Evaluation of choroidal thickness in Malay children with myopia

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ABSTRACT

Introduction: This study aims to evaluate the choroidal thickness and its correlation with age, spherical equivalent, and axial length in Malay children with myopia, addressing the limited data available on this topic in Southeast Asia.

Material and Methods: A cross-sectional, hospital-based study was conducted from 2022 to 2024 at Hospital Shah Alam and Hospital Pakar Universiti Sains Malaysia. A total of 109 Malay children aged 7-17 years participated, including 88 with myopia and 21 with emmetropia. Each participant underwent a comprehensive ocular examination, including non-cycloplegic refraction and axial length measurement. Choroidal thickness was assessed using Cirrus SD-optical coherence tomography, with one eye from each subject randomly selected for analysis.

Results: The mean subfoveal choroidal thickness was significantly thinner in myopic children (284.91 µm) compared to emmetropic children (347.62 µm) (p<0.001). Additionally, choroidal thickness varied significantly with the degree of myopia: mild myopia had a mean subfoveal thickness of 319.69 µm, moderate myopia 290.04 µm, and high myopia 225.72 µm, with high myopia showing the thinnest choroid (p<0.001). A significant negative correlation was observed between axial length and subfoveal choroidal thickness, while a positive correlation was found between spherical equivalent and choroidal thickness. No significant correlation was identified between age and subfoveal choroidal thickness.

Conclusion: Malay children with myopia exhibit a thinner mean choroidal layer compared to their emmetropic peers, with the thinnest choroid observed in cases of high myopia. This indicates that thinning of the choroidal vasculature occurs with the increase in axial length and worsening severity of myopia.

KEYWORDS:
choroidal thickness, myopia, axial length, spherical equivalent, children

INTRODUCTION

Myopia has become an alarming epidemic due to its rapidly increasing prevalence over the past three decades, now representing a significant public health challenge. The condition imposes a substantial burden, both in terms of the need for optical correction and the management of visual impairment associated with pathological myopia. Uncorrected myopia negatively impacts school performance, employability, and overall quality of life. Globally, myopia affects approximately 28.3% of the population, with 4.0% classified as high myopia.[1] The prevalence of myopia among children varies across continents, ranging from 0.7% in Saudi Arabia and 1.4% in South America to 7.5% in India and 36.2% in Hong Kong.[2-5] Population-based studies have reported an exceptionally high prevalence of myopia among East Asian children, with the highest rates observed in Taiwan (85.1%), followed by China (80.7% in Beijing) and South Korea (78.8%).[6,7] The highest prevalence of myopia among schoolchildren has been documented in Southeast Asian countries and China, affecting approximately 13.9% of Malay children in Malaysia.[8]

The choroid plays a crucial role in supplying nutrients and growth factors to the retina, and it is likely also involved in predicting biomarkers for axial length changes that correlate with myopia progression.[9] It is believed that before myopia develops, the rapid elongation of the eyeball causes choroidal thinning. This thinning may be associated with reduced choroidal blood flow, potentially leading to scleral ischemia and hypoxia. As a result, the sclera becomes thinner and weaker, which in turn leads to excessive elongation of the eyeball and accelerates the onset of myopia.[10] Thinner choroidal thickness has been reported to correlate with poorer best-corrected visual acuity and associated with various myopic pathological lesions, such as choroidal neovascularization, lacquer cracks, staphyloma, and chorioretinal atrophy.[11]

Choroidal thickness has been shown to be thinner in myopic compared to emmetropic and hyperopic children and adults.[12-16] However, the available studies among children primarily involved very young age with only mild to moderate degrees of myopia. There is limited research focusing on older children and those with a high degree of myopia. The aim of this study was to compare the mean choroidal thickness between emmetropic and myopic children across a wide range of refractive errors and to explore its correlation with age, axial length, and spherical equivalent.

This article was accepted: 27 February 2025
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MATERIALS AND METHODS

This cross-sectional study was conducted at the Ophthalmology Clinics of Hospital Shah Alam and Hospital Pakar Universiti Sains Malaysia, Malaysia, from June 2022 to May 2024. Healthy children aged seven to 17 years with myopia and emmetropia were recruited. The study was conducted in accordance with the Declaration of Helsinki for Human Research and was approved by the Human Research Ethics Committee of Universiti Sains Malaysia (USM/JEPeM/22030159) and the Medical Research and Ethics Committee, Ministry of Health Malaysia (NMRR ID-22-01226-MS8). Written consent and assent were obtained from the subjects and their parents.

Children aged seven to 17 years with myopia who attended the Myopia Clinics at both institutions were recruited for the study. The inclusion criteria included full-term myopic children. Age-matched healthy children were prospectively enrolled as controls. Children with any ocular pathology other than myopia, such as glaucoma, corneal scars, optic neuropathy, or those who had undergone ocular surgery or experienced trauma, were excluded. Additionally, patients with myopic maculopathy or chorioretinal scars were also excluded.

Demographic data, including age, gender, education level, and household income, were collected. Comprehensive ophthalmic evaluations were conducted, which included assessments of visual acuity, non-cycloplegic manifest refraction, anterior segment examination, intraocular pressure measurement, and fundus examination. Axial length was measured using the IOL Master (Carl Zeiss Meditec Inc.), a partial coherence interferometer.

The spherical equivalent (SE) was calculated as the sum of the spherical power plus half of the cylindrical power. Myopia was defined as a spherical equivalent refraction worse than -0.5 diopters (D). Participants were categorized into four groups:

- Emmetropia: SE between +1.00D and >-0.50D
- Mild Myopia: SE between -0.50D and -3.00D
- Moderate Myopia: SE between <-3.00D and -6.00D
- High Myopia: SE worse than <-6.00D[1,8]

Spectral-domain optical coherence tomography (SD-OCT) was used to capture high-definition (HD) images of the choroid, utilizing the HD radial mode of the Cirrus HD-OCT instrument (Carl Zeiss Meditec Inc.) to enhance choroidal depth imaging. Choroidal thickness was measured from the outer border of the retinal pigment epithelium to the inner border of the choroidoscleral interface. Measurements were taken across multiple locations: temporal, superotemporal, superior, superonasal, nasal, inferonasal, inferior, and inferotemporal. These measurements were analyzed in three zones:

- Central Foveal Zone: From the foveal center to a 1 mm diameter
- Inner Macular Zone: From the inner 1 mm diameter to the outer 3 mm diameter
- Outer Macular Zone: From the inner 3 mm diameter to the outer 6 mm diameter (Fig. 1).

To minimize the effects of diurnal variation, measurements were conducted between 9:00 a.m. and 1:00 p.m. Only OCT images with a signal strength of six or higher were included in the analysis. Images were centered on the fovea, and only those with clear visualization extending to the choroidoscleral interface were accepted. Choroidal layer measurement was done once manually by a single trained observer. The observer underwent formal training for segmentation of the choroidal layer and measurement of the choroidal thickness.

Data entry and statistical analysis were performed using IBM SPSS Statistics, version 27.0 (IBM Corp., Armonk, NY, USA). Socio-demographic details and clinical characteristics of the patients were analyzed using descriptive statistics, including frequencies, percentages, means, standard deviations, and ranges. Although data were acquired from both eyes, only one eye was randomly selected from each subject for statistical analysis.

An independent t-test was employed to compare the mean choroidal thickness between myopic and emmetropic Malay children. To examine differences in choroidal thickness across mild, moderate, and high myopia groups, a one-way analysis of variance (ANOVA) was performed. The correlations between mean choroidal thickness and variables such as age, spherical equivalent, and axial length were evaluated using bivariate analyses, including Pearson's and Spearman's correlation tests. Statistical significance was determined at the 5% level ($p<0.05$) for all analyses.

RESULTS

A total of 109 subjects were enrolled in this study. 88 Malay children with myopia and 21 age and gender-matched emmetropic Malay children were included. The spherical equivalent of the children ranged from -15.25 D to +1.00 D. The axial length ranged from 21.73 to 30.19 mm. Table I provides a summary of the demographic and clinical comparisons between the myopia and emmetropia groups. Statistically significant differences were observed between the two groups in terms of mean spherical equivalent and axial length ($p<0.001$).

The subfoveal choroidal thickness of all studied children ranged from 109 to 423 µm with a mean of 296.99 (70.00) µm. The subfoveal choroidal thickness in the myopia group was significantly thinner than the emmetropia group as demonstrated in Table I ($p<0.001$).

Table II presents the comparisons based on the severity of myopia. Patients with high myopia had the thinnest mean choroidal thickness in all zones, followed by those with moderate and mild myopia. A gradual decrease in mean subfoveal choroidal thickness was observed as the degree of myopia increased. Post hoc analysis (Bonferroni) demonstrated in Table III showed a significant difference between mild and high myopia groups in all macula zones. Moderate to high groups showed statistically significant differences in most of the macula zones except in temporal, superior and inferior outer macula zones. However, in mild to moderate group analysis, significant differences were

Table I: Demographic and clinical characteristics between myope and emmetrope (n = 109)

Characteristic	Myopia (n = 88)	Emmetropia (n = 21)	p-value
Age (year), Median (IQR)	10 (4)	9 (4)	[a]0.420
Gender, n (%)			
Male	45 (51.1)	11 (52.4)	[b]0.918
Female	43 (48.9)	10 (47.6)	
Spherical equivalent (diopters), Mean (SD)	-4.76 (3.56)	+0.14 (0.40)	[c]<0.001
Axial length (mm), Mean (SD)	25.02 (1.73)	22.77 (0.60)	[c]<0.001
Subfoveal choroidal thickness (μm), Mean (SD)	284.91 (70.88)	347.62 (35.81)	[c]<0.001

IQR = interquartile range, SD = standard deviation,
[a]Mann-Whitney U test
[b]Pearson Chi-squared test
[c]Independent t-test

Table II: Comparison of choroidal thickness between mild, moderate and high myopia (n = 88)

Zone (μm)	Mild myopia (n = 39) Mean (SD)	Moderate myopia (n = 24) Mean (SD)	High myopia (n = 25) Mean (SD)	F-statistic (df)	*p-value
Subfovea	319.69 (53.77)	290.04 (49.68)	225.72 (75.02)	19.07 (2)	<0.001
Nasal Fovea	297.31 (56.83)	267.08 (46.70)	204.80 (71.56)	18.82 (2)	<0.001
Temporal Fovea	310.44 (53.96)	283.33 (51.76)	217.44 (68.44)	19.89 (2)	<0.001
Superior Fovea	299.41 (53.50)	275.17 (47.18)	205.44 (67.17)	21.74 (2)	<0.001
Inferior Fovea	297.90 (51.59)	273.83 (46.58)	202.56 (69.68)	22.47 (2)	<0.001
Nasal Inner Macula	262.44 (63.24)	224.67 (48.34)	159.76 (61.07)	23.13 (2)	<0.001
Temporal Inner Macula	299.21 (55.14)	263.25 (49.91)	219.68 (58.49)	16.13 (2)	<0.001
Superior Inner Macula	280.77 (46.98)	251.96 (44.79)	200.76 (65.58)	17.79 (2)	<0.001
Inferior Inner Macula	277.13 (48.79)	251.50 (45.89)	195.24 (77.41)	15.46 (2)	<0.001
Nasal Outer Macula	185.05 (53.99)	146.88 (34.69)	97.72 (43.50)	26.93 (2)	<0.001
Temporal Outer Macula	257.77 (51.84)	221.83 (53.23)	205.40 (58.59)	7.82 (2)	<0.001
Superior Outer Macula	245.21 (46.96)	201.38 (64.56)	193.40 (68.38)	7.37 (2)	0.001
Inferior Outer Macula	236.33 (44.46)	199.29 (54.21)	179.24 (69.18)	8.82 (2)	<0.001

*One-way ANOVA test followed by post-hoc multiple comparison test Bonferroni procedure applied

Table III: Comparison of choroidal thickness between mild, moderate and high myopia (n = 88)

Zone (μm)	Mild vs moderate myopia		Mild vs high myopia		Moderate vs high myopia	
	MD (95% CI)	*p-value	MD (95% CI)	*p-value	MD (95% CI)	*p-value
Subfovea	29.65 (-8.10, 67.40)	0.175	93.97 (56.69, 131.25)	< 0.001	64.32 (22.74, 106.90)	0.001
Nasal Fovea	30.22 (-7.15, 67.60)	0.155	92.51 (55.60, 129.42)	< 0.001	62.28 (21.11, 103.45)	0.001
Temporal Fovea	27.10 (-9.57, 63.77)	0.224	93.00 (56.78, 129.21)	< 0.001	65.89 (25.50, 106.29)	<0.001
Superior Fovea	24.24 (-11.35, 59.84)	0.300	93.97 (58.82, 129.12)	< 0.001	69.73 (30.52, 108.93)	<0.001
Inferior Fovea	24.06 (-11.49, 59.62)	0.306	93.34 (60.23, 130.45)	< 0.001	71.27 (32.11, 110.43)	<0.001
Nasal Inner Macula	37.77 (0.43, 75.11)	0.047	102.68 (65.80, 139.55)	< 0.001	64.91 (23.77, 106.04)	0.001
Temporal Inner Macula	35.96 (1.25, 70.66)	0.040	79.53 (45.26, 113.79)	< 0.001	43.57 (5.35, 81.79)	0.020
Superior Inner Macula	28.81 (-4.38, 62.00)	0.111	80.01 (47.24, 112.78)	< 0.001	51.20 (14.64, 87.75)	0.003
Inferior Inner Macula	25.63 (-10.91, 62.17)	0.271	81.89 (45.80, 117.97)	< 0.001	56.26 (16.01, 96.51)	0.003
Nasal Outer Macula	38.18 (8.71, 67.64)	0.006	87.33 (58.23, 116.43)	< 0.001	49.16 (16.70, 81.61)	0.001
Temporal Outer Macula	35.94 (1.60, 70.28)	0.037	52.37 (18.46, 86.28)	0.001	16.43 (-21.39, 54.26)	0.875
Superior Outer Macula	43.83 (6.70, 80.96)	0.015	51.81 (15.14, 88.47)	0.003	7.98 (-32.92, 48.87)	1.000
Inferior Outer Macula	37.04 (2.16, 71.92)	0.034	57.09 (22.65, 91.54)	< 0.001	20.05 (-18.37, 58.47)	0.618

*One-way ANOVA test with post hoc Bonforreni correction.

observed in the nasal and temporal inner and all outer macula zones.

The mean subfoveal choroidal thickness demonstrated a significant positive correlation with spherical equivalent (r=0.67, p<0.001) and negative correlation with axial length (r=-0.63, p< 0.001). However, no significant correlation was found between mean subfoveal choroidal thickness and age (r=0.06).

DISCUSSION

Our study exhibited thinner subfoveal choroid among myopic children compared to emmetropic children. Myopic children also had thinner choroids in most areas of the posterior pole. In our study, the mean subfoveal choroidal thickness in the myopic children aged 7 to 17 years old was 284.91 (70.88) μm which is similar to the study done in Nanchang, Jiangxi, China which recruited myopic Chinese children aged 6 to 16 years old with mean subfoveal

Table IV: Comparison of choroidal thickness among studies

Author/year	Read et al. 2013[9]	Jin et al. 2016[13]	Lee et al. 2017[20]	Fontaine et al. 2017[22]	Qi et al. 2018[19]	Xiong et al. 2020[15]	Present study. 2025
Country	Australia	China	Korea	France	China	China	Malaysia
Age	10 – 15	7 – 13	6 – 12	2 – 16	8 – 11	6 – 16	7 – 17
Number of subjects	104	276	89	115	120	402	109
Myopia	41	86	28	35	120	402	88
Emmetropia	63	91	39	80			21
Hyperopia		99	22				
SFCT in myope (μm), Mean (SD)	303 (79)	227 (61)	267.46 (63.14)	268.55 (86.95)	252.80 (46.95)	294.16 (77.59)	284.91 (70.88)
SFCT in emmetrope (μm), Mean (SD)	359 (77)	253 (58)	301.97 (55.93)	328.85 (33.90)			347.62 (35.81)
Axial length in myope (mm), Mean (SD)	24.46 (1.07)	24.17 (0.96)	24.32 (0.70)	24.5	24.54 (0.79)	24.67 (0.93)	25.02 (1.73)
Axial length in emmetrope (mm), Mean (SD)	23.26 (0.64)	23.25 (0.72)	23.16 (0.77)	22.1			22.77 (0.60)

SFCT = subfoveal choroidal thickness, SD = standard deviation

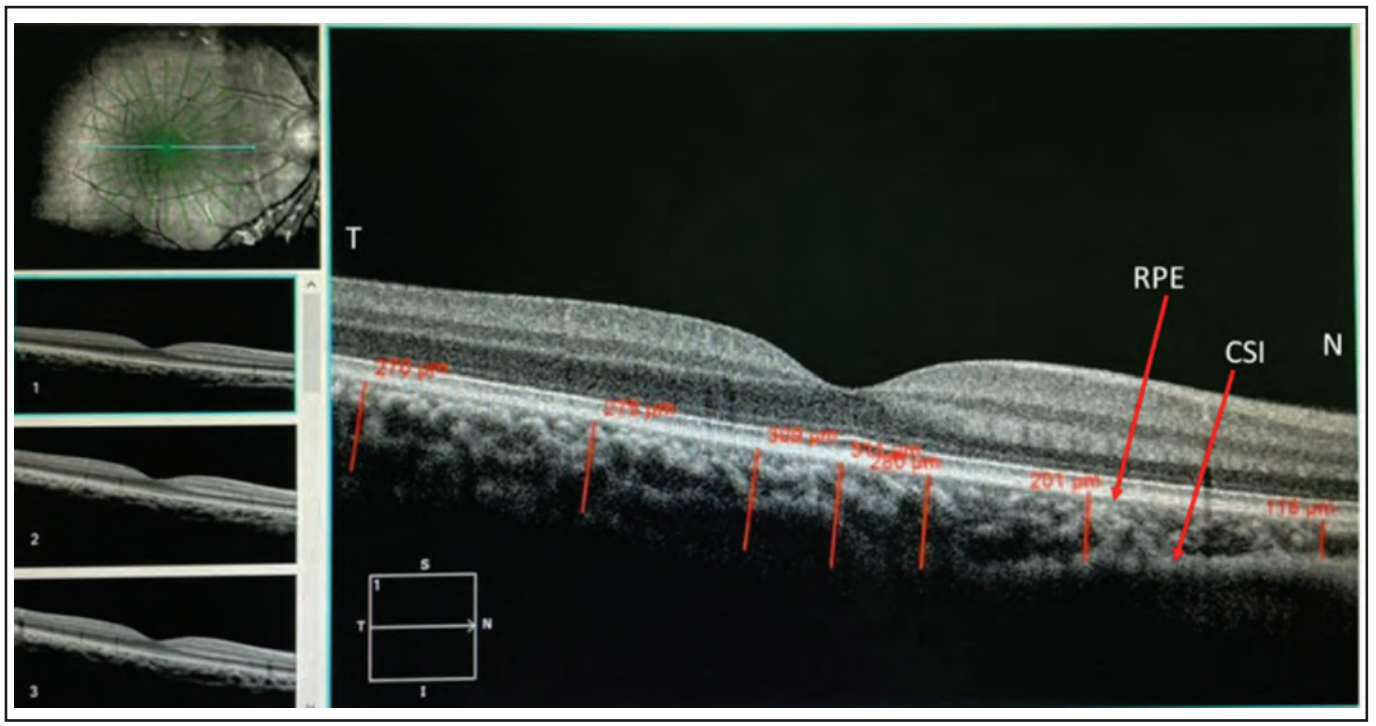

Fig. 1: Overview of OCT scanning protocol and analysis procedure used in the study. Each subject had 12 HD radial OCT scan line images captured centred on the fovea

choroidal thickness was 294.[16] (77.59) μm.[15] The mean subfoveal choroidal thickness in myopic Malay children in our study was consistent with the range of reported choroidal thickness among the Chinese myopic children as illustrated in Table IV (227.00 (62.00) to 294.16 (77.59) μm).[13,15,17] Our findings agree with other myopic adult and children studies that myopia has been associated with thinner choroid.[9,14,15,18] It is hypothesized that rapid axial elongation before myopia onset causes choroidal layer thinning leading to decreased choroidal blood flow and subsequently scleral ischaemia and hypoxia, as well as scleral thinning and weakening, which would lead to excessive axial elongation and development of myopia.[9]

Our population showed significant differences in choroidal thickness among different degrees of refractive error. We found that the high myopia group has marked thinning of the choroidal layer compared to mild and moderate myopia groups. The difference in mean choroidal thickness between the moderate and high myopia group was twice greater than the difference between the moderate and mild myopia group. This finding was similar to other studies in China, Indonesia, Egypt and Spain.[19-22] Populations with a high prevalence of myopia tended to have thinner choroid.[10,13,23] Accelerated growing eyeball due to myopia leads to choroidal vascular and connective tissue remodeling resulting in loss of choroidal volume and diminished blood supply.[9,16,24] This indicated that choroidal thinning is a feature observed in

myopia progression. Our observation is supported by histological study of the highly myopic eyes showed defect in the macula Bruch membrane with the absence of choriocapillaries except very few large choroidal vessels and almost complete absence of photoreceptors.[25] These findings could be due to excessive stretching of the posterior segment. Thus, the high myopia group is at very high risk of developing choroidal neovascularization resulting in poor visual function.

Our study observed the thickest choroid at the subfoveal zone in all degrees of refractive error. The choroids progressively thinner towards the periphery with the thinnest choroid observed at the nasal outer macula zone in both myopic and emmetropic eyes. Our findings were comparable with a study among myopic Australian children aged ten to fifteen where the choroidal layer was thickest in the central macula and thinnest nasally.[11] Studies of choroidal thickness in normal eyes without refractive error also found a topographic variation of choroidal thickness at the posterior pole with the thickest choroid at the subfoveal zone.[22] Few studies, meanwhile, have documented the thickest choroidal layer in the temporal zone of myopic children and adults.[13,17,20,26,27] This could be due to the elongation of the eyeball resulting in the shifting of the choroids temporally. However, we believe that growing choroids in children may not have the same pattern as adults, as observed in our populations.

We also found a greater difference between central and nasal macula choroidal thickness between eyes with high myopia and mild myopia compared to differences in more temporal locations. This showed that the degree of choroidal thinning from centre to the peripheral nasal macula was greater in high myopic eyes. The thin nasal choroidal layer observed in many studies is also associated with the severity of myopic maculopathy which can be a devastating myopia complication.[20]

Many studies concluded that choroidal thickness increases in growing children without refractive error until it reaches a peak in adolescence.[9,27,28] However, our study found no significant correlation between age and choroidal thickness, similar to a study done in Daegu, Korea involving children aged six to twelve years.[18] On the contrary, studies done in Shanghai, China found a decrease in choroidal thickness with age.[13,14] However, their studies involved younger children aged six to nine. It was reported that there was a negative correlation between choroidal thickness and age in Asian children which could be due to the very high prevalence of myopia in their population but a positive correlation was noted among white children.[29] We postulated that changes in choroidal thickness with myopia development in our study population could not be due to passive stretching alone. The high metabolic demand of the growing eyes could explain the increase in choroidal thickness with age.[27] Thus, our study observed the presence of balance between changes in choroidal thickness due to ocular growth and axial elongation contributing to myopia development.

A positive correlation between choroidal thickness and spherical equivalence has been well established in previous adult and child studies.[9,14,28,30] We observed that the choroidal layer became progressively thinner in myopia as the spherical equivalent became more negative. Our findings consistent with experimental myopia induced in animal studies showed rapid thinning of choroid followed by an increase in eye growth.[31] Visual deprivation and the addition of a plus lens which makes the animal eyes myopic caused modulation of the choroidal layer in order to bring the image to focus on the retina.[31] Thus, optical factors such as chronic hyperopic defocus associated with a lag of accommodation during near tasks could contribute to thinner choroid in myopic children.

We reported a significant negative correlation between choroidal thickness and axial length. Our findings agree with most previous studies that a significant negative correlation exists between axial length and choroidal thickness.[5,26] A large myopia study in China found that the rate of change in refraction and axial elongation accelerated before the onset of myopia and slowed gradually after myopia was established.[32] A study done in two to 16 years old France children showed thinning of subfoveal choroid with myopia progression and an increase in subfoveal choroidal thickness in nonmyopic children.[20] Axial length increases rapidly in early childhood as the child grows. It is possible that due to growing eyeball causes passive stretching of the outer coats of the eyeball which leads to thinner choroid. However, the degree of choroidal thinning could be higher than the thinning predicted based on a passive stretch of the choroid from the axial elongation of myopia.[9]

The first limitation of our study is the cross-sectional design did not allow us to attribute causation to the association between choroidal thinning to myopia onset and progression. Individual variations in choroidal thickness are common, and choroidal thickness alone may not fully explain the complexities of myopia development in children. Choroidal thinning in our myopic children may not be the consequence of myopia but rather its onset of development and progression. We suggest that a longitudinal study to monitor choroidal thickness alongside other parameters may provide a more comprehensive understanding of myopia progression and its potential impact on ocular health.

Cycloplegic agents such as tropicamide, phenylephrine and cyclopentolate 1% cause significant decrease in the subvofeal choroidal thickness.[33,34] Use of anti-muscarinic agent such as atropine caused significant increase in the choroidal layer of healthy children even without significant change in axial length.[35] Thus, non-cycloplegic refraction was preferred to avoid confounding effect of cycloplegic agents on the choroidal layer. However, lack of cycloplegia may influence reliability of refraction in children thus, a limitation in our study. Another limitation of the present study is that the measurement of the choroidal thickness was performed manually. However, other studies done in adults and children with myopia using Cirrus OCT with manual measurement of the choroidal layer produce high reliability and reproducibility.[14-16,36] Automated software will be required for more objective evaluation.

CONCLUSION

This study found new data on variations of choroidal thickness among myopic and emmetropic Malay children. The choroidal layer in myopic Malay children was thinner than in the emmetropic group with the greatest thinning observed in the high myopia group. The thinning of the choroidal layer occurs with the worsening severity of myopia and the increase in axial length. The increasing prevalence of high myopia in our population is alarming and warrants early detection of myopia development and control. Thus, myopic children need regular and close follow-ups for axial length, choroidal imaging and various strategies to control myopia progression.

ACKNOWLEDGEMENT

We would like to thank all the faculty members of the Department of Ophthalmology at Hospital Shah Alam and Hospital Pakar Universiti Sains Malaysia for extending their help and support in our data collection.

CONFLICT OF INTEREST

The authors declare they have no conflicts of interest.

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