MYOPIA AND RETINAL BIOMETRY ANALYSIS: A PILOT STUDY AMONG MALAY POPULATION IN SELANGOR

Zerrouki Hocine Elmehdi[1*] Mohd Zaki Awg Isa[2] Mohammad Mizanur Rahman[3]

1. School of Graduate Studies, Management and Science, Malaysia*
MSc Email: mehdihocine55@gmail.com
2. Centre of Excellence for Vision and Eyecare, Management and Science, Malaysia.
Department of Optometry and Vision Science, Faculty of Health and Life Sciences, Management & Science University, University Drive, Off Persiaran Olahraga, Section 13, Shah Alam 40100, Selangor, Malaysia
PhD Email: m_zaki@msu.edu.my
3. Centre of Excellence for Vision and Eyecare, Management and Science, Malaysia
PhD Email: mohd_mizanur@msu.edu.my

Corresponding Author: **Zerrouki Hocine Elmehdi**, MSc Email: mehdihocine55@gmail.com

ABSTRACT
Investigation of myopia's pathophysiology becoming a focus to prevent its complications. It provides vital information for early intervention to reduce the potential for visual impairment and blindness. This study aimed to analyse and determine the correlation of retinal biometrics with myopia. A healthy Malay participant with myopia aged 18- to 39-year-old were recruited, and had a comprehensive eye examination at the MSU Eye Centre. The axial length (AL) measurement was done using The ZEISS IOL Master 700, and fundus imaging was done using the ZEISS CIRRUS HD-OCT 5000. A control participant was also recruited. 41 participants (male: 17 and female: 24) were enrolled. The mean age of the myopic groups with mild, moderate, and high myopia was 27.33 ± 5.75, 26.18 ± 4.97, and 30.25 ± 7.27, and control group was 26.09 mm ± 4.71 respectively. The Retinal Nerve Fibre Layer (RNFL) showed a significant thinning at the superior quadrant as the SE increased ($p=0.03$). There was a significant correlation between the AL, SE and the RNFL thinning at all quadrants ($p <0.05$). The study also revealed that myopic eyes had a meaningful RNFL thinning at the superior quadrant layer as AL increased**.** This study shows that increases in AL and SE significantly reduce the RNFL thickness at superior and inferior quadrants. It is recommended that fundus imaging and AL assessment be included in comprehensive eye examinations for patients with myopia, thus, it will help to reduce myopia complications as well as the prevalence of blindness in the community.

Keywords: myopia, myopia management, RNFL, retinal thickness, fundus imaging,

Introduction

Myopia is expected to affect around 5 billion people globally by 2050, representing an alarming 50% increase in prevalence from the current estimated of 30%. It becomes a major global public health concern affecting between 85% and 90% of young adults over the past few decades (Chen-Wei Pan et al.,2013; Holden et al., 2016; Madhavan et al., 2018). In Asia, myopia especially high

myopia, is one of the most prevalent forms of visual impairment and eye health problems (Gyan Prakash et al., 2021; Yi Zha et al., 2017).

In Malaysia, it was estimated that 42% of Chinese and 15% of Malay people were myopic have reached a "concerning" level among Malaysians (Omar R et al., 2022). The risks of developing certain eye illnesses such glaucoma, retinal detachment, choroidal neovascularization, and other visual impairment conditions may rise as myopia progresses. According to (Yi Zha et al.,2017), the myopic eyeball enlarges due to an increase in axial length and straining beyond normal proportions, which may cause the retina to thin. The strong correlation between glaucoma and myopia is already widely acknowledged. Those with myopias have a two- to three-fold increased chance of acquiring glaucoma compared to those without (Ahnul Ha et al., 2022).

Histological investigations reveal that in myopic eyes, the retina atrophies and degenerates, especially at the posterior pole., and these changes are associated with a high frequency of macular abnormalities (Zhennan Zhao et al., 2015). The macular thickness was significantly decreased in myopic eyes compared to emmetropic eyes. However, the central foveal thickness was significantly high in high myopes. The analysis of macular thickness in the evaluation of macular diseases or glaucoma should be considered based on refractive errors (Choudhary, Arathi et al., 2021). Therefore, this study aimed to analyse correlation between retinal biometrics with degree of myopia

Method

A cross-sectional study was carried out on a Malay population, aged between 18 to 39 years old, who came to MSU Medical Center and MSU Eye Center for thorough eye exams. Participants with varying degrees of myopia severity, those without refractive problems (emmetropic patients), individuals free of systemic disorders, and individuals with no prior history of ocular injury were all included in the study. Participants who were younger than 18 or older than 39, as well as those who have hyperopia, a cataract, or other eye conditions as retinal and optic nerve complications or diseases, were not allowed to participate. The eyes in the myopic group had an axial length of less than 24 mm and a SE ranging from -0.75 to -6.00D above. Axial length (AL<24 mm) of the control eyes showed refractive error ranging from +0.75 to -0.75D. All patients were subjected to Medical & ophthalmic history taking received a comprehensive eye examination, which included best-corrected visual acuity (BCVA) with result recorded in LogMAR 0.00, or 20/20. The participants' refractive error was objectively measured using an autorefractor Topcon KR-800; their distance visual acuity at normal and low contrast was assessed using the Bailey-Lovie Chart; their intraocular pressure (IOP) was measured using non-contact tonometry (Huvitz HNT-7000); and their axial length was measured using an IOL Master 700 (Carl Zeiss, Jena, Germany). The ZEISS CIRRUS (HD-OCT 5000) was used to determine the thickness of the macula and the retinal nerve fiber layer (RNFL).

The Management and Science University Ethics Committee accepted the study, and it was conducted in accordance with the principles of the Declaration of Helsinki.

All responses were aware of the need to complete a permission form outlining the procedures and techniques of our study to the participants, as well as the goals of our study while protecting the candidates' rights during the examination. In this kind of study, participants are chosen according

to specific variables of interest; in our case, the population of interest was Myopic Malay adults. This kind of observational study helped us to identify traits present in a community, draw conclusions about potential correlations between variables, and collect initial data to facilitate more investigation and research

Statistical Analysis

Descriptive analysis was performed for all variables. The ocular parameters in the myopic and control groups were compared using one-way ANOVA. Statistical significance was defined as a p-value ≤ 0.05. All data were analyzed using SPSS version 27. Values for measurements were presented as mean ± standard deviation (SD).

OCT Imaging and IOL value

Myopic group:

Fig 1A:

(RNFL quadrants: superior, inferior, nasal and temporal)

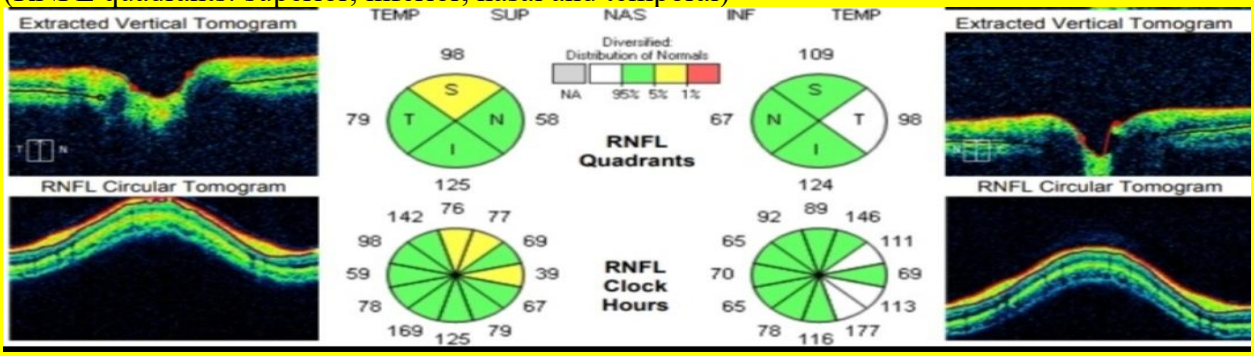


Fig 1B:

RNFL thickness

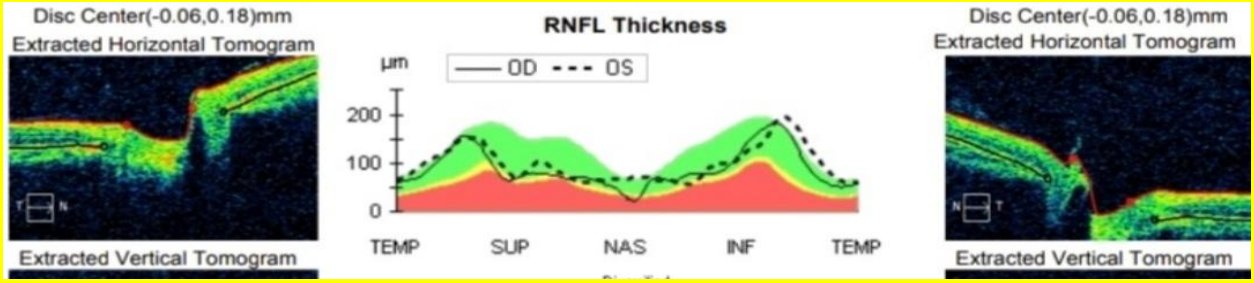
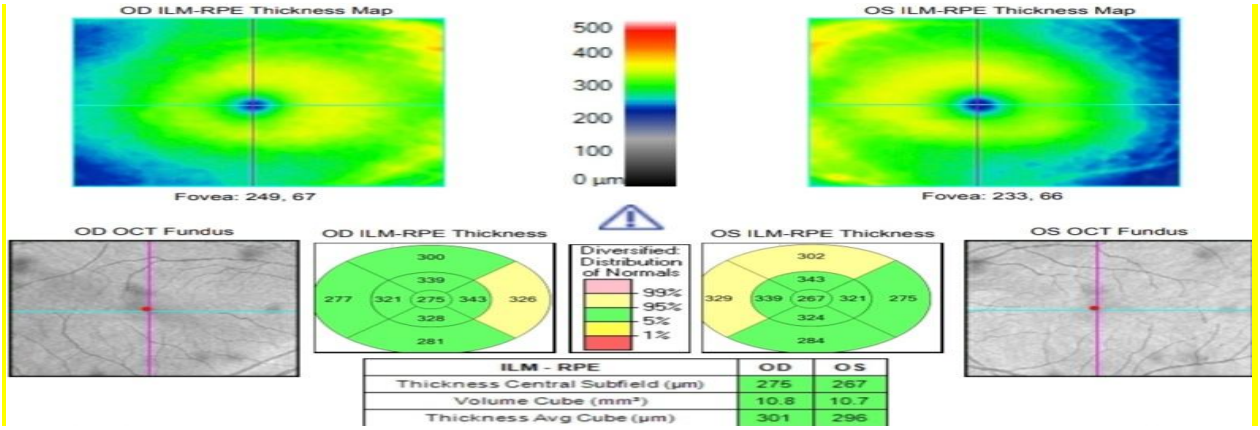


Fig 1C:

Macular thickness



Control group:

Fig 2A:
(RNFL quadrants: superior, inferior, nasal and temporal)

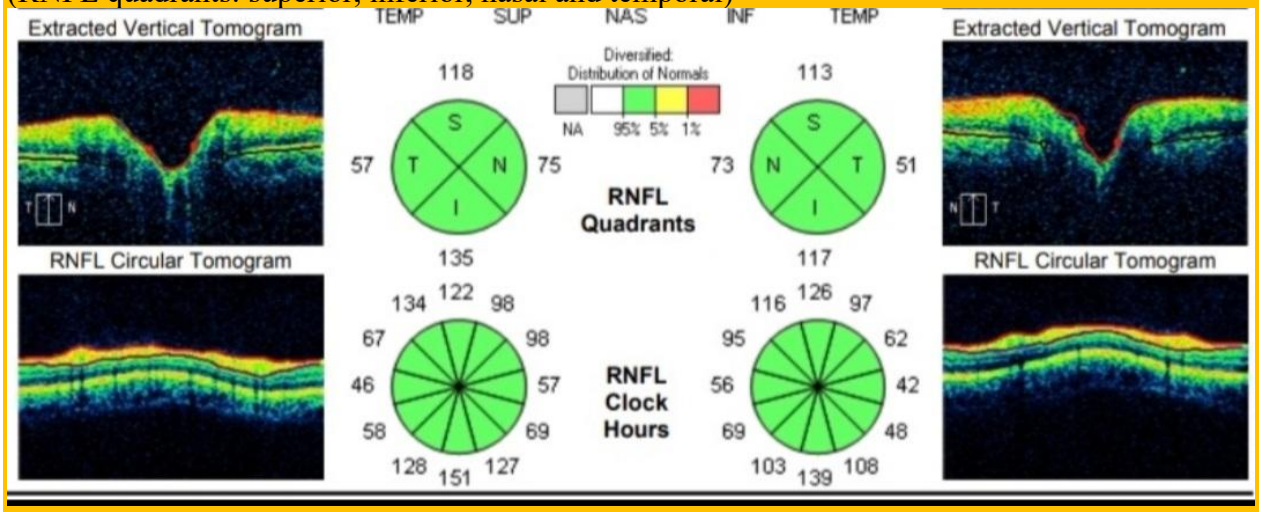


Fig 2B:
RNFL thickness

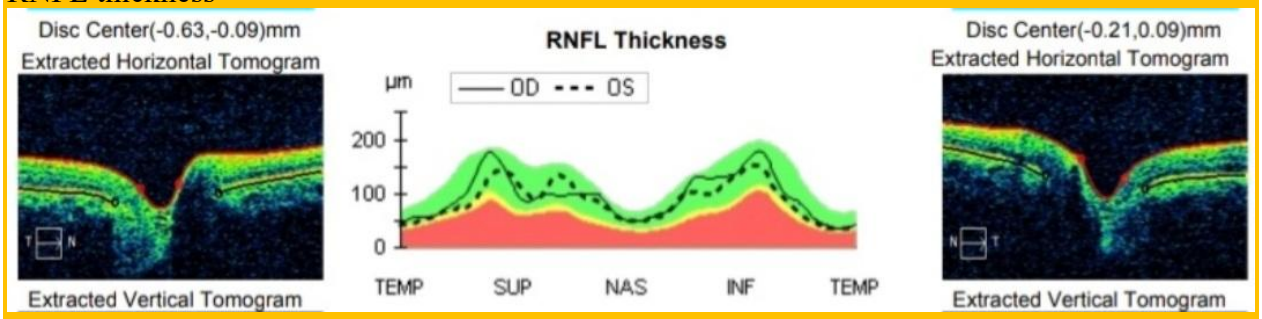
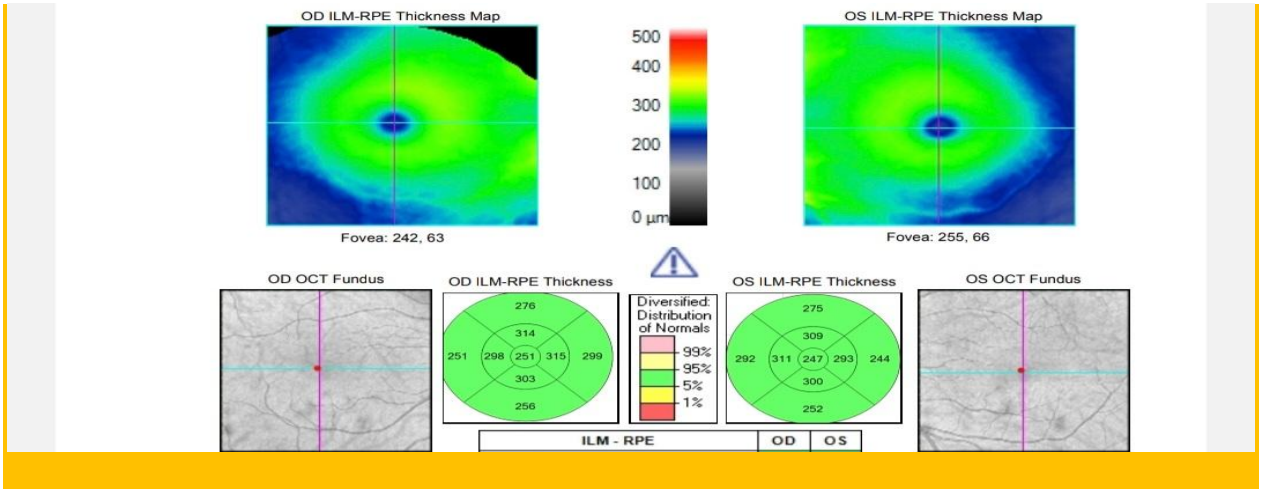


Fig 2C:
Macular thickness



Myopic Eyes (AL)

OD right	Biometric values	OS left
Eye status		
LS: Phakic Ref: --- LVC: Untreated	VS: Vitreous body VA: ---	LS: Phakic Ref: --- LVC: Untreated	VS: Vitreous body VA: ---
Biometric values		
AL: **26.60** mm	SD: 5 µm	AL: **26.29** mm	SD: 7 µm

Control Eyes (AL)

OD right	Biometric values	OS left
Eye status		
LS: Phakic Ref: --- LVC: Untreated	VS: Vitreous body VA: ---	LS: Phakic Ref: --- LVC: Untreated	VS: Vitreous body VA: ---
Biometric values		
AL: **24.06** mm	SD: 8 µm	AL: **24.11** mm	SD: 5 µm

Results

Table 1: Demographic profile of the participants

Participants		N	%	Mean ± SD
Age	**Male**	***24***	**58.5**	**27.83 ± 5.26**
	Female	**17**	**41.5**	**25.76 ± 5.43**
Age (average)		**41**	**100**	**26.89 ± 5.37**
	18-20	**2**	**4.9**	
	21-30	**31**	**75.6**	
	31-40	**8**	**19.5**	
Myopia				
	Low	**26**	**57.4**	
	Moderate	**11**	**26.8**	
	High	**4**	**9.8**	
Spherical Equivalent (RE)				
-6.00 above		4	9.8	
-6.00>-3.00		11	26.8	
-3.00>-0.75		15	36.6	
Control eye		**11**	**26.8**	
Spherical Equivalent (LE)				
-6.00 above		4	9.8	
-6.00>-3.00		9	22	
-3.00>-0.75		15	36.6	
Control eye		**13**	**31.7**	

Demographic: A total of 41 participants in this study between Myopic and normal group were enrolled, the mean ages of Myopic group with low, moderate, and high myope were 27.33 ± 5.75; 26.18 ± 4.97 and 30.25 ± 7.27
respectively. While the mean age for normal group was 26.09 mm ± 4.71 which were not significantly different (P=0.55). in this study we had 30 Myopic subjects from low myope with SE= -3.00>-0.75 D; Moderate myope with SE= -6.00>-3.00; and High myope with SE= -6.00 D above, while the control eye group presented with SE= less than -0.75D.

Axial length (AL) distribution between Myopic and Control Eyes:

In this study we had 30 Myopic subjects from low myope with ALs 24.31mm± 1.14; Moderate myope with ALs 25.57mm ± 1.02; and High myope with ALs 26.12mm ± 0.49 while the normal eye group their ALs was 23.79mm ± 0.6, there was a highly significant between groups with Axial Length which showed P-value <0.01.

Table 3:

Macular thickness			
	n	Mean	SD
-6.00 above	4	244.50	39.23
-6.00>-3.00	11	277.27	14.32
-3.00>-0.75	15	282.00	8.61
-0.75 less	11	275.73	8.58
Total	41	269.87	17.68

Table 2:

RNFL thickness			
	n	Mean	SD
-6.00 above	4	92.50	5.26
-6.00>-3.00	11	96.82	7.41
-3.00>-0.75	15	104.67	19.53
-0.75 less	11	96.45	17.09
Total	41	99.17	15.55

RNFL thickness between Myopic and control Eyes:
In the low, moderate, and high myopia groups (**Table 2**), the mean average RNFL thickness was 104.67mm ± 19.53, 96.82mm ± 7.41, and 92.50mm ± 5.26, respectively. The mean RNFL thickness for the normal group was 96.45 ± 17.09, indicating that the high myope group's RNFL thickness appeared thinner than that of the normal group, whereas the low and moderate myope groups' RNFL thickness nearly matched that of the normal eyes group. With P-value=0.37, there was no statistically significant difference between the group means.

Macular thickness between Myopic and control Eyes.
In the low, moderate, and high myopia groups, the mean thickness average cube was 282 mm ± 8.61, 277.27 mm ± 14.32, and 244.50 mm ± 39.23, as indicated in (**Table 3**). The mean thickness average cube in the normal group was found to be 275.73mm ± 8.58. This indicates that the high myope group's macular thickness average cube is thinner than that of the normal eyes group. The low and moderate myope groups exhibited nearly identical thicknesses; nonetheless, a significant difference in mean (P-value <0.01) was seen between the groups in this instance

Table 4: Spherical Equivalent (RE), RNFL Quadrants (RE): (Inferior, Superior, Nasal, Temporal)

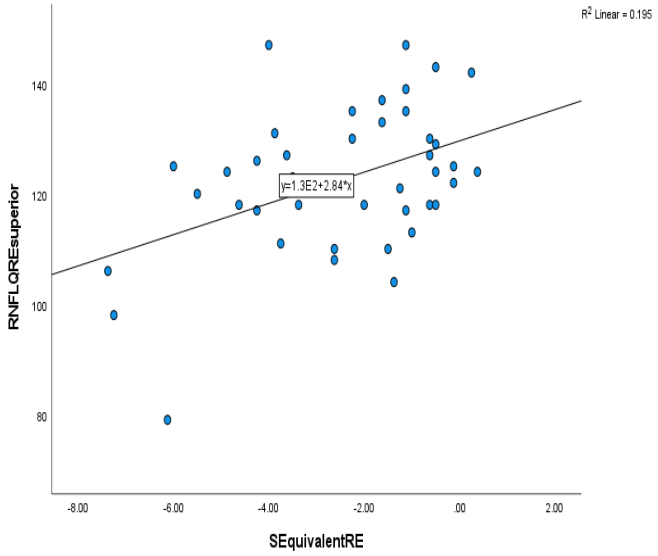
		Inferior Q	Superior	Nasal	Temporal	SE

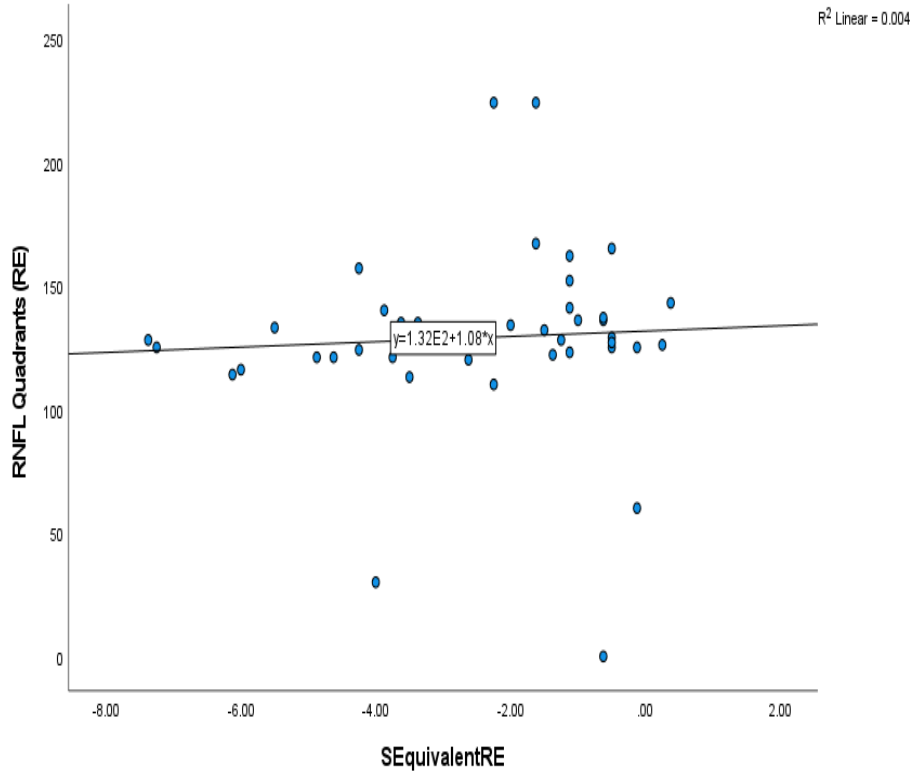
Inferior Q	Correlation Coefficient	1.000	.244	.379	.239	.228
	P-value	.	.12	.01	.13	.15
Superior Q	Correlation Coefficient	.244	1.000	.030	.134	.334*
	P-value	.12	.	.85	.40	.03
Nasal Q	Correlation Coefficient	.379*	.030	1.000	-.124	.202
	P-value	.01	.85	.	.43	.20
Temporal Q	Correlation Coefficient	.239	.134	-.124	1.000	-.150
	P-value	.13	.40	.43	.	.34
SE	Correlation Coefficient	.228	.334*	.202	-.150	1.000
	P-value	.15	.03	.20	.34	.
	N	41	41	41	41	41

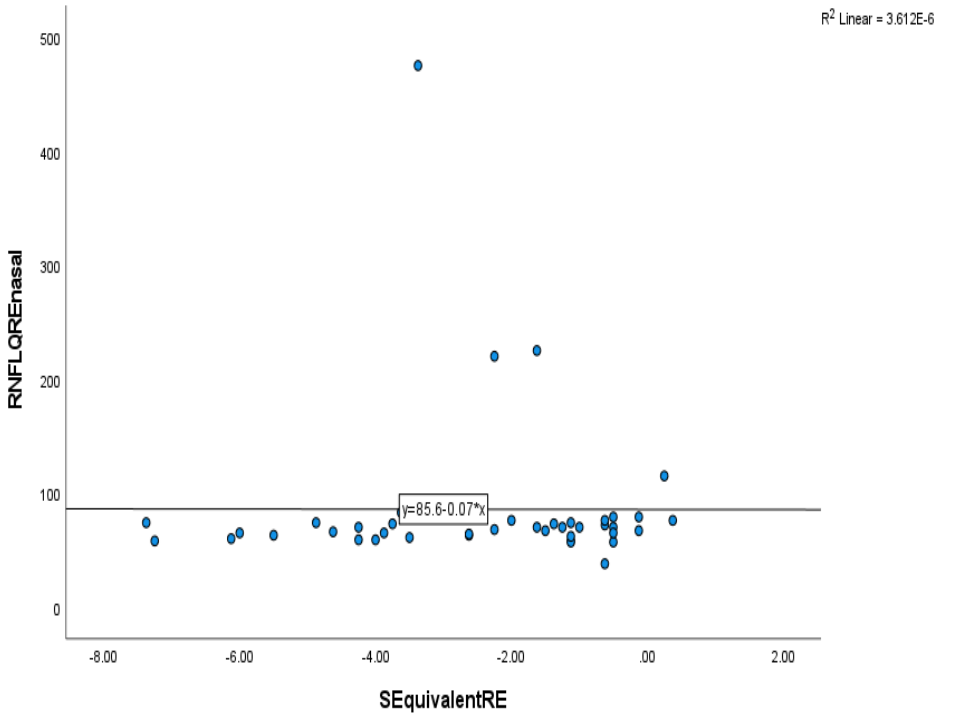
Table 4 showed that, there was a positive correlation in the right eye (RE) between spherical equivalent (SE) and RNFL quadrant on the superior part as stated weak to moderate with coefficient of 0.33 (33%) and P-value= 0.03, which was significant relationship between the variables. Also, in here we had a positive correlation between the nasal quadrant and the inferior quadrant which showed a coefficient as 0.37 (37%) still considered weak to moderate, but highly significant relationship as P-value= 0.01. in this study we found there was a weak correlation with coefficient of 0.22 (22%) and P-value =0.15, which was non-significant relationship showed between the variables, while the spherical equivalent (SE) in relation to temporal quadrant we had a negative weak correlation stated as -0.15 (15%) however the relationship between the variables was non-significant with P-value= 0.34

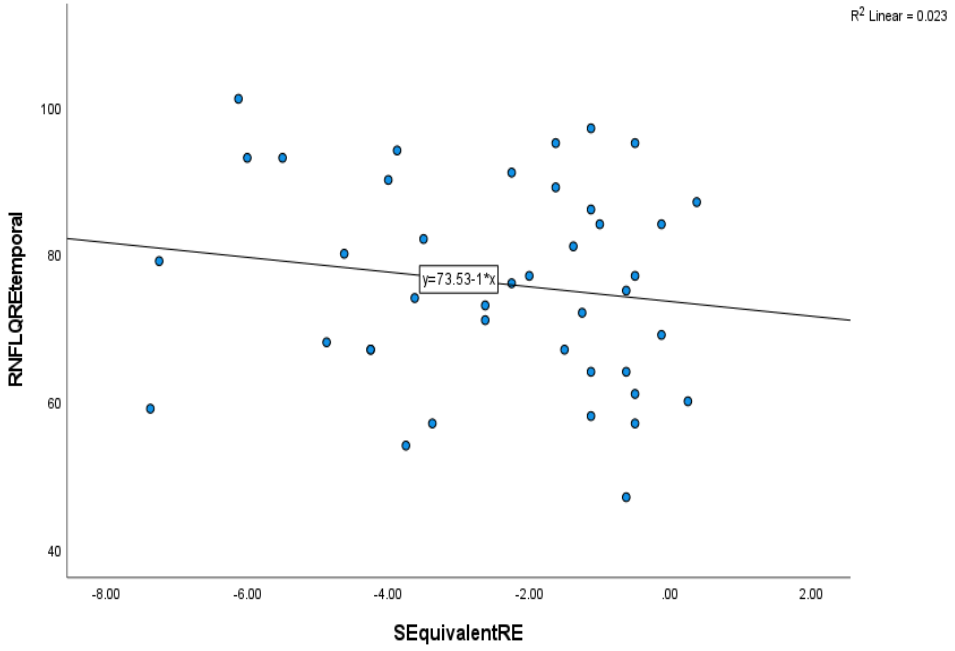
For the left eye (LE) there was no correlation stated in the analysis between spherical equivalent (SE) and RNFL quadrants (Inferior, Superior, Nasal, and Temporal). Concerning the left eye some errors happened during the study conduction and analysis which affected the results to achieve the targets among the relationship between

different parameters that could be useful for the correlation as we did in the right eye and achieved to find the relationship among some RNFL parameters.


R² Linear = 0.195
y=1.3E2+2.84*x
RNFLQREsuperior
SEquivalentRE
140
120
100
80
-8.00
-6.00
-4.00
-2.00
.00
2.00


R² Linear = 0.004
y=1.32E2+1.08*x
RNFL Quadrants (RE)
SEquivalentRE
250
200
150
100
50
0
-8.00
-6.00
-4.00
-2.00
.00
2.00





Discussion

Researchers are working to determine risk factors for myopia as the disease has gained global attention[2,3]. and the optimal management of the disease and its complications[4,5]. Specifically, high myopia is linked to glaucomatous optic neuropathy and maculopathy, making OCT an essential

imaging modality in these individuals[6,7]. Our investigation shows significant RNFL thickness variations between myopic and normal eyes groups and gives mean RNFL values of Zeiss Cirrus HD-OCT as a baseline data for assessment of myopic patients in the future. Early identification of those at risk of developing myopia is made feasible by monitoring the pattern of changes in peripheral refraction[33]. During progression of myopia, the role of the optical components of the eye should be taken into account, including axial length (AL)[34,35]. Myopia develops when AL increases relative to the focal point of the ocular refractive components[36]. In our observations, we found that the RNFL thickness was notably reduced in myopic eyes in comparison to emmetropic eyes. Both an increase in axial length and a more negative Spherical equivalent (SE) have previously been linked to thinning of the RNFL[8,9]. Our findings supported to those of Sezgin Akcay et al[10]. and Kim et al[11]. who observed that patients with myopia have a thinner RNFL.

Significant thinning was observed in the superior and nasal quadrant RNFL of highly myopic eyes as showed in figure (**1A,1B**) for the highly myopic group. However, the retina is shifted temporally, resulting in the thickening of the RNFL in the temporal quadrant and its thinning in the other quadrants, especially the nasal[53]. In the superior-temporal region, the RNFL trajectories are associated with the course of the retinal vessels, while in the inferior-temporal region, they are associated with the course of the retinal vessels and disc torsion. This implies that, in 7.5% of the myopes, the RNFL raphe rotated enough to produce a false nasal step in the VF and is, generally, in poor agreement with the ISNT rule (67% in high myopes vs. 8% in emmetropes)[39].

Our study failed to observe any significant inter-group differences in RNFL thickness of the inferior and temporal quadrants. These findings are in inverse correlation to the two studies mentioned[10,11], which observed that the RNFL was thicker in the Low myope group than in the moderate and High myope groups for the superior, nasal and inferior quadrants. The differences between our study and those cited may be due to the effect of confounders such as age[12,13].

Retinal thinning in myopia has been referred as reducing the thickness of the middle to inner retina, this thinning has been demonstrated by stretching of the ocular layers during the elongation of the eyeball, as occurs in pathologic myopia[14]. Increased axial length has also been associated with narrowed retinal arterioles[15,16]. Previous studies have reported that the average thickness of all sectors of the ganglion cell (GC)-IPL is significantly lower in patients with high myopia and significantly correlated with SE and AL[17,18]. Differences in measured RNFL thickness in eyes with greater AL have been speculated to be caused by mechanical elongation and stretching of the sclera[28], although other reports support an ocular magnification effect resulting in factitious RNFL thinning[37].

Mohammad Salih[19] conducted a study comparing the peripapillary RNFL thickness in three different degrees of myopic groups and discovered that the average RNFL thickness was lower in highly and moderately myopic eyes compared to low myopic eyes. In our research, we categorized subjects into four groups, consisting of one emmetropic group and three myopic groups. It was noted that myopic eyes exhibited a thinner average global RNFL thickness compared to emmetropic eyes, with high myopic eyes displaying the thinnest average global RNFL thickness. We revealed a significant relationship between RNFLT and the disc area as well as the rim area. According to Tariq et al., a larger disc and rim area were linked to thicker RNFL, while the larger CDR was associated with the thinner RNFL[38].

The correlation we found indicates that a thicker macula is associated with better vision and patient-centred visual function, suggesting that macular thickness could influence visual outcomes. The observed connection may be due to the fact that a thicker macula may indicate a higher number of ganglion cells, which are responsible for transmitting important visual information from the retina to the brain. Our study revealed that macular thickness was lower in high myopic eyes, as showed in the figure (**1C**), the Macular thickness was thinner in the subfoveal (SF) region with the diameter of 1 mm, then thicker in the parafoveal region ranging from 1 to 3 mm from the SF region and the perifoveal region from 3 to 6 mm from the SF region looked thinner as well. This may be because the majority of the ganglion cells are located in the inner retinal layer of the macular and have greater influence on visual function[31]. Overall, our study supports the existing literature that GCIPL thickness is a determinant of visual outcomes in myopic eyes and even in healthy eyes[29]. We have found also that peripapillary RNFL thickness decreased significantly at the superior quadrant as the myopia increased and that have been proved with the spherical equivalent power as one of the relevant factors that have been distinguished among myopic patients compare to control group[28].

Strengths of our study include a specific ethnic group as Malay adults' population which eliminate the ethnics and ageing conflicts of the study, adjustment for confounders and the elimination of inter-observer errors by using a single operator to perform refraction, the gold standard in optical biometry as IOL master 700 and cirrus HD- OCT of the RNFL. However, we acknowledge our limitation of an unequal number of samples in each refractive error group, with the highly myopic group comprising the smallest proportion

Despite our limitations, our study clearly demonstrates that highly myopic eyes have a thinner RNFL than normal eyes. On one hand, this thinning may be a risk factor for glaucoma development, as variations in the arrangement of optic nerve head fibers have been postulated to render myopic eyes more susceptible to glaucomatous damage[1,20].

Some reports have found that macular thickness differed by sex, race, and age[21,22]. These studies just compared macular thickness values of each sector. Previous methods could have limitations on identifying changes of macular thickness with axial elongation.

Conclusion

In this pilot study among the Malay population in Selangor, we have identified significant correlations between macular thickness, retinal nerve fiber layer (RNFL) thickness, and axial length in individuals with myopia. Our findings indicate that thicker macular and ganglion cell-inner plexiform layer (GCIPL) measurements are associated with better visual function outcomes. Conversely, higher degrees of myopia correlate with thinner average RNFL, particularly in the superior and nasal quadrants compared to emmetropic eyes.

The observed relationship between spherical equivalent and RNFL quadrant thickness underscores the impact of refractive error severity on retinal structural changes. Specifically, as spherical equivalent increased, the thickness of the superior and nasal RNFL quadrants decreased among myopic individuals, whereas the inferior and temporal quadrants showed less sensitivity to spherical equivalent changes.

Given the heightened risks associated with high myopia, including vision-threatening conditions, our study underscores the importance of comprehensive eye examinations that include retinal assessments beyond mere refraction. Optometrists and other eye care providers should integrate retinal evaluations as routine practice, especially among patients with varying degrees of myopia.

The implications of our findings extend to clinical practice and public health interventions. Early detection and management of myopia are crucial for preventing severe ocular complications that may lead to blindness. Educating communities, healthcare professionals, and caregivers about the risks of myopia and the importance of regular eye examinations is imperative for effective prevention and treatment strategies.

Study contributes to the growing body of evidence supporting the integration of retinal biometry assessments in the management of myopia. By promoting proactive eye care practices, we aim to mitigate the impact of myopia-related visual impairments and improve long-term visual outcomes among affected individuals.

Conflicts of Interest

All authors certify that they have no entity with any financial interest or nonfinancial interest in the subject matter or materials discussed in the study.

Acknowledgment

This study was supported by MSU Eye Centre, MSU Medical Centre. We acknowledge MSU Eye Centre and MSU Medical Centre staff for their invaluable contributions to the completion to the research, data collection and analysis.

References

1. Ma F, Dai J, Sun X. Progress in understanding the association between high myopia and primary open-angle glaucoma. Clin Exp Ophthalmol. 2014;42(2):190–197.

2. Cuellar-Partida G, Lu Y, Kho PF, Hewitt AW, Wichmann HE, Yazar S, Stambolian D, Bailey-Wilson JE, Wojciechowski R, Wang JJ, Mitchell P, Mackey DA, MacGregor S. Assessing the genetic predisposition of education on myopia: a mendelian randomization study. Genet Epidemiol. 2016;40(1):66–72.

3. Parssinen O, Kauppinen M. Associations of reading posture, gaze angle and reading distance with myopia and myopic progression. Acta Ophthalmol. 2016;94(8):775–779.

4. Davidson SL, O'Hara M, Wagner RS. Management of progressive myopia. J Pediatr Ophthalmol Strabismus. 2016;53(3):134–136.

5. Wolffsohn JS, Calossi A, Cho P, et al. Global trends in myopia management attitudes and strategies in clinical practice. Cont Lens Anterior Eye. 2016;39(2):106–116.

6. Chen LW, Lan YW, Hsieh JW. The optic nerve head in primary open-angle glaucoma eyes with high myopia: characteristics and association with visual field defects. J Glaucoma. 2016;25(6):569–575.

7. Ohno-Matsui K. Pathologic myopia. Asia Pac J Ophthalmol (Phila) 2016;5(6):415–423.

8. Leung CK, Mohamed S, Leung KS, Cheung CY, Chan SL, Cheng DK, Lee AK, Leung GY, Rao SK, Lam DS. Retinal nerve fiber layer measurements in myopia: an optical coherence tomography study. Invest Ophthalmol Vis Sci. 2006;47(12):5171–5176.

9. Zhao Z, Jiang C. Effect of myopia on ganglion cell complex and peripapillary retinal nerve fibre layer measurements: a Fourier-domain optical coherence tomography study of young Chinese persons. Clin Exp Ophthalmol. 2013;41(6):561–566.

10. Sezgin Akcay BI, Gunay BO, Kardes E, Unlu C, Ergin A. Evaluation of the ganglion cell complex and retinal nerve fiber layer in low, moderate, and high myopia: a study by RTVue spectral domain optical coherence tomography. Semin Ophthalmol. 2017;32(6):682–688.

11. Kim MJ, Lee EJ, Kim TW. Peripapillary retinal nerve fibre layer thickness profile in subjects with myopia measured using the Stratus optical coherence tomography. Br J Ophthalmol. 2010;94(1):115–120.

12. Uchida H, Yamamoto T, Araie M, Tomita G, Shirakashi M, Yoshikawa K, HRT Study Group Topographic characteristics of the optic nerve head measured with scanning laser tomography in normal Japanese subjects. Jpn J Ophthalmol. 2005;49(6):469–476.
13. Ozdek SC, Onol M, Gürelik G, Hasanreisoglu B. Scanning laser polarimetry in normal subjects and patients with myopia. Br J Ophthalmol. 2000;84(3):264–267.

14. Yanoff M, Fine BS. Ocular Pathology: A Text and Atlas. Philadelphia: Harper & Row; 1982.

15. Gopinath B, Wang JJ, Kifley A, Tan AG, Wong TY, Mitchell P. The association between ocular biometry and retinal vascular caliber is comparable from early childhood to adolescence. Invest Ophthalmol Vis Sci. 2013;54(2):1501–1508.

16. Tai EL, Li LJ, Wan-Hazabbah WH, Wong TY, Shatriah I. Effect of axial eye length on retinal vessel parameters in 6 to 12-year-old Malay girls. PLoS One. 2017;12(1):0170014.

17. Choi YJ, Jeoung JW, Park KH, Kim DM. Glaucoma detection ability of ganglion cell-inner plexiform layer thickness by spectral-domain optical coherence tomography in high myopia. Invest Ophthalmol Vis Sci. 2013; 54:2296–304.

18. Zhao Z, Jiang C. Effect of myopia on ganglion cell complex and peripapillary retinal nerve fibre layer measurements: a Fourier-domain optical coherence tomography study of young Chinese persons. Clin Exp Ophthalmol. 2013; 41:561–6.

19. Mohammad Salih PA. Evaluation of peripapillary retinal nerve fiber layer thickness in myopic eyes by spectral-domain optical coherence tomography. J Glaucoma. 2012; 21:41–44.

20. Cahane M, Bartov E. Axial length and scleral thickness effect on susceptibility to glaucomatous damage: a theoretical model implementing Leplace's law. Ophthalmic Res. 1992;24(5):280–284.

21. Demirkaya N., van Dijk H. W., van Schuppen S. M., et al. Effect of age on individual retinal layer thickness in normal eyes as measured with spectral-domain optical coherence tomography. Investigative Opthalmology & Visual Science. 2013;54(7):4934–4940.

22. Pilat A. V., Proudlock F. A., Mohammad S., Gottlob I. Normal macular structure measured with optical coherence tomography across ethnicity. British Journal of Ophthalmology. 2014;98(7):941–945.

25. Madhavan I, Batumalai UM, Barodawala FS, Ariffin AE. Prevalence of Myopia Among Indian School Children in Kuala Lumpur. Online J Health Allied Scs. 2018;17(1):7.
26. Chen-Wei Pan; Ying-Feng Zheng; Ainur Rahman Anuar; Merwyn Chew; Gus Gazzard; Tin Aung; Ching-Yu Cheng; Tien Y. Wong; Seang-Mei Saw. Investigative Ophthalmology & Visual Science. 2013; 54, 2590-2598.

27. Omar R, Wong MES, Majumder C, et al. Distribution of refractive error among chinese primary school children in a rural area in Pahang, Malaysia. Malays Fam Physician. 2022;17(1);29–35.

28. Du J, Du Y, Xue Y, Wang H, Li Y. Factors Associated with Changes in Peripapillary Retinal Nerve Fibre Layer Thickness in Healthy Myopic Eyes. *J Ophthalmol*. 2021:3462004.

29. Poh S, Tham YC, Chee ML, et al. Association between Macular Thickness Profiles and Visual Function in Healthy Eyes: The Singapore Epidemiology of Eye Diseases (SEED) Study. *Sci Rep*. 2020;10(1):6142.

30. Ha, A., Kim, Y.K., Baek, S.U. et al. Longitudinal changes of circumpapillary retinal nerve fiber layer thickness profile during childhood myopia progression. Sci Rep. 2022;12, 2555.

31. Scott A. Read, * David Alonso-Caneiro, and Stephen J. Vincent. Longitudinal changes in macular retinal layer thickness in pediatric populations: Myopic vs non-myopic eyes. journal. Pone. 2017; 0180462.

32. Choudhary, Arathi; Venkatesh, Raksha Halmuthur; Jayashree, M. P.; Surendrappa, Hamsa Dyamenahalli; Divya, R.; Darshini, L. M. Effect of high myopia on macular thickness: An optical coherence tomography study in a tertiary care hospital, Karnataka, India. Journal of Clinical Ophthalmology and Research. 2021; 9(1):10.4103.

33. Atchison DA, Rosén R. The possible role of peripheral refraction in development of myopia. *Optom Vis Sci.* 2016;93(9):1042–1044.

34. Kang P, Gifford P, McNamara P, Wu J, Yeo S, Vong B, Swarbrick H. Peripheral refraction in different ethnicities. Invest Ophthalmol Vis Sci. 2010;51(11):6059–6065.

35. Kim J, Lim DH, Han SH, Chung TY. Predictive factors associated with axial length growth and myopia progression in orthokeratology. *PLoS One.* 2019;14(6):e0218140.

36. Hou W, Norton TT, Hyman L, Gwiazda J, COMET Group Axial elongation in myopic children and its association with myopia progression in the correction of myopia evaluation trial. *Eye Contact Lens.* 2018;44(4):248–259.

37. Ho, H., Tham, Y. C., Chee, M. L., Shi, Y., Tan, N. Y. Q., Wong, K. H., Majithia, S., Cheung, C. Y., Aung, T., Wong, T. Y., & Cheng, C. Y. Retinal Nerve Fiber Layer Thickness in a Multiethnic Normal Asian Population: The Singapore Epidemiology of Eye Diseases Study. *Ophthalmology*. 2019; *126*(5), 702–711.

38. Amelia, A., Fatimah-Halwani, I., & Shatriah, I. Optic Nerve Head and Retinal Nerve Fiber Layer Analysis in Emmetropic Malay Children. *Cureus*. 2024; *16*(2),53890.

39. Bedggood, P.; Mukherjee, S.; Nguyen, B.N.; Turpin, A.; McKendrick, A.M. Geometry of the Retinal Nerve Fibers from Emmetropia Through to High Myopia at Both the Temporal Raphe and Optic Nerve. Investig. Opthalmol. Vis. Sci. 2019; 60, 4896.

40. Fan, Y.Y.; Jonas, J.B.; Wang, Y.X.; Chen, C.X.; Wei, W. Bin Horizontal and vertical optic disc rotation. The Beijing Eye Study. PLoS ONE 2017, 12, 0175749.

41. Zha Y, Zhuang J, Lin D, Feng W, Zheng H, Cai J. Evaluation of myopia on retinal nerve fiber layer thickness measured by Spectralis optical coherence tomography. *Exp Ther Med*. 2017;14(3):2716-2720.

42. Zhao Z, Zhou X, Jiang C, Sun X. Effects of myopia on different areas and layers of the macula: a Fourier-domain optical coherence tomography study of a Chinese cohort. *BMC Ophthalmol*. 2015; 15:90.

43. Holden BA, Fricke TR, Wilson DA, et al. Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050. *Ophthalmology*. 2016;123(5):1036-1042.