Retinal Nerve Fiber Layer Measurements in Myopia: An Optical Coherence Tomography Study

Christopher Kai-Shun Leung,[1,2] Shaheeda Mohamed,[1] King Sai Leung,[1] Carol Yim-Lui Cheung,[1] Sylvia Lai-wa Chan,[1] Daphne Ka-yee Cheng,[1] August Ki-cheung Lee,[1] Gloria Yuk-oi Leung,[1] Srinivas Kamalakara Rao,[1] and Dennis Shun Chiu Lam[1]

Purpose. To evaluate the relationship between retinal nerve fiber layer (RNFL) thickness measured by optical coherence tomography (OCT) and the axial length/refractive error of the eye.

Methods. A total of 115 eyes of 115 healthy subjects, comprising 75 eyes with high myopia (spherical equivalent [SE] < −6.0 D) and 40 eyes with low to moderate myopia (SE between −6.0 D and −0.5D), were analyzed in this cross-sectional study. Total average and mean clock hour RNFL thicknesses were measured by OCT and compared between the two myopia groups. Associations between RNFL measurements and axial length and spherical equivalent were evaluated by linear regression analysis.

Results. The RNFL measurements were significantly lower in the high myopia group compared with those of the low-to-moderate myopia group at 12, 1, and 7 o'clock (right eye orientation). Apart from the temporal clock hours, significant correlations were evident between RNFL measurements and the axial length and spherical equivalent. The average RNFL thickness decreased with increasing axial length ($r = -0.314$, $P = 0.001$) and negative refractive power ($r = 0.291$, $P = 0.002$). A significant proportion of myopic eyes were classified as outside normal limits, with reference to the normative database. The most frequently abnormal sector was at 2 o'clock, where 16.5% of myopic eyes were outside normal limits.

Conclusions. RNFL measurements vary with the axial length/refractive error of the eye. Analysis of RNFL thickness in the evaluation of glaucoma should always be interpreted with reference to the refractive status. Although the normative database provided by OCT has been helpful in identifying ocular diseases involving the RNFL, it may not be reliable in the analysis of myopic eyes. (*Invest Ophthalmol Vis Sci.* 2006;47:5171–5176) DOI:10.1167/iovs.06-0545

From the [1]Department of Ophthalmology and Visual Sciences, The Chinese University of Hong Kong, Hong Kong, Peoples Republic of China; and the [2]Department of Ophthalmology, Caritas Medical Centre, Hong Kong, Peoples Republic of China.

Submitted for publication May 17, 2006; revised July 3 and 17, 2006; accepted September 22, 2006.

Disclosure: **C.K.S. Leung**, None; **S. Mohamed**, None; **K.S. Leung**, None; **C.Y.-L. Cheung**, None; **S.L.-w. Chan**, None; **D.K.-y. Cheng**, None; **A.K.-c. Lee**, None; **G.Y.-o. Leung**, None; **S.K. Rao**, None; **D.S.C. Lam**, None

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be marked "*advertisement*" in accordance with 18 U.S.C. §1734 solely to indicate this fact.

Corresponding author: Christopher Kai-shun Leung, Department of Ophthalmology and Visual Sciences, The Chinese University of Hong Kong, Hong Kong Eye Hospital, 147K Argyle Street, Kowloon, Hong Kong; tlims00@hotmail.com.

Myopia is the most common ocular abnormality worldwide. The prevalence of myopia in adults has been reported to be 22.7% and 26.2% in the Baltimore Eye Survey and the Beaver Dam Study, respectively.[1–2] In some of the Asia-Pacific countries, the increase in prevalence has reached an epidemic scale. In Singapore, it has been estimated that 38.7% of adult Chinese are myopic, and 9.1% are high myopes.[3] The ocular morbidity related to myopia presents a major concern from clinical and socioeconomic perspectives, especially in East Asian countries, in view of its high prevalence and projections for increasing rate and severity of the condition.[4]

One of the potentially blinding ocular diseases associated with myopia is glaucoma, which is characterized by progressive degeneration of retinal ganglion cells. An important approach to detecting early structural change in glaucoma is based on assessment of the retinal nerve fiber layer (RNFL). Numerous studies have confirmed that RNFL measurement is sensitive for detection of glaucoma, and the extent of RNFL damage correlates with the severity of functional deficit in the visual field.[5–7] Although RNFL thinning is indicative of glaucomatous damage, it remains uncertain whether RNFL thickness would vary with the refractive status of the eye. It is therefore important to investigate whether any correlation exists between RNFL measurements and axial length/refractive error in myopia, with regard to the observation that the risk of development of glaucoma is increased with an increasing degree of myopia.[8,9] The optical coherence tomographer (OCT) is a modern imaging device designed to measure the RNFL in a noncontact and noninvasive manner. With the high axial scanning resolution (<10 μm) provided with the latest model of OCT (StratusOCT; Carl Zeiss Meditec Inc., Dublin, CA), RNFL measurements have been reliable and reproducible.[10–12] The purpose of this study was to investigate the relationship between myopia and RNFL thickness measured by OCT.

Methods

Subjects

One hundred thirty-eight healthy Chinese subjects with myopia who met the inclusion criteria were recruited. All subjects were examined in the Hong Kong Eye Hospital during the recruitment period from October 2005 to April 2006. All subjects underwent a full ophthalmic examination including visual acuity, refraction, intraocular pressure measurement with Goldmann tonometry, dilated fundus examination with stereoscopic biomicroscopy of the optic nerve head under slit lamp, indirect ophthalmoscopy, refraction, and A-scan ultrasound biometry. Other than refractive error, all included eyes had no concurrent disease and had best corrected visual acuity of at least 20/40. Subjects were divided into two diagnostic groups, according to refractive error: high myopia (spherical equivalent, < −6.00 D) and low to moderate myopia (spherical equivalent between −0.50 D and −6.00 D). Subjects with spherical equivalent more than −0.5 D, clinical evidence of glaucoma, myopic macular degeneration, peripapillary

Investigative Ophthalmology & Visual Science, December 2006, Vol. 47, No. 12

Table 1. Characteristics of the High and Low-to-Moderate Myopia Groups

	High Myopia (n = 75)	Low–Moderate Myopia (n = 40)	P*	Correlation with AL/SE (r)
SE mean ± SD	−9.1 ± 1.8	−3.9 ± 1.5	<0.001	−0.781 (P < 0.001)/−
Arial length mean ± SD	26.7 ± 0.96	24.8 ± 1.0	<0.001	−/−0.781 (P < 0.001)
Sex (Male/Female)	34/41	13/27	0.156†	−/−
Age (yrs) mean ± SD	36.5 ± 8.1	35.0 ± 12.0	0.427	−0.122 (P = 0.195)/0.078 (P = 0.410)
Visual field MD (dB) ± SD	−1.08 ± 1.07	−0.60 ± 1.0	0.026	−0.197 (P = 0.035)/0.222 (P = 0.017)
Visual field PSD (dB) ± SD	1.68 ± 0.63	1.60 ± 0.32	0.328	0.058 (P = 0.535)/−0.035 (P = 0.708)
Average RNFL thickness (μm)	100.69 ± 10.36	107.49 ± 12.74	0.003	−0.314 (P = 0.001)/0.291 (P = 0.002)

SD, standard deviation; D, dioptres; MD, mean deviation; PSD, pattern standard deviation; AL, axial length; SE, spherical equivalent; *r*, Pearson coefficient of correlation.

* Independent *t*-test.

† χ^2 test.

atrophy extending >1.7 mm (the radius of the OCT RNFL scan) from the center of the disc, intraocular pressure >21 mm Hg, visual field defects, intraocular surgery, refractive surgery, neurologic diseases, or diabetes were excluded. OCT was performed in one randomly selected eye. The study was conducted in accordance with the ethical standards stated in the Declaration of Helsinki and was approved by the local clinical research ethics committee, with informed consent obtained.

OCT Imaging

OCT was performed with OCT version 3 (StratusOCT, Carl Zeiss Meditec Inc.) RNFL thickness was measured with the fast RNFL (3.4) (256 A-scans) scanning protocol. Average measurements of three sequential circular scans of diameter 3.4 mm centered on the optic disc were recorded. The RNFL with its high reflectivity signal can be visualized as the first layer in red on the scan. Its thickness is determined by the difference in distance between the vitreoretinal interface and a posterior border, based on a predefined reflectivity signal level. All the scans had signal strength of at least 7. To avoid potential measurement error when scanning over the area of peripapillary atrophy, we excluded 18 myopic eyes with peripapillary atrophy extending more than 1.7 mm from the center of the optic disc.

Parameters including average RNFL thickness and mean RNFL thickness in each clock hour were generated automatically in the analysis report of the StratusOCT. These measurements were aligned based on the right eye orientation. The superior clock hour was 12 o'clock and the others were assigned accordingly in a clockwise manner in the right eye and counterclockwise in the left.

Visual Field Testing

Standard visual field testing was performed with static, automated, white-on-white threshold perimetry (program 24-2, Humphrey Field Analyzer II; Carl Zeiss Meditec). A visual field was defined as reliable when fixation losses and false-positive and false-negative rates were less than 25%. A visual field defect was defined as having three or more significant (P < 0.05) non–edge-contiguous points with at least one at the P < 0.01 level on the same side of the horizontal meridian in the pattern deviation plot and classified as outside normal limits in the glaucoma hemifield test. Five subjects were not included because of repeatable visual field defects. After 18 eyes with extended peripapillary atrophy and 5 eyes with repeatable visual field defects were excluded, 115 eyes were included in the analysis.

Statistical Analysis

Statistical analyses were performed with commercially available software (SPSS ver. 11.0; SPSS Inc, Chicago, IL). The total average and mean clock hour RNFL measurements between high myopia and low-to-moderate myopia groups were compared by using an independent *t*-test. Correlations between RNFL thicknesses and axial length-refractive error were examined by linear regression analysis and expressed as the Pearson coefficient of correlation (r). P < 0.05 was considered statistically significant.

Results

One hundred fifteen myopic eyes of 115 subjects were analyzed. The mean age, axial length, and spherical equivalent were 35.9 ± 9.6 years (range, 22–60), 26.08 ± 1.33 mm (range, 22.73–28.79), and −7.31 ± 3.04 D (range, −0.75 to −13.88), respectively. Significant correlation was found between the axial length and the spherical equivalent (r = −0.778, P < 0.001). Table 1 presents the characteristics of the high myopia (spherical equivalent < −6.0 D, n = 75) and low-to-moderate myopia (spherical equivalent between −6.0 D and −0.5 D, n = 40) groups. No significant age difference was found between the groups, and age did not correlate significantly with axial length (P = 0.195), spherical equivalent (P = 0.410), visual field mean deviation (MD; P = 0.683)/pattern standard deviation (P = 0.116), or the average RNFL thickness (P = 0.681). The visual field MD of the high myopia group was −1.08 ± 1.08 dB, which was worse than that of the low-to-moderate myopia group (−0.61 ± 1.04 dB, P = 0.026). The visual field MD correlated significantly with average RNFL thickness (r = 0.242, n = 115, P = 0.009). The average RNFL thickness in highly myopic eyes was 100.69 ± 10.36 μm, which was significantly thinner than that in low-to-moderately myopic eyes (107.49 ± 12.74 μm; P = 0.003). Analyses at individual clock hours showed that the high myopia group had significantly lower RNFL measurements at 12, 1, and 7 o'clock than did the low-to-moderate myopia group (P < 0.05; right eye orientation; Table 2) and the respective RNFL profiles are

Table 2. Clock Hour RNFL Measurements

Clock Hours	High Myopia (n = 75)	Low–Moderate Myopia (n = 40)	P*
12	112.17 ± 28.21	123.83 ± 20.94	0.024
1	96.69 ± 24.06	110.28 ± 24.73	0.005
2	69.33 ± 19.76	76.30 ± 20.32	0.077
3	53.36 ± 13.74	57.48 ± 15.41	0.145
4	59.91 ± 16.71	63.53 ± 15.87	0.263
5	91.60 ± 23.50	97.40 ± 18.88	0.181
6	128.44 ± 28.65	138.20 ± 25.28	0.073
7	159.23 ± 22.53	173.63 ± 23.82	0.002
8	103.15 ± 23.75	106.73 ± 23.27	0.440
9	76.32 ± 19.95	77.13 ± 18.69	0.834
10	113.48 ± 29.82	112.20 ± 23.47	0.814
11	144.36 ± 21.98	152.28 ± 25.93	0.087

* Independent *t*-test.

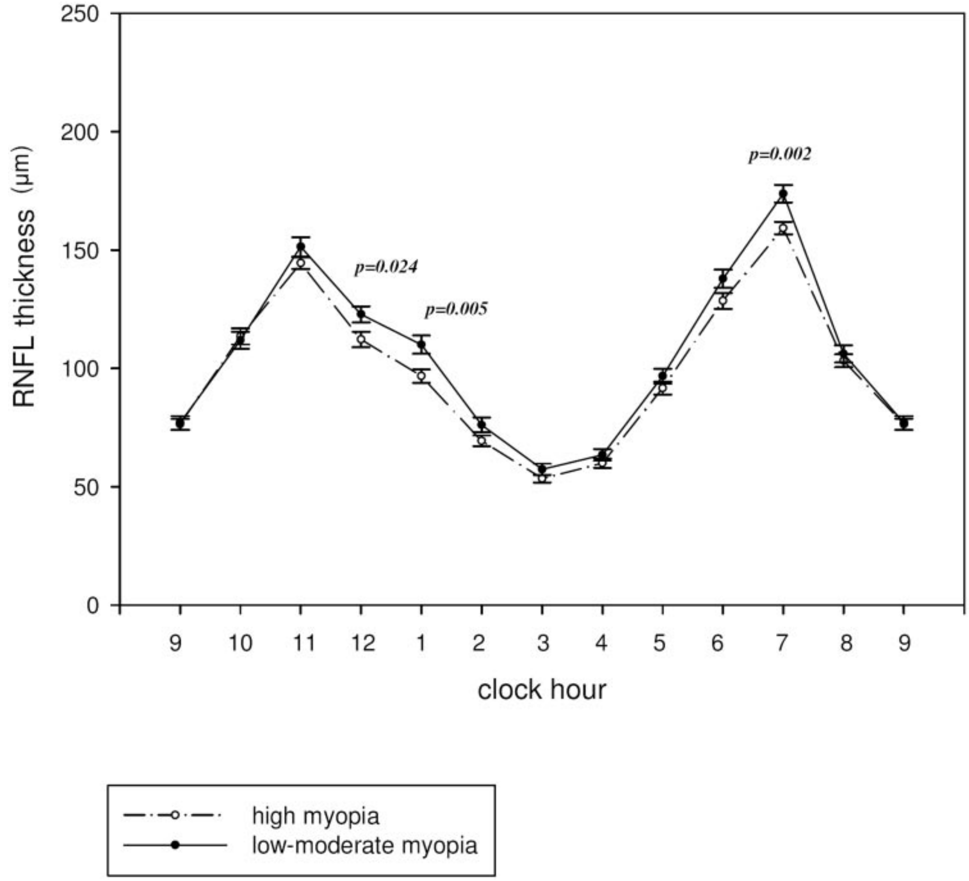

FIGURE 1. RNFL profiles of the high myopia group (n = 75) and the low-to-moderate myopia group (n = 40). Significant differences were found at 12, 1, and 7 o'clock (righthand orientation).

plotted in Figure 1. A double-hump pattern, with peaks over the superotemporal (11 o'clock) and inferotemporal (7 o'clock) sectors and troughs over the nasal (3 o'clock) and temporal (9 o'clock) sectors, was observed in both groups. The average RNFL thickness decreased with the axial length/negative spherical equivalent, with coefficients of correlation of −0.314 (P = 0.001) and 0.291 (P = 0.002), respectively (Fig. 2). Significant correlations between RNFL thickness and axial length/spherical equivalent were found in each clock hour except in the temporal sector (8–11 o'clock; Table 3). A subgroup analysis including only young subjects with age ranging from 25 to 29 (n = 36) was also performed. (This age range was selected because it constituted the highest proportion of subjects: 36/115, or 31.3%, in the study group.) A similar correlation profile was evident with $r = -0.569$ ($P < 0.001$) and 0.542 (P = 0.001) for the association between average

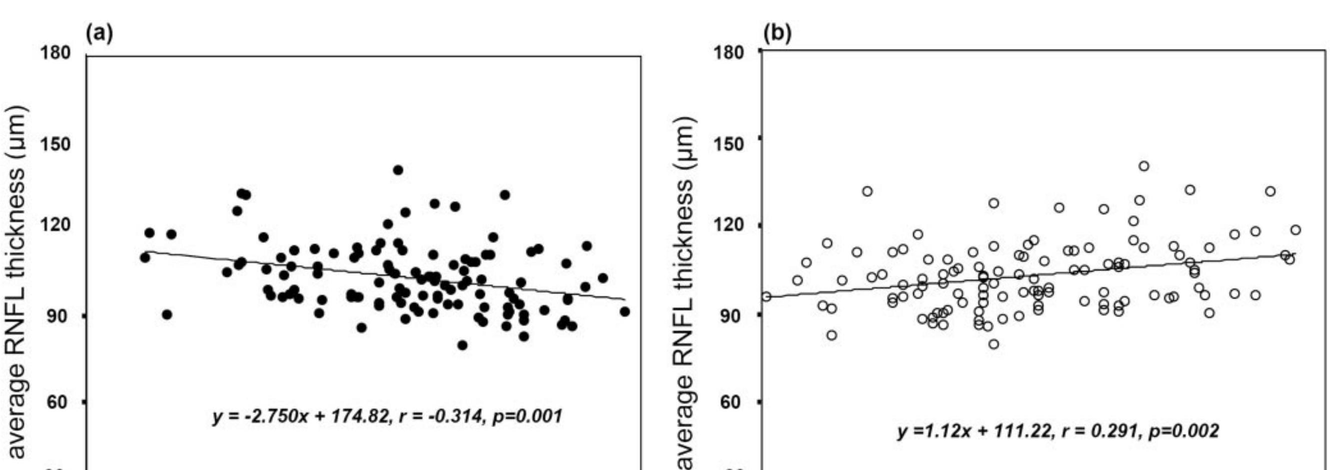

FIGURE 2. Scatter plots of the average RNFL thickness against the axial length (**a**) and the spherical equivalent (**b**).

Table 3. Correlation Analyses between Clock Hour RNFL Measurement and Axial Length/Spherical Equivalent (n = 115)

Clock Hours	AL		SE	
	r	***P***	***r***	***P***
12	−0.326	<0.001	0.264	0.004
1	−0.321	<0.001	0.252	0.007
2	−0.306	0.001	0.288	0.002
3	−0.210	0.024	0.207	0.027
4	−0.194	0.038	0.210	0.024
5	−0.248	0.008	0.263	0.005
6	−0.252	0.006	0.250	0.007
7	−0.219	0.019	0.246	0.008
8	0.037	0.692	−0.104	0.270
9	0.070	0.459	−0.070	0.460
10	0.068	0.473	−0.067	0.474
11	−0.180	0.054	0.132	0.158
Average thickness	−0.314	0.001	0.291	0.002

AL, axial length; SE, spherical equivalent; *r,* Pearson correlation coefficient.

RNFL thickness and axial length and spherical equivalent, respectively (Table 4).

Figure 3 presents the proportion of eyes identified as abnormal based on the normative database provided in StratusOCT. The RNFL measurement is classified as "outside normal limits" (signal in red) if it is below the 99% confidence interval of the age-matched RNFL thickness normogram. Values falling between the 95% and 99% confidence intervals are classified as "borderline" (signal in yellow). RNFL measurement at 2 o'clock (superonasal sector) was the location most frequently classified outside normal limits. Of the myopic eyes, 16.5% and 28.7% were identified as outside normal limits and borderline, respectively, at 2 o'clock (Fig. 3a). More eyes were classified as abnormal in the high myopia group than in the low-to-moderate myopia group (Figs. 3b 3c).

Discussion

In this OCT study, we found that RNFL measurements were lower in highly myopic eyes than in eyes with low to moderate myopia, and there was a linear correlation between RNFL thickness and axial length/spherical equivalent. Previous investigations on the relation between RNFL and refractive error have been essentially based on scanning laser polarimetry (SLP) without customized corneal birefringence compensation, and the findings have been equivocal.[13,14] Ozdek et al.[13] studied 85 subjects with myopia (age range, 7–83 years) with mean spherical equivalent of −4.56 ± 2.72 D using the first generation of SLP (NFA-I, NFA version 2.1.17; Diagnostic Technologies, San

Table 4. Correlation Analyses between Clock Hour RNFL Measurement and Axial Length/Spherical Equivalent in a Group Consisting of Only Young Subjects (Age, 25–29 years, n = 36)

Clock Hours	AL		SE	
	r	***P***	***r***	***P***
12	−0.481	0.003	0.581	<0.001
1	−0.489	0.002	0.504	0.002
2	−0.507	0.002	0.586	<0.001
3	−0.544	0.001	0.561	<0.001
4	−0.566	<0.001	0.577	<0.001
5	−0.466	0.004	0.467	0.004
6	−0.444	0.007	0.405	0.014
7	−0.203	0.236	0.153	0.373
8	0.097	0.575	−0.180	0.292
9	0.148	0.389	−0.193	0.259
10	0.052	0.765	−0.148	0.390
11	−0.532	0.001	0.407	0.014
Average thickness	−0.569	<0.001	0.542	0.001

AL, axial length; SE, spherical equivalent; *r,* Pearson correlation coefficient.

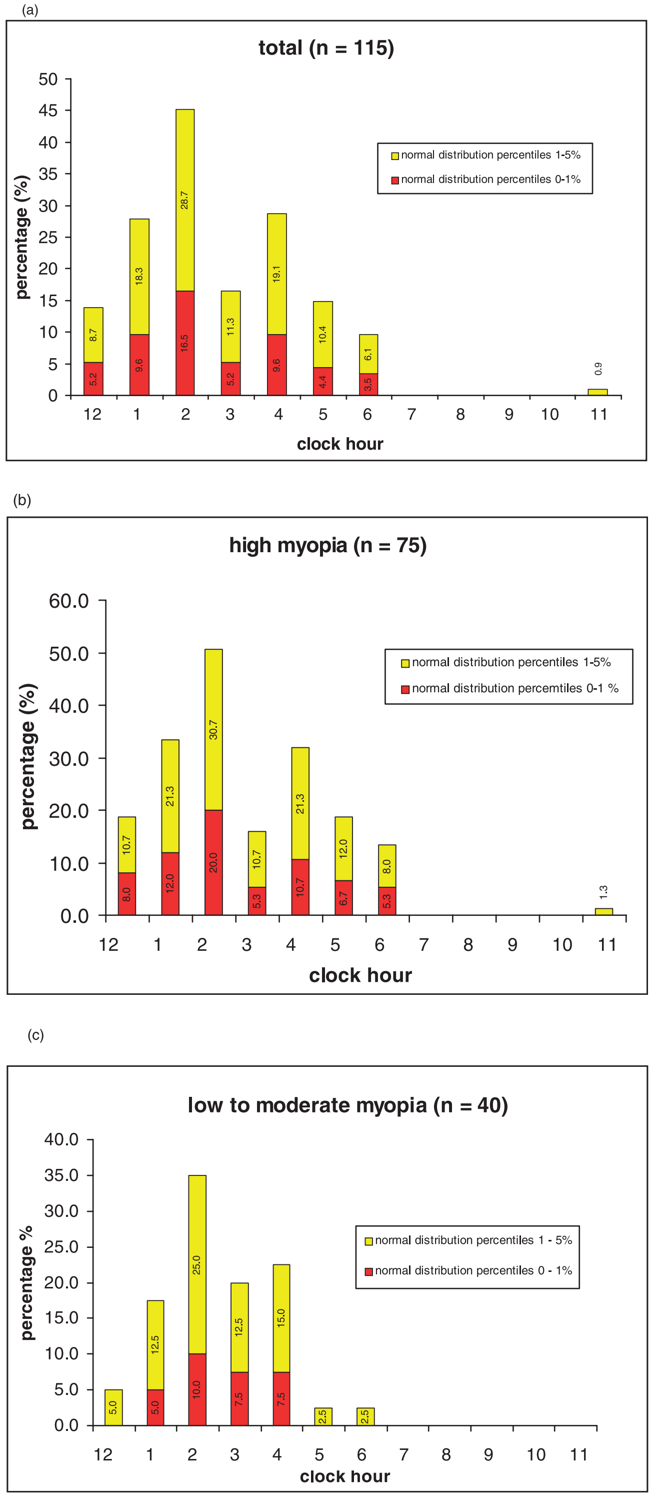

Figure 3. Bar charts showing the percentage of eyes classified as borderline (*yellow*) and outside normal limits (*red*) in total subjects (**a**), the high myopia group (**b**), and the low-to-moderate myopia group (**c**).

Diego, CA). They showed that there was a gradual decrease in the superior and inferior RNFL with increasing myopia. For each diopter decrease in spherical equivalent, there were 0.122- and 0.092-μm reductions in superior and inferior RNFL thicknesses, respectively. With the use of the nerve fiber analyzer (GDx; Carl Zeiss Meditec, Inc.), Kremmer et al.[14] also reported a linear correlation between average RNFL thickness and spherical equivalent (average RNFL thickness = $-2.848 \times$ SE + 78.529) in 75 myopic eyes of healthy volunteers (age range, 21–40 years; mean spherical equivalent = −4.6 D; range −0.75 to −8.5 D). However, no correlation was found between axial length and any of the GDx parameters. In the imaging study by Bowd et al.[15] in a group of 155 subjects (age range, 23.0–80.8 years; refractive error −5.0 to +5.0 D), it was concluded that refraction is not associated with any of the RNFL parameters measured by GDx or OCT (OCT1; Carl Zeiss Meditec, Inc.). In a recent study, Hoh et al.[16] also reported no correlation between axial length/spherical equivalent and the mean peripapillary RNFL measured by OCT1. Of note, Bozhurt et al.[17] showed that the average RNFL thickness measured by GDx in myopic eyes (n = 41; age range, 7–66 years; mean spherical refractive error = −12.5 ± 3.5 D; range, −7.50 to −22.00 D) was significantly higher than the age-matched healthy control eyes (mean spherical refractive error = −0.25 ± 0.50 D). The discrepancy was attributed to the high scleral reflectivity as a result of peripapillary chorioretinal atrophy associated with high myopia, which led to an apparent increase in retardation values.

Compared with OCT 1/2000, StratusOCT (both Carl Zeiss Meditec, Inc.) provides superior image quality and allows higher axial and transverse resolution scanning of the RNFL. It has been shown that poor-quality RNFL images are significantly more likely to be obtained with the OCT 1/2000 than with the StratusOCT.[18] The diagnostic sensitivity for detecting RNFL change in glaucoma is also higher with the StratusOCT than with OCT 1/2000.[18] Therefore, we believe the relationship between RNFL and refractive error could be assessed with higher accuracy by StratusOCT compared with the findings in previous studies. The collection of a relatively large number of highly myopic eyes (75 eyes had spherical equivalent < −6.0 D) in this study also allowed a better characterization in this relation. Our findings demonstrated a clear association between RNFL thickness and refractive error/axial length. The reduction of RNFL thickness with increasing axial length could be explained by the observation that there is increased scleral and retinal thinning in myopia.[19,20] In myopic eyes, the elongation of the globe leads to mechanical stretching and thinning of the retina. Therefore, it is conceivable that the extent of the elongation would be related to the degree of retinal thinning, although it is yet to be ascertained whether the RNFL thickness is decreased at the histologic level.

Population-based studies indicate that the risk of glaucoma increases with the increasing degree of myopia. The Blue Mountains Eye Study found a strong relationship between open-angle glaucoma and myopia, with an odds ratio of 2.3 in eyes with low myopia (between −1.0 and −3.0 D) and 3.3 in eyes with moderate-to-high myopia (< −3.0 D).[8] A large population-based study in Sweden with >32,000 subjects also identified myopia as an important risk factor for glaucoma.[9] Although the mechanisms responsible for the link between glaucoma and myopia are poorly understood, it has been postulated that the optic nerve head in myopic eyes may be structurally more susceptible to glaucomatous damage because of the changes in connective tissue structure and arrangement.[21,22] As the integrity of RNFL is a recognized surrogate for glaucomatous change, the finding of decreasing RNFL thickness with increasing myopia supports the conclusions of these population-based studies. On the one hand, the increased risk of development of glaucomatous change may be related to the already reduced RNFL thickness in myopic eyes. On the other hand, the reduced RNFL thickness in myopia may itself represent a risk factor for development of glaucoma. The lower RNFL measurement in highly myopic eyes would therefore translate to a higher risk. Further studies with longitudinal follow-up would be useful to address this question fully.

In this study, weak but significant correlations were also recorded between the visual field MD and the axial length (r = −0.197, P = 0.035)/spherical equivalent (r = 0.222, P = 0.017; Table 1). Several explanations have been proposed for the reduction in visual field sensitivity in myopia.[23] Retinal stretching in axial elongation may widen photoreceptor spacing and induce distortion of photoreceptors, resulting in decreased sensitivity to light stimulus. Reduced visual sensitivity may also be due to the relative scotoma induced by fundus ectasia. We found that the observed decline of visual sensitivity in myopia could also be related to the reduction in RNFL (r = 0.242, P = 0.009). Understanding this structure–function relationship may be important in unraveling the specific pattern of glaucomatous change in myopic subjects.

It remains unclear whether age could influence the thickness of the RNFL. Although some in vivo imaging studies have found significant correlations between age and the average RNFL thickness,[24–26] others have reported different results.[27–29] Funaki et al.[27] showed that RNFL thickness measured by SLP did not correlate significantly with age. Using StratusOCT, Ramakrishnan et al.[28] reported no correlation between age and RNFL thickness. In a recent study, Salchow et al.[29] also found age had no correlation with RNFL thickness as measured by StratusOCT after adjustment for refraction. All these studies were limited by cross-sectional design, and the potential confounding effect of refractive error was not considered in most studies. Although we did not find any association between age and RNFL thickness, we repeated the correlation analysis including only young subjects (25–29 years; n = 36), to minimize the potential confounding effect of age, and we found the same pattern of correlations. Apart from the temporal clock-hour RNFL thicknesses, for which no association with axial length/spherical equivalent was found, a higher coefficient of correlation was evident in each of the clock-hour RNFL measurements (Table 4).

An age-matched normative database consisting of 328 normal subjects of different ethnicity is available in the analysis package in StratusOCT and provides information on the normal limits of RNFL thickness.[12] This normative database was designed to provide a useful diagnostic aid in the detection of ocular disease involving RNFL. Jeoung et al.[30] have shown that the localized nerve fiber defect identified by this normative database had good agreement with that by red-free photographs in Asian eyes. However, the validity of applying this database to healthy subjects with myopia has not been verified. In this study, a considerable proportion of myopic eyes were classified outside normal limits on the nasal sectors (from 12 to 6 o'clock) based on this normative database. Ten percent of low-to-moderately myopic eyes were classified outside normal limits at 2 o'clock (superonasal sector) and the proportion increased to 20% in the high myopia group. Therefore, the normative database may not be reliable when analyzing RNFL in myopic subjects, and refractive error should always be considered in the interpretation of RNFL measurements. More data on RNFL measurements in myopia should be collected to refine the confidence limits in the current OCT normative database. It would also be of interest to examine whether there is any difference in RNFL measurements between Asian and non-Asian myopic eyes.

The default axial length in every OCT scan is 24.46 mm, and the scanning radius for the fast/standard RNFL scanning protocol is fixed at 1.7 mm. Although one can input the patient's axial length and refractive correction in OCT, it has no impact on the magnification during scanning. Therefore, the actual scanning radius in a myopic eye could be longer than 1.7 mm due to the magnification effect. The relationship between the measurement of the OCT image and the size of the actual fundus dimension can be expressed as $t = p \cdot q \cdot s$, where t is the actual fundus dimension, s is the measurement on OCT, p is a magnification factor related to the camera of the OCT imaging system, and q is a magnification factor related to the eye.[31] The correction factor q (in millimeters per degree) can be determined with the formula $q = 0.01306(x - 1.82)$, where x is the axial length.[32] Therefore, the actual scanning radius in an eye of axial length 28.79 mm (the longest axial length in our series) would be: $1.7 \times [0.01306(28.79 - 1.82)]/[0.01306(24.46 - 1.82)] = 2.0$ mm. Although the actual scanning radius is longer than 1.7 mm, it may not suggest that the RNFL is being measured farther from the disc margin. It is because the optic disc size may also increase with myopia.[33,34]

In summary, RNFL thickness decreases with the axial length and negative spherical equivalent of the eye. Although both highly and low-to-moderately myopic eyes have similar double-hump RNFL profiles, highly myopic eyes have significantly lower RNFL thickness than do low-to-moderately myopic eyes. As corrections for refractive error and axial length in the measurement of RNFL have not been incorporated in the StratusOCT, RNFL measurements should be interpreted carefully in myopic subjects and should not just rely on the normative database.

References

1. Katz J, Tielsch JM, Sommer A. Prevalence and risk factors for refractive errors in an adult inner city population. *Invest Ophthalmol Vis Sci*. 1997;38:334–340.
2. Wang Q, Klein BE, Klein R, Moss SE. Refractive status in the Beaver Dam Eye Study. *Invest Ophthalmol Vis Sci*. 1994;35:4344–4347.
3. Wong TY, Foster PJ, Hee J, et al. Prevalence and risk factors for refractive errors in adult Chinese in Singapore. *Invest Ophthalmol Vis Sci*. 2000;41:2486–2494.
4. Seet B, Wong TY, Tan DT, et al. Myopia in Singapore: taking a public health approach. *Br J Ophthalmol*. 2001;85:521–526.
5. Leung CK, Chan WM, Yung WH, et al. Comparison of macular and peripapillary measurements for the detection of glaucoma: an optical coherence tomography study. *Ophthalmology*. 2005;112:391–400.
6. Hoffmann EM, Medeiros FA, Sample PA, et al. Relationship between patterns of visual field loss and retinal nerve fiber layer thickness measurements. *Am J Ophthalmol*. 2006;141:463–471.
7. Medeiros FA, Zangwill LM, Bowd C, et al. Comparison of the GDx VCC scanning laser polarimeter, HRT II confocal scanning laser ophthalmoscope, and StratusOCT optical coherence tomograph for the detection of glaucoma. *Arch Ophthalmol*. 2004;122:827–837.
8. Mitchell P, Hourihan F, Sandbach J, et al. The relationship between glaucoma and myopia: the Blue Mountains Eye Study. *Ophthalmology*. 1999;106:2010–2015.
9. Grodum K, Heijl A, Bengtsson B. Refractive error and glaucoma. *Acta Ophthalmol Scand*. 2001;79:560–566.
10. Budenz DL, Chang RT, Huang X, et al. Reproducibility of retinal nerve fiber thickness measurements using the StratusOCT in normal and glaucomatous eyes. *Invest Ophthalmol Vis Sci*. 2005;46:2440–4.
11. Paunescu LA, Schuman JS, Price LL, et al. Reproducibility of nerve fiber thickness, macular thickness, and optic nerve head measurements using StratusOCT. *Invest Ophthalmol Vis Sci*. 2004;45:1716–1724.
12. Patella VM. *StratusOCT—Establishment of Normative Reference Values for Retinal Nerve Fiber Layer Thickness Measurements*. Dublin, CA: Carl Zeiss Meditec, Inc.; 2003.
13. Ozdek SC, Onol M, Gurelik G, et al. Scanning laser polarimetry in normal subjects and patients with myopia. *Br J Ophthalmol*. 2000;84:264–267.
14. Kremmer S, Zadow T, Steuhl KP, et al. Scanning laser polarimetry in myopic and hyperopic subjects. *Graefes Arch Clin Exp Ophthalmol*. 2004;242:489–494.
15. Bowd C, Zangwill LM, Blumenthal EZ, et al. Imaging of the optic disc and retinal nerve fiber layer: the effects of age, optic disc area, refractive error, and gender. *J Opt Soc Am A Opt Image Sci Vis*. 2002;19:197–207.
16. Hoh ST, Lim MC, Seah SK, et al. Peripapillary retinal nerve fiber layer thickness variations with myopia. *Ophthalmology*. 2006;113:773–777.
17. Bozkurt B, Irkec M, Gedik S, et al. Effect of peripapillary chorioretinal atrophy on GDx parameters in patients with degenerative myopia. *Clin Exp Ophthalmol*. 2002;30:411–414.
18. Bourne RR, Medeiros FA, Bowd C, et al. Comparability of retinal nerve fiber layer thickness measurements of optical coherence tomography instruments. *Invest Ophthalmol Vis Sci*. 2005;46:1280–8.
19. Apple DJ, Fabb MF. Clinicopathologic correlation of ocular disease: a text and stereoscopic atlas. St. Louis: CV Mosby; 1978:39–44.
20. Yanoff M, Fine BS. *Ocular Pathology: A Text and Atlas.* Philadelphia: Harper & Row; 1982:513–514.
21. Curtin BJ, Iwamoto T, Renaldo DP. Normal and staphylomatous sclera of high myopia: an electron microscopic study. *Arch Ophthalmol*. 1979;97:912–915.
22. Cahane M, Bartov E. Axial length and scleral thickness effect on susceptibility to glaucomatous damage: a theoretical model implementing Laplace's law. *Ophthalmic Res*. 1992;24:280–284.
23. Rudnicka AR, Edgar DF. Automated static perimetry in myopes with peripapillary crescents. Part II. *Ophthalmic Physiol Opt*. 1996;16:416–429.
24. Schuman JS, Hee MR, Puliafito CA, et al. Quantification of nerve fiber layer thickness in normal and glaucomatous eyes using optical coherence tomography. *Arch Ophthalmol*. 1995;113:586-.
25. Kanamori A, Escano MF, Eno A, et al. Evaluation of the effect of aging on retinal nerve fiber layer thickness measured by optical coherence tomography. *Ophthalmologica*. 2003;217:273–278.
26. Toprak AB, Yilmaz OF. Relation of optic disc topography and age to thickness of retinal nerve fibre layer as measured using scanning laser polarimetry, in normal subjects. *Br J Ophthalmol*. 2000;84:473–478.
27. Funaki S, Shirakashi M, Abe H. Relation between size of optic disc and thickness of retinal nerve fibre layer in normal subjects. *Br J Ophthalmol*. 1998;82:1242–1245.
28. Ramakrishnan R, Mittal S, Ambatkar S, et al. Retinal nerve fibre layer thickness measurements in normal Indian population by optical coherence tomography. *Indian J Ophthalmol*. 2006;54:11–15.
29. Salchow DJ, Oleynikov YS, Chiang MF, et al. Retinal nerve fiber layer thickness in normal children measured with optical coherence tomography. *Ophthalmology*. 2006;113:786–791.
30. Jeoung JW, Park KH, Kim TW, et al. Diagnostic ability of optical coherence tomography with a normative database to detect localized retinal nerve fiber layer defects. *Ophthalmology*. 2005;112:2157–2163.
31. Littmann H. Determination of the real size of an object on the fundus of the living eye. *Klin Monatsbl Augenheilkd*. 1982;180:286–289.
32. Bennett AG, Rudnicka AR, Edgar DF. Improvements on Littmann's method of determining the size of retinal features by fundus photography. *Graefes Arch Clin Exp Ophthalmol*. 1994;232:361–367.
33. Jonas JB. Optic disk size correlated with refractive error. *Am J Ophthalmol*. 2005;139:346–348.
34. Wang Y, Xu L, Zhang L, et al. Optic disc size in a population based study in northern China: the Beijing Eye Study. *Br J Ophthalmol*. 2006;90:353–356.