm). Given that emmetropic axial length is typically close to this value, the impact is expected to be minimal. Fifth, while we present a discussion of ethnic comparisons using data collected from Han Chinese, we did not include a matched Han cohort. We took this opportunity to avoid Han becoming a strong cross-ethnic conclusion to significance. Finally, while SS-OCT provides high-resolution, deep-penetration choroidal imaging, our study design is based on a cross-sectional approach, while previous studies were longitudinal to confirm how changes in choroidal and retinal thickness coincided with refractive progression over a period.

CONCLUSIONS: In summary, myopic youth from Ejin had considerably thinner choroids than their emmetropic and hyperopic counterparts. Retinal thickness displayed slight variability, but the choroid was strongly correlated with refractive error and axial length, suggesting its possible role in refractive development. These normative data provide an informative reference/reference data point for future multiethnic and longitudinal ocular studies.

ACKNOWLEDGMENTS

The authors have no acknowledgments to report. Ethics approval and consent to participate: The study was approved by the Ethics Committee of the Taiyuan Aier Eye Hospital (Approval number: EYETYYY-20250206–3). All procedures were in accordance with the Declaration of Helsinki guidelines for clinical research. Written informed consent was obtained from all patients or family members where the patient was a minor. Clinical register number: Not Applicable. Consent for publication: Not Applicable. Conflict of Interest Statement: The authors declare that they have no conflict of interest. Funding Sources: This research did not receive any specific funding. Author Contributions: We declare that all the listed authors have participated actively in the study and all meet the requirements of authorship. YZ designed the study and wrote the paper, JL performed the study and managed the literature searches, and YG undertook the data acquisition and analysis. All authors reviewed the manuscript. Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

This is an open-access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits reusers to copy and distribute the material in any medium or format in unadapted form only, for noncommercial purposes only, and only so long as attribution is given to the creator. CC BY-NC-ND includes the following elements: BY: credit must be given to the creator. NC: Only noncommercial uses of the work are permitted. ND: No derivatives or adaptations of the work are permitted.

REFERENCES

1. Dolgin E. The myopia boom. Nature 2015; 519:276-8. [PMID: 25788077].

2. Summers JA. The choroid as a sclera growth regulator. Exp Eye Res 2013; 114:120-7. [PMID: 23528534].

3. Vincent SJ, Collins MJ, Read SA, Carney LG. Retinal and choroidal thickness in myopic anisometropia. Invest Ophthalmol Vis Sci 2013; 54:2445-56. [PMID: 23482471].

4. Wong AC, Chan CW, Hui SP. Relationship of gender, body mass index, and axial length with central retinal thickness using optical coherence tomography. Eye (Lond) 2005; 19:292-7. [PMID: 15258609].

5. Lim MC, Hoh ST, Foster PJ, Lim TH, Chew SJ, Seah SK, Aung T. Use of optical coherence tomography to assess variations in macular retinal thickness in myopia. Invest Ophthalmol Vis Sci 2005; 46:974-8. [PMID: 15728555].

6. Yamashita T, Tanaka M, Kii Y, Nakao K, Sakamoto T. Association between retinal thickness of 64 sectors in posterior pole determined by optical coherence tomography and axial length and body height. Invest Ophthalmol Vis Sci 2013; 54:7478-82. [PMID: 24168996].

7. Pang Y, Goodfellow GW, Allison C, Block S, Frantz KA. A prospective study of macular thickness in amblyopic children with unilateral high myopia. Invest Ophthalmol Vis Sci 2011; 52:2444-9. [PMID: 21071748].

8. Lam DS, Leung KS, Mohamed S, Chan WM, Palanivelu MS, Cheung CY, Li EY, Lai RY, Leung CK. Regional variations in the relationship between macular thickness measurements and myopia. Invest Ophthalmol Vis Sci 2007; 48:376-82. [PMID: 17197557].

9. Luo HD, Gazzard G, Fong A, Aung T, Hoh ST, Loon SC, Healey P, Tan DT, Wong TY, Saw SM. Myopia, axial length, and OCT characteristics of the macula in Singaporean children. Invest Ophthalmol Vis Sci 2006; 47:2773-81. [PMID: 16799013].

10. Jin P, Zou H, Zhu J, Xu X, Jin J, Chang TC, Lu L, Yuan H, Sun S, Yan B, He J, Wang M, He X. Choroidal and Retinal Thickness in Children With Different Refractive Status Measured by Swept-Source Optical Coherence Tomography. Am J Ophthalmol 2016; 168:164-76. [PMID: 27189931].

11. Wang M, Ma J, Pan L, Chen T, Wang HL, Wang YH, Wang WR, Pan XD, Qian YG, Zhang X, Zhong Y, Shan GL. Prevalence of and risk factors for refractive error: a cross-sectional study in Han and Mongolian adults aged 40-80 years in Inner Mongolia, China. Eye (Lond) 2019; 33:1722-32. [PMID: 31160702].

12. Kirik F, Ekinci C, Akbulut E, Bayraktar H, Ozdemir H. Regional analysis of segmented-macular structure in patients with myopic anisometropia. Int Ophthalmol 2021; 41:3713-26. [PMID: 34185229].

13. Unterhuber A, Povazay B, Hermann B, Sattmann H, Chavez-Pirson A, Drexler W. In vivo retinal optical coherence tomography at 1040 nm - enhanced penetration into the choroid. Opt Express 2005; 13:3252-8. [PMID: 19495226].

14. Read SA, Collins MJ, Vincent SJ, Alonso-Caneiro D. Choroidal thickness in myopic and nonmyopic children assessed with enhanced depth imaging optical coherence tomography. Invest Ophthalmol Vis Sci 2013; 54:7578-86. [PMID: 24176903].

15. Harb E, Hyman L, Gwiazda J, Marsh-Tootle W, Zhang Q, Hou W, Norton TT, Weise K, Dirkes K, Zangwill LM. COMET Study Group. Choroidal Thickness Profiles in Myopic Eyes of Young Adults in the Correction of Myopia Evaluation Trial Cohort. Am J Ophthalmol 2015; 160:62-71.e2. [PMID: 25896460].

16. Hirata M, Tsujikawa A, Matsumoto A, Hangai M, Ooto S, Yamashiro K, Akiba M, Yoshimura N. Macular choroidal thickness and volume in normal subjects measured by swept-source optical coherence tomography. Invest Ophthalmol Vis Sci 2011; 52:4971-8. [PMID: 21622704].

17. Duan F, Chen Z, Wang Z, Deng J, Yeo ACH, Yang A, Drobe B, Wong YL, Chen X. Longitudinal choroidal thickness changes among Chinese young adults with various refractive errors. Front Med (Lausanne) 2023; 10:1036087[PMID: 37035313].

18. Xie J, Ye L, Chen Q, Shi Y, Hu G, Yin Y, Zou H, Zhu J, Fan Y, He J, Xu X. Choroidal Thickness and Its Association With Age, Axial Length, and Refractive Error in Chinese Adults. Invest Ophthalmol Vis Sci 2022; 63:34-[PMID: 35703547].

19. Bafiq R, Mathew R, Pearce E, Abdel-Hey A, Richardson M, Bailey T, Sivaprasad S. Age, Sex, and Ethnic Variations in Inner and Outer Retinal and Choroidal Thickness on Spectral-Domain Optical Coherence Tomography. Am J Ophthalmol 2015; 160:1034-1043.e1. [PMID: 26210861].

20. Bidaut-Garnier M, Schwartz C, Puyraveau M, Montard M, Delbosc B, Saleh M. Choroidal thickness measurement in children using optical coherence tomography. Retina 2014; 34:768-74. [PMID: 24013259].

21. Ikuno Y, Tano Y. Retinal and choroidal biometry in highly myopic eyes with spectral-domain optical coherence tomography. Invest Ophthalmol Vis Sci 2009; 50:3876-80. [PMID: 19279309].

22. Nishida Y, Fujiwara T, Imamura Y, Lima LH, Kurosaka D, Spaide RF. Choroidal thickness and visual acuity in highly myopic eyes. Retina 2012; 32:1229-36. [PMID: 22466466].

23. Niyazmand H, Lingham G, Sanfilippo PG, Blaszkowska M, Franchina M, Yazar S, Alonso-Caneiro D, Mackey DA, Lee SS. The effect of transverse ocular magnification adjustment on macular thickness profile in different refractive errors in community-based adults. PLoS One 2022; 17:e0266909[PMID: 35417477].

24. Margolis R, Spaide RF. A pilot study of enhanced depth imaging optical coherence tomography of the choroid in normal eyes. Am J Ophthalmol 2009; 147:811-5. [PMID: 19232559].

25. Ho M, Liu DT, Chan VC, Lam DS. Choroidal thickness measurement in myopic eyes by enhanced depth optical coherence tomography. Ophthalmology 2013; 120:1909-14. [PMID: 23683921].

26. Ikuno Y, Kawaguchi K, Nouchi T, Yasuno Y. Choroidal thickness in healthy Japanese subjects. Invest Ophthalmol Vis Sci 2010; 51:2173-6. [PMID: 19892874].

27. Fujiwara T, Imamura Y, Margolis R, Slakter JS, Spaide RF. Enhanced depth imaging optical coherence tomography of the choroid in highly myopic eyes. Am J Ophthalmol 2009; 148:445-50. [PMID: 19541286].

28. Shao L, Xu L, Wei WB, Chen CX, Du KF, Li XP, Yang M, Wang YX, You QS, Jonas JB. Visual acuity and subfoveal choroidal thickness: the Beijing Eye Study. Am J Ophthalmol 2014; 158:702-709.e1. [PMID: 24878308].

29. Flores-Moreno I, Ruiz-Medrano J, Duker JS, Ruiz-Moreno JM. The relationship between retinal and choroidal thickness and visual acuity in highly myopic eyes. Br J Ophthalmol 2013; 97:1010-3. [PMID: 23766433].

30. Al-Haddad C, El Chaar L, Antonios R, El-Dairi M, Noureddin B. Interocular symmetry in macular choroidal thickness in children. J Ophthalmol 2014; 2014:472391[PMID: 25525509].

31. Karahan E, Zengin MO, Tuncer I. Correlation of choroidal thickness with outer and inner retinal layers. Ophthalmic Surg Lasers Imaging Retina 2013; 44:544-8. [PMID: 24144175].

32. Ooto S, Hangai M, Tomidokoro A, Saito H, Araie M, Otani T, Kishi S, Matsushita K, Maeda N, Shirakashi M, Abe H, Ohkubo S, Sugiyama K, Iwase A, Yoshimura N. Effects of age, sex, and axial length on the three-dimensional profile of normal macular layer structures. Invest Ophthalmol Vis Sci 2011; 52:8769-79. [PMID: 21989721].

33. Ooto S, Hangai M, Sakamoto A, Tomidokoro A, Araie M, Otani T, Kishi S, Matsushita K, Maeda N, Shirakashi M, Abe H, Takeda H, Sugiyama K, Saito H, Iwase A, Yoshimura N. Three-dimensional profile of macular retinal thickness in normal Japanese eyes. Invest Ophthalmol Vis Sci 2010; 51:465-73. [PMID: 19696169].

Articles are provided courtesy of Emory University and The Abraham J. & Phyllis Katz Foundation. The print version of this article was created on 12 August 2026. This reflects all typographical corrections and errata to the article through that date. Details of any changes may be found in the online version of the article.