Use of Optical Coherence Tomography to Assess Variations in Macular Retinal Thickness in Myopia

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PURPOSE. To investigate the variation in macular retinal thickness in otherwise normal young Asian myopic subjects by using optical coherence tomography (OCT).

METHODS. One hundred thirty ophthalmically normal men 19 to 24 years of age with myopia (spherical equivalent, −0.25 to −14.25 D) underwent examination of one randomly selected eye. Visual acuity, refraction, slit lamp examination, applanation tonometry, gonioscopy, A-scan ultrasound, fundus examination, visual field testing, and optic disc photography were performed. Exclusion criteria were visual acuity worse than 20/30, previous intraocular surgery, intraocular pressure >21 mm Hg, or other ocular diseases. Three horizontal transfixation and three vertical transfixation OCT scans (ver.4.1; Carl Zeiss Meditec, Dublin, CA) of 6 mm each were conducted on each eye by a single operator. Neurosensory retinal thicknesses at 100 points along each scan were measured, and the overall average, maximum, and minimum retinal thicknesses were analyzed by simple linear regression and analysis of variance.

RESULTS. The average macular retinal thickness (overall) was 230.9 ± 10.5 μm and was not significantly related to the degree of myopia. The mean maximum retinal thickness (at the parafovea) was 278.4 ± 13.0 μm, and correlated negatively with axial length (P = 0.03). The mean minimum retinal thickness (at the foveola) was 141.1 ± 19.1 μm, and this was positively correlated with axial length (P = 0.015) and spherical equivalent (P = 0.0002). The retina was thicker at the superior and nasal parafovea compared to the inferior or temporal parafovea.

CONCLUSIONS. Average retinal thickness of the macula does not vary with myopia. However, the parafovea was thinner and the fovea thicker with myopia. (Invest Ophthalmol Vis Sci. 2005;46:974–978) DOI:10.1167/iovs.04-0828

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Optical coherence tomography (OCT) is a new noninvasive technique that can be used to measure retinal thickness using time delays of reflected or backscattered light and interferometry.1,2 It is increasingly being used to image lesions at the macula, such as macular thickening in diabetic macular edema.3 OCT may also have a role in the clinical assessment of glaucoma, as recent studies have shown macular and peripapillary thinning in glaucomatous eyes.4–6

Myopia is increasing in prevalence in East Asia. This trend has been documented in Taiwan7 and Singapore.8 Estimates of the proportion of myopia in the young population of Singapore range from 30% to 65%.8–10 According to the histopathologists Yanoff and Fine,11 in high myopia (generally greater than −6.00 D), the retina thins and degenerates, especially at the posterior pole. These changes in the myopic retina with increase in myopia and axial length may confound retinal thickness measurements by OCT. The purpose of our study was to investigate the variations in macular retinal thickness with myopia in a demographically homogenous group of young healthy male subjects.

METHODS

One hundred thirty myopic Asian men with various degrees of myopia were randomly recruited from a cohort of 15,000 Singaporean National Service enlisting between July 1996 and July 1997. Informed consent was obtained from all study subjects, and the project had the approval of the ethics committees of the Singapore Eye Research Institute and the Defence Medical Research Institute, Singapore. This work was performed in accordance with The World Medical Association’s Declaration of Helsinki.

Study subjects had participated in an earlier study that assessed the influence of myopia and its method of correction on automated static perimetry.12 The methodology of the study has been described previously, a summary of which is provided herein. All the subjects were ophthalmically normal. In one randomly selected eye, a complete ocular examination was conducted that included measurement of best corrected visual acuity, subjective refraction, slit lamp examination, Goldmann applanation tonometry, gonioscopy, A-scan ultrasound biometry, dilated fundus examination with a 78-D fundus lens, visual field testing in the form of static automated white-on-white threshold perimetry (program 24-2, model 750; Carl Zeiss Meditec, Dublin, CA), and OCT. Exclusion criteria were best corrected visual acuity worse than 6/9; previous intraocular or refractive surgery; IOP greater than 21 mm Hg; gonioscopic findings of angle closure; evidence of pseudoexfoliation, uveitis, or pigment dispersion syndrome; corneal or media opacities, retinal disease; or neurologic conditions that could affect visual fields. In addition, a history of glaucoma in a first-degree relative and a history of glaucoma or any other optic neuropathy were exclusion criteria. Apart from optic disc and peripapillary changes associated with myopia, subjects did not have any other ocular abnormalities.

Optical Coherence Tomography

OCT (Carl Zeiss Meditec, Dublin, CA) was performed by the same operator (STH) and analyzed with the version 4.1 software. The OCT instrumentation (first generation) and imaging technique have been...
described in detail elsewhere.1–5 Pupils were dilated to at least 5-mm diameter during the OCT examination. All eyes’ axial lengths and refractive errors were entered into the machine. Correction for magnification errors were provided by means of the Littman formula-based correction factors implemented in the software. Scan length was adjusted to 6 mm before scanning, to allow for correction of scan size for magnification error. The scanner was calibrated with a Gullstrand model eye before each session. An automated computer algorithm developed by the manufacturer analyzed optical scattering properties of the retinal layers based on the threshold values calculated from the overall signal quality of the longitudinal (z-axis) OCT scan. Retinal thickness was measured automatically with the retinal thickness algorithm built into version 4.1 of the OCT software, which automatically determines the anterior and posterior borders of the internal limiting membrane and retinal pigment epithelium respectively. The operator simply read off the vertical thicknesses from the individual A-scan measurements. Horizontal and vertical 6-mm scans centered against the point of fixation of each eye were taken by the same operator (STH). Three good-quality horizontal and three good-quality vertical scans were retained for analysis. Each scan was composed of 100 A-mode scans providing 100 data points of retinal thickness. The version 4.1 software did not have the capability of providing a mean retinal thickness of all 100 data points for each scan. The operator recorded the retinal thickness measurements manually at 10 evenly spaced points along each scan, starting with point 10, 20, 30, and so on, until point 100 was reached (Fig. 1).

Two points of maximum retinal thickness (RT-Max) measured on either side of the fovea were recorded from each scan (Fig. 2). These readings were presumed to correspond to the parafoveal crests and generally lay around points 25 and 75 (of 100). From the direction of the scan, it was also possible to correspond the point to the area of the macula—that is, superior, inferior, temporal, or nasal to the fovea and these were termed RT-Max (sup), RT-Max (inf), RT-Max (temp), and RT-Max (nas), respectively. One point of minimum retinal thickness measurement, which is presumed to correspond to the fovea (RT-Min) and that lay around point 50, was also recorded (Fig. 2).

Data Analysis

All data were analyzed on computer (Statistical Package for Social Sciences, ver. 11.0; SPSS Inc, Chicago, IL), and statistical significance was assumed at the \( P < 0.05 \) level. Descriptive statistics, simple linear regression, and analysis of variance (ANOVA) were performed on the data.

RESULTS

Of the 130 study subjects, there were 111 Chinese (85.4%), 12 Malays (9.2%), and 7 Indians (5.4%), and the average age was 21.2 ± 1.1 years (range, 19–24). The mean spherical equivalent was −5.9 ± 3.5 D (range, −0.25 to −14.25 D). Forty-six (55%) subjects ranged from −0.25 to −4.00 D, 49 (38%) from greater than −4.00 to −8.00 D and 35 (27%) greater than −8.00 D. The mean axial length was 26.0 ± 1.43 mm (range, 23.22–29.23). The longest axial length of 29.23 mm was within the focusing range of the machine. The axial length correlated significantly with the spherical equivalent (Pearson correlation coefficient = −0.84, \( P < 0.0001 \)). Simple regression of RT-Min...
measurement variance as the dependent variable and axial length as the independent variable yielded \( P = 0.26 \).

The OCT macular thickness measurements are summarized in Table 1. The average macular thickness (overall) was 230.9 ± 10.5 μm. ANOVA showed no difference between myopia and mean macular thickness (\( P = 0.73 \)). Using simple linear regression, mean macular thickness did not relate to axial length (\( P = 0.37 \)) or to spherical equivalent (\( P = 0.69 \)). The mean RT-Max was 278.4 ± 13.0 μm. RT-Max showed a negative correlation with axial length (\( P = 0.03 \)) with a slope of -1.77 μm/mm (Fig. 3), but was not correlated with spherical equivalent (\( P = 0.48 \)). The mean RT-Max (sup), RT-Max (inf), RT-Max (temp), and RT-Max (nas) were 288.3 ± 20.7, 278.4 ± 16.5, 262.2 ± 14.6, and 284.2 ± 17.1 μm, respectively. RT-Max (sup) decreased with increasing axial length (\( P = 0.003 \)) at a rate of -3.27 μm/mm. RT-Max (inf) decreased with increasing axial length (\( P = 0.008 \)) at a rate of -2.47 μm/mm. RT-Max (temp) and RT-Max (nas) were not related to axial length. The mean RT-Min was 141.1 ± 19.1 μm. RT-Min increased with axial length (\( P = 0.015 \); Fig. 4) and increasing spherical equivalent (\( P = 0.0002 \)).

Figure 5 shows the lack of relationship between the variance of RT-Min measurements and increasing axial length (\( P = 0.26 \)).

**DISCUSSION**

This study has shown that in a young healthy cohort of myopic subjects, overall average macular retinal thickness does not vary with increasing myopia or axial length. This is in agreement with recent reports in which OCT was used to investigate retinal thickness variations in myopia. Our results contrast with histologic descriptions of increasing scleral and retinal thinning with myopia. In another study, chorioretinal atrophy in the posterior pole was found to be more frequent in eyes of longer axial length. We believe that the disparity in our findings may be related to the different approach used to measure retinal thickness, with OCT retinal measurements having been shown to be highly reproducible, being more sensitive in detecting subtle and regional variations in retinal thickness compared to histologic mounts and their susceptibility to shrinkage and processing artifacts. Another study showed increasing chorioretinal degeneration in the peripheral fundus with myopia. Unfortunately, it is difficult to measure peripheral retinal thickness at present with the OCT. One report using ultrasound and Fourier analysis showed that the midperipheral retina in myopic eyes was thinner than in emmetropic eyes. If this is the case, then retinal thinning in myopia may be more common in the peripheral retina.

The overall average macular thickness in this study was 230.9 ± 10.5 μm, which compares favorably with the thickness in Wakitani et al. of 251 ± 15 μm and in Hee et al. of 250 ± 15 μm. Subjects in the former study were a mixture of male and female with mean age 46.2 ± 15.9 years (range, 12–74). In a similarly heterogeneous group, Asrani et al. found an average posterior pole retinal thickness of 229 μm. The similar values of mean macular thickness found in these studies suggests that there may not be great variation in aver-
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age retinal thickness with age,\textsuperscript{18,19} though one Japanese paper on OCT reported macular retinal thinning with age.\textsuperscript{20}

We observed regional differences in parafoveal retinal thickness in different sectors of the macula. The maximum parafoveal thickness at the superior, inferior, temporal, and nasal regions were 288.3 \( \pm \) 20.2, 278.4 \( \pm \) 16.3, 262.2 \( \pm \) 14.6, and 284.2 \( \pm \) 17.1 \( \mu \text{m} \), respectively, indicating that the retina is thickest in the superior and nasal parafovea. This is consistent from results in other studies showing maximum thickness at the superior and nasal parafoveal quadrants.\textsuperscript{18}

Our study showed that the point of maximum retinal thickness on either side of the fovea, which we assume to correspond to the parafovea, decreased with increasing axial length (Fig. 2), whereas minimum thickness corresponding to foveolar thickness increased. From the scatterplot (Fig. 3), it is evident that this is a linear relationship, and we used unstandardized univariate linear regression for this analysis. In contrast, Wakitani et al.\textsuperscript{13} did not note any change in foveolar or parafoveal thicknesses with increasing myopia. They calculated average thicknesses for three concentric zones: 350, 1850, and 2850 \( \mu \text{m} \) in diameter and compared the groups with an ANOVA. For their data, perhaps a simple regression would yield results similar to ours. Subjects in that study were also more heterogeneous, whereas our subjects were all men and of a similar age.

FIGURE 5. Relationship between variance of RT-Min measurements and increasing axial length.

Looking on in isolation, the finding of decreasing parafoveal thickness with myopia may be consistent with retinal thinning in this region. However, when we found simultaneous increasing foveolar thickness, the possibility of poorer fixation with high myopia arose, as fixation not through the fovea would produce overestimated foveal thicknesses, perhaps because in our version of OCT scanning, using version 4.1 software, the landmark point is used as a fixation target. The subjects were told to fixate this target, and the scans were positioned over it, giving rise to transfixation scans. Therefore, the scans were obtained over the points of fixation but this does not guarantee that they correspond to the foveola of subjects. Off-foveola fixation may have resulted in larger foveolar thickness measurements.

However, our subjects fixated quite consistently. Evidence of this is shown in the scatterplot (Fig. 5) showing the relationship between variance of RT-Min measurements and increasing axial length, which does not show any evidence of increasing variance with increasing axial length (\( P = 0.26, R^2 = 0.0097 \)). If fixation was inconsistent with increasing myopia, then the variance of measurements through the thinnest point of the retina should be significantly higher.

The mean thickness of the thinnest retinal thickness point was 141.1 \( \pm \) 19.1 \( \mu \text{m} \), remarkably similar to the mean thickness of the foveola of 142 \( \pm \) 18 \( \mu \text{m} \), as measured by Gobel et al.\textsuperscript{21} in subjects ranging from 13 to 92 years of age, and by Kanai et al.\textsuperscript{20} (142 \( \pm \) 15 \( \mu \text{m} \) ), and it suggests that the thinnest point we measured was indeed the foveola. From our results, it can be concluded that the variation in thickness between the foveal pit and parafoveal crest decreases in increasing myopia. In effect, the macular area might be said to become flatter.

Our results may be affected by enrollment bias, as the study subjects recruited were all young and had good visual acuity with no evidence of retinal degeneration. It is likely that older myopic subjects may have greater ocular morbidity related to myopia. In summary, we have found unique variations in macular thickness with myopia. Although overall mean macular thickness is not affected by degree of myopia, there is evidence that the thickest point at the parafoveal region decreases with myopia, whereas the fovea thickness increases with myopia. These variations in macular thickness should be considered in the evaluation of retinal diseases and glaucoma using the OCT.

References


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