

# Assessment of macular retinal thickness and volume in normal eyes and highly myopic eyes with third-generation optical coherence tomography

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CLINICAL STUDY

## Abstract

**Purpose** To compare the macular retinal thickness and macular volume between subjects with high myopia and non-myopia.

**Methods** This prospective nonrandomized, comparative study recruited healthy subjects with high myopia subjects, defined as a spherical equivalence (SE) over  $-6$  dioptres (D) or AXL  $\geq 26.5$  mm and the best corrected visual acuity better than 20/25, and subjects with non-myopia, defined as an with SE between 1.5D and  $-1.5$  D and the BCVA better than 20/25. Optical coherence tomography was performed in each eye.

**Results** Eighty high myopic eyes and 40 non-myopic eyes were included. The mean age of the high myopic group and non-myopia group was 29.6 and 27.5 years old, respectively. The mean refraction was  $-9.27$  D in the high myopia group and  $-0.22$  D in the non-myopia group. The high myopia group had significantly greater mean retinal thickness in the foveola and fovea 1 mm area than the non-myopia group (166 vs 149  $\mu\text{m}$ ,  $P < 0.0001$ , 199 vs 188  $\mu\text{m}$ ,  $P = 0.0063$ , respectively). However, the mean retinal thickness in the inner and outer macular area (superior, nasal, inferior, or temporal) of the high myopia group was significantly less than in the non-myopia group. In addition, the high myopia group had significantly smaller macular volume than the non-myopia group ( $P < 0.0001$ ).

**Conclusion** This study demonstrated that the retinal thickness in individuals with high myopia is thicker in the foveola and fovea, but

thinner in the inner and the outer macular region. The retina of individuals with high myopia had smaller macular volume than those with non-myopia.

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**Keywords:** myopia; fovea; macula; retinal thickness; optic coherence tomography

## Introduction

Optical coherence tomography (OCT) is an objective method that provides useful information regarding macular characteristics and relative morphological changes.<sup>1–4</sup> Third-generation OCT (OCT-3) is a recent modification of this method, which provides a better resolution than first-generation OCT.

Myopia is a highly prevalent condition with reported rates as high 80% in South-East Asia and 25% in the West.<sup>5–7</sup> High myopia is typically defined as in excess of 6 dioptres (D). High myopia is invariably attributable to increased eye size. Excessively large eyes are also at great risk of developing sight-threatening pathology of the retina and choroids.<sup>8,9</sup> Recent studies using OCT demonstrated asymptomatic macular holes and myopic traction maculopathy in highly myopic eyes.<sup>10,11</sup> The purpose of this study was to use OCT to evaluate the variations in macular retinal thickness in normal eyes and otherwise healthy highly myopic eyes.

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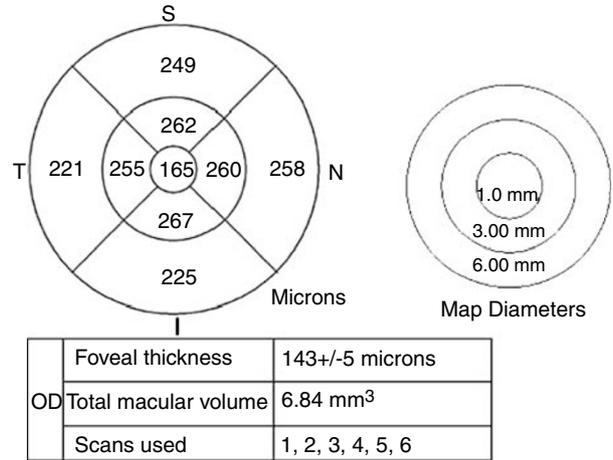
This work has previously been presented at the 21st Congress of the Asia-Pacific Academy of Ophthalmology

**Materials and methods**

Subjects for this study were recruited from among young adults aged from 18 to 40 who visited the ophthalmology clinic of Chang Gung Memorial Hospital, Kaohsiung Medical Center between December 2004 and December 2005. Subjects with the diagnosis of high myopia as well as healthy controls meeting eligibility requirements were eligible for participation. This study was approved by the hospital's institutional review board and was carried out in accordance with the World Medical Association's Declaration of Helsinki. Informed consents were obtained for each subject before enrolment. Patients enrolled in this study underwent a complete ophthalmologic examination, which included the following: best-corrected visual acuity testing; intraocular pressure measurement; slit-lamp examination; dilated slit-lamp examination with stereo biomicroscopy; and indirect ophthalmoscopy. A-scan test were obtained. OCT-3 was performed on one or both eyes of each subject after pupil dilation.

A normal eye was defined as having spherical equivalence refraction (SE) between +1.5 and -1.5 D. Otherwise healthy highly myopic eyes were defined as having an SE less than -6D. In addition, the best corrected visual acuity in each eye of both groups was better than 16/20. Exclusion criteria were as follows: visual acuity worse than 16/20; previous intraocular surgery; coexisting retinal diseases and uveitis; corneal abnormalities; media opacities; and glaucoma.

The OCT-3 system used in this study (model 3000, software version B 3.0) (Carl Zeiss Meditec, Dublin, CA, USA) permits cross sectional imaging by acquiring a sequence of 128 interferometric axial reflectance profiles (A-scans) of the retina. The OCT-3 fast scan protocol completed total data acquisition in 1.92 s. To obtain a map of retinal thickness at the macula, six equally spaced intersecting radial scans through the centre of the fovea were performed. Each radial scan had a diameter of 6.0 mm and comprised a circular area centred on the fovea. Again, the OCT-3 fast scan protocol was used, with each radial line consisting of 128 A-scans (768 total A-scans). Foveola thickness and fovea thickness within 1 mm concentric diameter were determined using the commercial OCT-3 B 3.0 software. Foveola thickness was calculated from the mean of the central point of foveal thickness. Average thickness values within four quadrants (superior, temporal, inferior, and nasal) were calculated in each of two concentric circles outside the fovea central circle of 1 mm diameter. The outer circle diameters of 3 mm and 6 mm represented the inner and outer macular area, respectively (Figure 1). Data from the superior, temporal, inferior and nasal quadrants of the outer ring, as well as the total macular volume of the



**Figure 1** Schematic diagrams of ocular coherence tomography scans of the right eye showing foveal thickness in a 1 mm concentric diameter and inner and outer macular thickness in the superior, temporal, and inferior positions. S: superior. N: nasal. I: inferior. T: temporal. The inferior column shows the foveolar thickness and total macular volume. Foveolar thickness was calculated from the central point of foveal thickness. Total macular volume is also shown in the column.

entire scan area were recorded. Ophthalmic photographers who were trained in the use of the OCT-3 system performed all OCT scans through a dilated pupil.

Statistical analysis was performed using the Statistical Package for Social Sciences (version 11.0, SPSS Inc., Chicago, IL, USA). Because of the non-normal distribution of these data, Mann-Whitney U test was used to generate *P*-values between the two groups. The association with categorical variables was assessed using a  $\chi^2$  test. *P* < 0.05 was defined as statistically significant.

**Results**

One hundred twenty eyes of 73 patients were included in this cross-sectional study. Eighty of the eyes of these patients met criteria for high myopia and 40 eyes met the criteria for normal (Table 1). The mean age  $\pm$  SD was 29.58  $\pm$  6.26 years (range, 18–40 years) in the non-myopia group and 27.50  $\pm$  6.72 years (range, 18–40 years) in the high myopia group. There was no significant difference in the mean age of patients in the two groups (*P* = 0.102). The mean SE  $\pm$  SD was -0.22  $\pm$  0.50 D (range from -1.25 to 0.5 D) in the non-myopia group and -9.27  $\pm$  3.30 D (range from -6 to -15.5 D) in the high myopia group (*P* < 0.0001). The mean axial length  $\pm$  SD was 23.13  $\pm$  0.54 mm (range, 22.00–23.97 mm) in the non-myopia group and 28.15  $\pm$  1.45 mm (range, 25.65–31.48 mm) in the high myopia group (*P* < 0.0001).

Highly myopic eyes had greater retinal thickness (microns) than normal eyes in both the foveola and fovea (166 vs 149  $\mu$ m, *P* < 0.0001, 199 vs 188  $\mu$ m, *P* = 0.0063,

**Table 1** Demographic characteristics in non-myopic and high myopic group

	Non-myope	High myope	P-value
Eyes	40	80	
Age	29.58±6.26	27.50±6.72	0.102
Sex (M/F)	20/20	38/42	0.848
Laterality (OD/OS)	17/23	39/41	0.564
Spherical equivalence (D)	-0.22±0.50	-9.27±3.30	<0.0001*
Axial length (mm)	23.13±0.54	28.15±1.45	<0.0001*

Data represents Mean±SD; \*represents statistically significance.

**Table 2** Retinal thickness ( $\mu\text{m}$ ) macula volume ( $\mu\text{m}^3$ ) in macula region

Location (concentric circle diameter)	Non-myopia	High myopia	P-value
Foveola	149.1±15.2	165.7±19.0	<0.0001*
Fovea (1 mm)	187.6±17.8	199.2±18.7	0.0063*
<i>Inner macula</i>			
Superior (3 mm)	280.9±13.5	265.3±18.0	<0.0001*
Nasal (3 mm)	279.8±15.8	265.7±17.7	<0.0001*
Inferior (3 mm)	276.8±14.5	260.0±15.7	<0.0001*
Temporal (3 mm)	263.9±13.5	250.7±15.4	<0.0001*
<i>Outer macula</i>			
Superior (6 mm)	249.5±12.6	231.0±18.4	<0.0001*
Nasal (6 mm)	267.4±16.7	248.5±17.2	<0.0001*
Inferior (6 mm)	237.8±13.9	212.3±15.0	<0.0001*
Temporal (6 mm)	228.8±12.8	205.3±13.4	<0.0001*
Macular volume	7.10±0.34	6.56±0.40	<0.0001*

\*Signifies the P-values.

respectively, Table 2). However, highly myopic eyes had thinner retinal thickness than normal eyes in both the mean inner and outer macular thickness of the four quadrants. Highly myopic eyes had smaller mean macular volume than normal eyes ( $6.56 \text{ mm}^3$  vs  $7.10 \text{ mm}^3$ ,  $P < 0.0001$ ).

Representative OCT scans are shown for a patient with two normal eyes in Figure 2a, and for a patient with highly myopic eyes (SE: OD -7.75 D, OS -10.13 D) in Figure 2b.

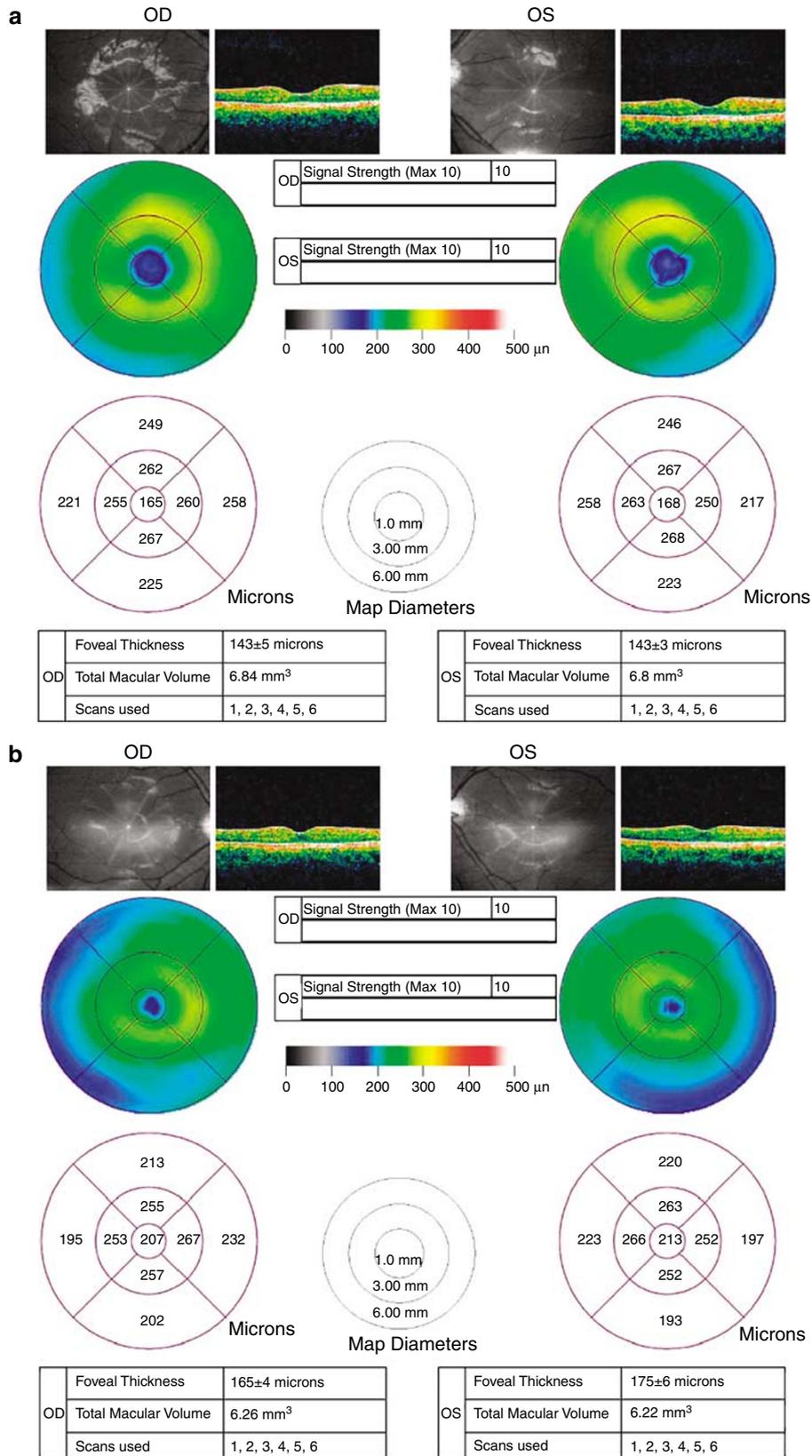
## Discussion

This study has demonstrated that highly myopic eyes of young adults (aged from 18 to 40 years) have thinner retinal thickness than normal eyes in inner and outer macular area, and smaller total macular volume. However, highly myopic eyes were also shown to have greater retinal thickness in the foveola and fovea than

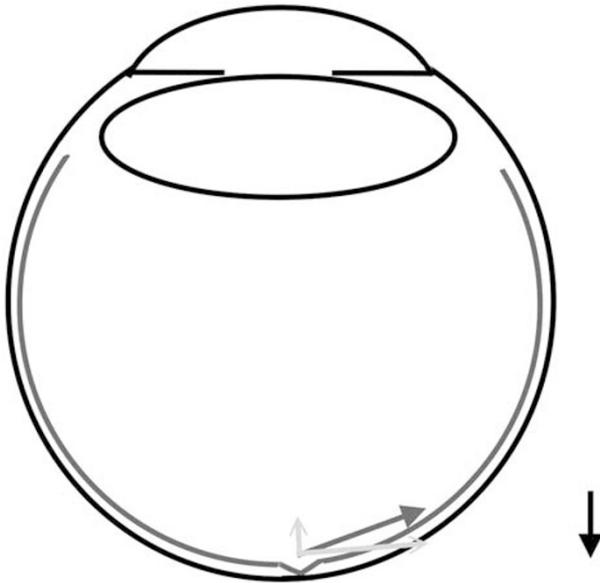
non-myopic eyes. There were similar results reported in Singaporean children aged from 11 to 12 years.<sup>12</sup>

The findings of small total macular volume and lesser retinal thickness in the inner and outer macular region in this study agree with histological findings of increasing scleral and retinal thinning with myopia.<sup>13</sup> In addition, photoreceptor cell degeneration was previously demonstrated by TdT-mediated biotin-dUTP nicked-end labelling stain in pathologic myopia.<sup>14</sup> Another study showed lesser mean retinal thickness in patients with high myopia patients than in controls.<sup>15</sup> However, there are discrepancies among the results of previous OCT studies in myopia. Lim *et al*<sup>16</sup> showed that average retinal thickness of the macula did not vary with myopia. This difference might have been due to their study design with linear regression method to compare of myopia groups with different degree in contrast to case-control study with highly myopic eyes as in the present study. Average retinal thickness does not accurately represent the difference in the two groups of this study owing to the differences in retinal thickness of different sectors, such as the greater thickness of the superior and nasal inner macula compared with the inferior or temporal inner macula in both normal eyes and myopic eyes.<sup>16,17</sup> Total macular volume might therefore be a more appropriate parameter than average retinal thickness for assessing these differences.

In this study, highly myopic eyes were found to have greater foveolar and fovea retinal thickness. The highly myopic subjects in this series were young, and had otherwise healthy ocular status and good vision. Although off-foveola fixation may occur in highly myopic eyes and result in overestimation of foveal thicknesses, we carefully checked the colour map of each eye. If the fovea area was off-centre, then repeat OCT scans were performed until the fovea was within the centre of the colour map. Lim *et al*<sup>16</sup> also showed that the inner macula was thinner and the fovea thicker in patients with myopia. We propose that this phenomenon may be due to the increased axial length of the enlarged eyeball, resulting in mechanical stretching of the sclera. Under this condition, retinal stretching would also occur with panretinal thinning. On the other hand, the stretching and flattening tendency of the internal limiting membrane and the centripetal force of the posterior vitreous result in elevation of the foveola and fovea. (Figure 3) With aging, in addition to mechanical stretching of the eyeball, these factors might play an important role in the development of myopic fundus changes.<sup>18</sup> The elevated foveola and fovea area in young, healthy highly myopic eyes might explain the high incidence of macular hole, which may be associated with retinal detachment, myopic traction maculopathy, and foveoschisis.<sup>10,11,19-23</sup>



**Figure 2** OCT scans of the macula (both eyes) in normal eyes (a) and highly myopic eyes (b) including the colour scale and scan schematic. The foveola and fovea (1 mm) were thicker but the inner macular area (3 mm) and outer macular area (6 mm) were thinner in highly myopic eyes. In addition, smaller macular volume was also found in highly myopic eyes.



**Figure 3** The elongated eyeball with scleral stretching force in highly myopic eye is indicated by the black arrow. This force generates a tangential stretching force along the retinal surface (heavy grey arrow) and induces fovea flattening and retinal thinning (light grey arrow).

In conclusion, the retinal thickness in high myopia is greater in the foveola and fovea, but significantly lesser in the inner and outer macular region. The retina in highly myopic individuals has smaller macular volume than that of non-myopic individuals. These variations in macular thickness should be considered in the evaluation of retinal disease and glaucoma using OCT.

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