Analysis of Peripapillary Retinal Nerve Fiber Distribution in Normal Young Adults

Seung Woo Hong, 1,2 Myung Douk Ahn, 2 Sbin Hee Kang, 1,3 and Seong Kyu Im 1,4

PURPOSE. To determine the anatomic variations in the peripapillary retinal nerve fiber layer (RNFL) thickness distribution and the relationship between these anatomic variations and other ocular variables.

METHODS. A complete ophthalmic examination, including measurement of visual acuity, refraction, and axial length, was performed on 269 subjects with no ophthalmic abnormalities. Further, fundus photographs and optic disc cube scans of the subjects’ eyes were obtained with a fundus camera and spectral domain OCT (Cirrus HD-OCT; Carl Zeiss Meditec, Inc., Dublin, CA), respectively. The distance between the fovea and the center of the optic nerve head was measured. The correlations of the angles of the peaks in the RNFL thickness profile with the axial length, spherical equivalent of refractive error (SE), and distance between the fovea and optic disc center were analyzed by simple linear regression.

RESULTS. Considerable interindividual variations were found in the angles of the peaks in the RNFL thickness profile. Further, the angles in the eyes in each individual showed significant differences. The angles of the superior and inferior first peak correlated significantly with the SE, axial length, and distance between the fovea and optic disc center.

CONCLUSIONS. Subjects with increased distance between the fovea and optic disc center are likely to have a temporal shift in peak RNFL thickness. RNFL profiles with horizontally deviated peak RNFL thickness differ considerably from the normative data provided with the HD-OCT system. The variations in RNFL thickness profiles should be taken into account. (Invest Ophthalmol Vis Sci. 2010;51:3515–3523) DOI:10.1167/iovs.09-4888

In early glaucoma, retinal nerve fiber layer (RNFL) damage is known to precede optic disc change and visual field (VF) damage,1,2 and the RNFL is known as a sensitive indicator of structural damage.2–4 Monochromatic photographs of the RNFL and slit lamp biomicroscopic observation of the fundus through a monochromatic filter are standard techniques for assessing the status of the RNFL. However, these methods are largely subjective in interpretation and are not suitable for quantitative evaluation. Currently, several imaging technologies are available for quantitative RNFL assessment. Optical coherence tomography (OCT) is one such method, and it can be used to measure the RNFL thickness in vivo.

OCT-based measurements of the RNFL thickness generally show good sensitivity and specificity for the detection of glaucomatous damage.5–14 However, there is considerable variation in RNFL thickness profiles, even among normal control eyes. Recently, a few investigators reported the high prevalence of temporally or nasally deviating peak RNFL thickness and considerable variability in RNFL thickness profiles.15–18 Understanding this variability is central to the understanding and improvement of OCT-based measurement of RNFL thickness as a test for glaucomatous damage. Although there is considerable evidence of anatomic variation in RNFL thickness distribution in normal eyes,16–18 our understanding of this variation is incomplete, and many factors like refractive errors and misalignment of the scan circle can affect the shape of the RNFL profile.19–22

The Cirrus HD-OCT (Carl Zeiss Meditec, Inc., Dublin, CA) is one of the latest versions of OCT scanners that use Fourier/spectral domain technology and offers higher axial image resolution and faster scanning speed than conventional time-domain OCTs. The 200 × 200 optic disc cube scan of the Cirrus HD OCT is designed to scan an area 6 mm2 in the optic disc region. Among the results, the RNFL thickness map three-dimensionally represents the RNFL thickness distribution in a 6-mm2 peripapillary region. In addition, the Cirrus HD OCT uses a line-scanning ophthalmoscope to detect eye movements during OCT imaging. Owing to these properties, with new spectral domain OCT, we can discard the unreliable results containing artifacts caused by eye movement and scan displacement and can get more reliable results. Hence, the Cirrus HD OCT can reliably determine the peripapillary RNFL thickness distribution pattern in a subject.

In a few studies, the anatomic variations in RNFL thickness distribution in normal healthy individuals has been investigated. However, our knowledge about these variations is incomplete. The purpose of this study was to determine the anatomic variations of RNFL thickness distribution and the relationship between these variations and ocular variables such as axial length, spherical equivalent of refractive error (SE), and distance between the fovea and optic disc center.

MATERIALS AND METHODS

Subjects
We recruited 269 individuals who met our eligibility criteria. These individuals were soldiers stationed in Gyeonggi Province, and they voluntarily enrolled in the study by answering an advertisement at the Armed Forces Capital Hospital. All the subjects gave informed consent. The study procedures adhered to the tenets of the Declaration of Helsinki and were approved by the institutional review board of the Armed Forces Capital Hospital.

From the 1Department of Ophthalmology, Armed Forces Capital Hospital of Korea, Seoul, Korea; the 2Department of Ophthalmology and Visual Science, Seoul St. Mary’s Hospital, College of Medicine, The Catholic University of Korea, Seoul, Korea; the 3Department of Ophthalmology, College of Medicine, Hallym University, Gangwon, Korea; and the 4Department of Ophthalmology, Chonnam National University Medical School and Hospital, Gwangju, Korea.

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Corresponding author: Myung Douk Ahn, Department of Ophthalmology, Seoul St. Mary’s Hospital, Banpo-dong 505, Seocho-gu, Seoul, Korea 137-701; narusia@catholic.ac.kr.
The exclusion criteria were as follows: best-corrected visual acuity (VA) worse than 20/20; any history of ocular trauma including intraocular or refractive surgery; history of any ocular, systemic, or neurologic disease; any presenting ocular disease capable of causing visual disturbance; closed or occluded angle on gonioscopic examination; intraocular pressure (IOP) >21 mm Hg or glaucoma in either eye; evidence of a reproducible VF defect (pattern SD significant at the <5% level or abnormal glaucoma hemifield test result) in either eye; unreliable VF results (false-positive or negative rate >15% or fixation losses >20%); any suspicious RNFL defect on RNFL and disc photographs; and definite incyclotorsion or excyclotorsion of the eye on fundus photographs.

Each subject underwent a complete ophthalmic evaluation. We performed SITA Standard VF examinations on all subjects with a VF analyzer (HFA II 750, ver. 4.1; Carl Zeiss Meditec, Inc.). Manifest refractions were measured with an autorefractometer (RF10; Canon Inc., Tokyo, Japan) and confirmed by an optometrist or ophthalmologist. Axial length measurements were made with an ocular biometer (IOL Master; Carl Zeiss Meditec, Inc.). The optic disc, fundus, and RNFL were photographed with digital fundus cameras (CF-60UD; Canon Inc.). The obtained images were digitally recorded and then analyzed by a single author (SWH).

Measurement of the Distance between the Optic Disc Center and the Foveola

The relationship between the fundus size, as measured on a fundus photograph, and the actual fundus size can be expressed as $t = p \cdot q \cdot s$, where $t$ is the actual fundus size, $s$ is the size measured on a fundus photograph, $p$ is the magnification factor related to the camera, and $q$ is the magnification factor related to the eye. By using image-editing software (Photoshop CS, ver. 9.0.2; Adobe Inc, San Jose, CA), we drew a rectangle with sides that corresponded to the outer boundary of the neuroretinal rim of the optic disc. We then drew vertical and horizontal lines that intersected the midpoints of the sides of the rectangle, to serve as the cross hair. We defined the disc center as the point where the horizontal and vertical lines met. We measured the distance between the foveola and the disc center on the digital image of the fundus photograph by using the Measure command of the software (Photoshop CS; Adobe). We calculated the magnification factor of the digital fundus camera by referring to a previous study on measurements obtained with fundus photographs.24 The ocular magnification factor of the eye was calculated by using the modified axial length method proposed by Bennett et al.25: $q = 0.01306 \cdot (\text{axial length (mm)} - 1.82)$.

OCT Technique

We induced pupil dilation in the study subjects and then scanned their eyes by OCT (Cirrus HD OCT; software ver. 3.0.0.64; Carl Zeiss Meditec, Inc.). Three individual $200 \times 200$-cube optic disc scans were obtained. If any eye movement within a 1.73-mm radius scan circle was detected during the scan or if the signal strength of the scan was <7, the image was discarded and the scanning process repeated. For each subject, the scan with the highest signal strength and least movements was selected.

RNFL Thickness Distribution Analysis

On the RNFL thickness profile graph, we defined the first maximum as the peak RNFL thickness closest to the temporal region (the superior temporal peak and inferior temporal peak closest to point 0 and point

![Figure 1](http://iovs.arvojournals.org/pdfaccess.ashx?url=/data/journals/iovs/932961/)

**Figure 1.** Peripapillary RNFL thickness profile (black line) against an age-matched normative database, obtained using a Cirrus HD OCT (Carl Zeiss Meditec, Inc.) TEMP, temporal; SUP, superior; NAS, nasal; INF, inferior; TEMP, temporal. (A) White arrow: superior first maximum (superior temporal peak RNFL thickness); black arrow: inferior first maximum (inferior temporal peak RNFL thickness); hatched arrow: superior second maximum (superior nasal peak RNFL thickness); gray arrow: inferior second maximum (inferior nasal peak RNFL thickness); $d$, the difference between the minimum and the second maximum should be more than 20 $\mu$m. (B) Measurement of the angle of the maximum. In this subject, the superior first maximum was located at point 50 (vertical line), and the angle of the superior first maximum measured from this point was $70.31^\circ$ ($70.31 = 50/256 \times 360^\circ$; $0^\circ$ represents the most temporal position, the 9 o’clock position in the right eye).

### Table 1. Summary of Ocular Variables

<table>
<thead>
<tr>
<th>Ocular Variables</th>
<th>Right Eye</th>
<th>Left Eye</th>
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<tbody>
<tr>
<td>Spherical equivalent of refractive errors, D</td>
<td>$-2.723 \pm 2.342$ (range, +1.375 to −11.0)</td>
<td>$-2.266 \pm 2.274$ (range, +2.125 to −10.0)</td>
<td>0.000</td>
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<tr>
<td>Axial length, mm</td>
<td>24.849 ± 1.197 (range, 22.25 to 28.15)</td>
<td>24.752 ± 1.149 (range, 21.56 to 27.91)</td>
<td>0.000</td>
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<tr>
<td>Distance from foveola to disc center, mm</td>
<td>4.503 ± 0.375 (range, 3.806 to 5.804)</td>
<td>4.458 ± 0.376 (range, 3.735 to 5.4405)</td>
<td>0.000</td>
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<tr>
<td>Angle of superior first maximum, deg</td>
<td>70.06 ± 9.482 (range, 40.78 to 97.05)</td>
<td>73.87 ± 10.02 (range, 37.96 to 104.06)</td>
<td>0.000</td>
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<tr>
<td>Angle of inferior first maximum, deg</td>
<td>290.14 ± 11.09 (range, 246.09 to 322.03)</td>
<td>290.22 ± 10.80 (range, 250.31 to 315)</td>
<td>0.567</td>
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<tr>
<td>Angle between the superior and inferior first maximums, deg</td>
<td>139.93 ± 17.39 (range, 85.78 to 203.91)</td>
<td>143.63 ± 17.14 (range, 92.81 to 202.59)</td>
<td>0.000</td>
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<td>Average RNFL thickness, $\mu$m</td>
<td>98.556 ± 8.699 (range, 72 to 125)</td>
<td>98.169 ± 8.656 (range, 78 to 125)</td>
<td>0.263</td>
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Statistical comparison by paired t test.
255, respectively; Fig. 1). We defined the discernible second maximum as the peak RNFL thickness (1) that was located in the region nasal to the first maximum (superior nasal peak and inferior nasal peak) but in the same hemipapillary disc area as the first maximum and (2) that included a trough that differed by at least 20 μm from the first and second maximums (Fig. 1). We selected a 20-μm difference, because it is the minimum difference necessary to discern the second maximum in RNFL thickness profiles. The locations (256 points in the circumference of the peripapillary area) of the first and second maximums were recorded and then were converted to an angle by multiplying them with 140625/360/256 points). In addition, from point 0 to 255, the RNFL thicknesses at each of the 256 points on the RNFL thickness profile were recorded. To eliminate artifacts caused by minor subclinical excyclotorsion or incyclotorsion of the eye, we also calculated the angle between the superior and inferior first maximums.

### Statistical Methods

One eye of each subject was randomly selected for analysis, although both eyes were studied to determine the bilaterality of the findings (SPSS, ver. 13.0; SPSS Corp., Chicago, IL). The RNFL thickness profiles of the study subjects were classified into five subgroups on the basis of the angles of the superior and inferior first maximums—those with angles smaller than the mean −2 SDs, between the mean −2 SDs and the mean −1 SD, between the mean −1 SD and the mean +1 SD, between the mean +1 SD and the mean +2 SDs, and larger than the mean +2 SDs—and the mean RNFL thickness profiles of the subgroups were calculated. Simple linear regression analysis was performed for correlation analysis. For all tests, the statistical significance was set at 5% and determined by P < 0.05.

### Results

In this study, of 269 healthy normal subjects, 258 (95.91%) were men and 11 (4.07%) were women. Every enrolled subject claimed to be an ethnically pure Korean. Their mean age was 21.50 ± 1.70 years (range, 19–26). The mean SE, axial length, average RNFL thickness, distance from the foveola to the disc center, and angle of the superior first maximum and that of the inferior first maximum of both eyes are shown in Table 1. The SE, axial length, distance from the foveola to the disc center, angle of superior first maximum, and angle between superior and inferior first maximums significantly differed between the right and left eyes (P < 0.001, paired t-test), whereas no differences were found in the average RNFL thickness and the angle of the inferior first maximum (P > 0.05). In all, 336 (62.22%) eyes of 211 (78.15%) subjects had a superior second maximum, 71 (13.15%) eyes of 61 (22.59%) subjects had a superior first maximum, and 71 (13.15%) eyes of 61 (22.59%) subjects had a superior second maximum. The mean angle of the second superior maximum and the difference between the angles of the superior first and second maximums were 122.37° ± 10.60° (range, 99.84–158.90) and 52.21° ± 11.25° (range, 32.34–87.19), respectively. The mean angle of the second inferior maximum and the difference between the angles of the inferior first and second maximums were 238.85° ± 7.85° (range, 225–262.97) and 53.47° ± 9.73° (range, 36.56–71.72), respectively. The distributions of the angles of the superior and inferior first maximums and the superior and inferior second maximums are shown in Figure 3. The mean RNFL thickness profiles for each subgroup of subjects, classified on the basis of the angle of the first superior and first inferior maximums, are shown in Figures 4 and 5.

![Histogram showing the distribution of (A) SE, (B) axial length, and (C) ocular magnification factor (p·q) of the study subjects (p = 3.3382, q = 0.01306 · [axial length (mm) – 1.82]).](image)

**Table 2. Summary of Ocular Variables of Randomly Selected Eyes**

<table>
<thead>
<tr>
<th>Ocular Variables</th>
<th>Mean ± SD</th>
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<tr>
<td>Spherical equivalent of refractive errors, D</td>
<td>−2.521 ± 2.297° (range, −10.125 to 1.5)</td>
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<tr>
<td>Axial length, mm</td>
<td>24.801 ± 1.170° (range, 22.5 to 27.93)</td>
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<tr>
<td>Distance from foveola to disc center, mm</td>
<td>4.481 ± 0.374° (range, 3.73 to 5.80)</td>
</tr>
<tr>
<td>Angle of superior first maximum, deg</td>
<td>72.18 ± 9.76° (range, 40.78 to 99.84)</td>
</tr>
<tr>
<td>Angle of inferior first maximum, deg</td>
<td>72.18 ± 9.76° (range, 40.78 to 99.84)</td>
</tr>
<tr>
<td>Average RNFL thickness, μm</td>
<td>98.247 ± 8.586° (range, 77 to 125)</td>
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**Figure 2.** Histogram showing the distribution of the angles of the first and second maximums. (●) ~70° and 290° areas, represent the frequency of the angles of the superior and inferior first maximums, respectively. (square) ~120° and 240° areas, represent the frequency of the angles of the superior and inferior second maximums, respectively.

**Figure 3.** Histogram showing the distribution of the angles of the maximums. (●) ~70° and 290° areas, represent the frequency of the angles of the superior and inferior first maximums, respectively. (square) ~120° and 240° areas, represent the frequency of the angles of the superior and inferior second maximums, respectively.
FIGURE 4. The mean RNFL thickness profiles in subgroups of participants, classified on the basis of the angle of the superior first maximum (95% confidence interval [CI] of the mean). (a–g) RNFL thickness maps, RNFL probability maps, and RNFL thickness profiles of the subjects in whom the angles of superior first maximums corresponded to the lowest value, the mean − 2 SDs, the mean − 1 SD, the mean, the mean + 1 SD, the mean + 2 SDs, and the highest value. TEMP, temporal; SUP, superior; NAS, nasal; INF, inferior; TEMP, temporal. (A) Angle of superior first maximum smaller than 52.66° (lower than the mean − 2 SDs, n = 8). (B) Angle of superior first maximum between 52.66° and 62.42° (between the mean − 2 SD and the mean − 1 SD, n = 29). (C) The angle of the superior first maximum between 62.43° and 81.94° (between the mean − 1 SD and the mean + 1 SD, n = 194). (D) Angle of superior first maximum between 81.95° and 91.70° (between the mean + 1 SD and the mean + 2 SDs, n = 31). (E) Angle of the superior first maximum larger than 91.70° (more than the mean + 2 SDs, n = 7).
**FIGURE 5.** The mean RNFL thickness profiles in subgroups of participants, classified on the basis of the angle of inferior first maximum (95% CI of the mean). (a–g) RNFL thickness maps, RNFL probability maps, and RNFL thickness profiles of the subjects whose angles of inferior first maxima corresponded to the highest value, the mean + 2 SDs, the mean + 1 SD, mean, the mean − 2 SDs, and the lowest value: TEMP, temporal; SUP, superior; NAS, nasal; INF, inferior; TEMP, temporal. (A) Angle of the superior first maximum larger than 311.42° (more than the mean + 2 SDs, n = 7). (B) Angle of the superior first maximum between 300.67° and 311.42° (between the mean + 2 SDs and the mean + 1 SD, n = 41). (C) Angle of the superior first maximum between 279.17° and 300.66° (between the mean + 2 SDs and the mean + 1 SD, n = 174). (D) Angle of the superior first maximum between 268.42° and 279.16° (between the mean − 1 SD and the mean + 2 SD, n = 38). (E) Angle of the superior first maximum smaller than 268.42° (lower than the mean − 2 SD, n = 9).
Significant correlations were observed between the following pairs of angles: the superior and inferior first maximums, the superior first maximum and the superior second hump, and the inferior first and second maximums ($P < 0.001$; Fig. 6).

The angles of the superior and inferior first maximums correlated significantly with the SE, axial length, and distance between the foveola and the disc center (Fig. 7).

**DISCUSSION**

The peak RNFL thicknesses observed in the RNFL thickness profile denote the points at which major retinal nerve fiber bundles pass the scan circle. Thus, the angles of the peak RNFL thicknesses represent the pattern of the extended retinal nerve fiber in the peripapillary area. In this study, the superior and inferior first maximums corresponded to the superior and inferior arcuate nerve fibers, respectively. As shown in Figure 2, the angles of the superior and inferior first maximums were normally distributed, and as shown in Figures 4 and 5, the angles of the superior and inferior first maximums exhibited considerable variability. Further, the angles of the superior first maximums and the angles between the superior and inferior first maximums significantly differed between the eyes of an individual ($P < 0.001$, paired $t$-test). These findings suggest that there are considerable interindividual variations in the retinal nerve fiber distribution patterns; moreover, these patterns vary significantly between the eyes of an individual. Previous studies have reported that RNFL thickness profiles in the eyes of an individual are very similar. The discrepancy between this and our findings is attributable to differences in

**FIGURE 6.** (A) Angle of the superior first maximum against the angle of the inferior first maximum, (B) angle of the superior first maximum against the angle of the superior second maximum, and (C) angle of the inferior first maximum against the angle of the inferior second maximum (0° corresponds to the most temporal position, the 9 o’clock position for the right eye).

**FIGURE 7.** Correlations (0° corresponds to the most temporal position, the 9 o’clock position for the right eye). (A) SE, (B) axial length, and (C) distance between foveola and disc center against the superior first maximum ($P < 0.001$, simple linear regression analysis). (D) SE, (E) axial length, and (F) distance between foveola and disc center against the inferior first maximum ($P < 0.001$, simple linear regression analysis).
the determining factors in this relationship. Those variations in the macular size and other factors could be the distance between the disc center and the foveola, and angles of the arcuate nerve fibers are not determined solely by the discrepancy between the two eyes in the angle of the present study, right eyes of the subjects exhibited significantly superior and inferior first maximums with the distance between the macular center and the optic nerve head center is large, the angle of the arcuate nerve fibers is small. (B) When the distance between the macular center and the optic nerve head center is small, the angle of the arcuate nerve fibers is wide.

In this study, the angles of the superior and inferior first maximums correlated with each other and with the SE, axial length, and distance between the disc center and the foveola. These findings imply that both these angles are concurrently affected by these variables. On the basis of these findings, we speculate that the angles of the superior arcuate nerve fibers (superior first maximum) and the inferior arcuate nerve fibers (inferior first maximum) are determined by the spatial relationship between the optic nerve head and the center of the macula (Fig. 8). If the macula is located far from the optic disc, the angle of the superior first maximum decreases and the macula expands to a size greater than the macular area, the eyeballs; if the retinal area located between the optic disc and the macula expands to a size greater than the macular area, the angle between the superior and inferior first maximums will decrease. However, the correlations of the angle of the superior and inferior first maximums with the distance between the disc center and the foveola were rather weak ($R^2 = 0.212$ and 0.154, respectively). Thus, we speculate that the angles of the arcuate nerve fibers are not determined solely by the distance between the disc center and the foveola, and those variations in the macular size and other factors could be the determining factors in this relationship.

In a few studies, the patterns of RNFL thickness profiles have been investigated. Lee and Shields reported the high prevalence of a horizontal shift in the peak RNFL thicknesses, as observed on RNFL thickness profiles from the glaucoma patients and those with suspected glaucoma. They found that a horizontal shift in the peak RNFL thickness did not correlate with demographic or glaucoma-related variables. In the present study, we found that the angles of the first maximums varied widely. However, the percentage of eyes with >20° deviation (7.06% in the superior disc area and 6.69% in the inferior disc area) in the present study was not as high as that reported by Lee and Shield. This difference may be attributable to differences in subject groups or between the devices used for measurement (Cirrus HD OCT and Stratus OCT; Carl Zeiss Meditec, Inc.). The high prevalence of horizontal deviations in the RNFL thickness profile in patients with glaucoma or suspected glaucoma observed by Lee and Shields may indicate that individuals with horizontally deviated RNFL thickness profiles are more susceptible to glaucoma or that glaucoma was misdiagnosed in such individuals. Another possibility is that because the Stratus OCT, which was used by Lee and Shield, cannot identify involuntary saccadic eye movements during scanning, their findings may have included artifacts caused by scan circle displacement.

To evaluate the likelihood of a misdiagnosis of glaucoma or suspected glaucoma in subjects with horizontally deviating RNFL thickness profiles, we grouped the subjects according to the angle of the superior and inferior first maximums and compared the mean RNFL thickness profiles of these subgroups with the normative data provided by Cirrus HD OCT. We independently compared the superior and inferior RNFL profiles with the normative reference because the correlation between the angles of the superior and inferior first maximums was rather weak ($R^2 = 0.112$). The comparison between the 95th percentile distributions of the RNFL thickness profiles of the subgroups and the normative data are shown in Figure 7 (the confidence limits of the 95th percentile distributions were calculated using the mean ± 1.96 SD). In the eyes in which the angle of the superior first maximums was less than 62.43° (mean − 1 SD), the superior and superior-nasal RNFLs tended to be labeled as abnormal in comparison with the normative data. In the eyes in which the angle of the superior first maximum was more than 81.95° (mean + 1 SD), the temporal and superior-temporal RNFLs tended to be labeled as abnormal. Further, in the eyes in which the angle of the inferior first maximum was more than 300.67° (mean + 1 SD), the inferior and inferior nasal RNFLs tended to be labeled as abnormal. As shown in Figure 9, the mean angle of the inferior temporal peak thickness for the subjects differed from the normative data provided with the Cirrus HD OCT. Therefore, we could not compare the nasally deviated inferior RNFL profile with the normative data. We speculated that this difference may be attributable to the ethnic properties of Koreans or to the properties of our subject group, which included many myopes, or to the selection bias caused by the enrollment of volunteers.

One of the major limitations of this study is that the scan circle during optic disc cube scanning was not adjusted for ocular magnification. According to studies on scan circle window size and RNFL thickness, this may have introduced some errors in the mean RNFL thickness profiles and the mean angles of maximums determined in this study. However, considering the extensive nature of peripapillary retinal nerve fibers, the angles of peak thicknesses seem to be less affected by ocular magnification. Another limitation is the method of centering the optic disc. The disc center definition used may not be appropriate for tilted optic nerve heads. Other limitations are that this was not a population-based study and that it involved subjects who were of similar age and ethnicity. Thus, the mean angles of the peak RNFL thicknesses in the general population may differ from those reported herein. These features may limit the application of our findings to subjects of other age groups or ethnicities.
No histologic evidence has been found regarding variations in the extension pattern of the retinal nerve fibers from the macula to the optic nerve head. This type of histologic analysis may be technically challenging. With the introduction of OCT, it has become possible to visualize the peripapillary RNFL thickness distribution pattern and the RNFL thickness profile of the eye. However, temporal or nasal shifts in the peak RNFL thickness can be caused by horizontal misalignment of the scan circle during OCT. The Stratus OCT scanner cannot differentiate between artifacts caused by saccadic eye movements during scanning and physiologic variations. However with the introductions of modern imaging devices like spectral domain OCT and the RNFL analyzer (GDx; Carl Zeiss Meditec, Inc.), we are able to obtain information about the overall pattern of peripapillary RNFL. Hence, it is possible to determine whether a given pattern of retinal nerve fibers deviates from the normal pattern. However, it remains difficult to judge whether the RNFL thickness profile of a patient is a normal physiologic variant or a pathologic characteristic. Thus, normative RNFL profiles of subjects with temporally or nasally deviated RNFL profiles should be established to improve the sensitivity and specificity of glaucoma diagnosis.

In this study, we found that temporally deviated RNFL thickness profiles correlate with myopia, increased axial length, and increased distance between the foveola and the optic disc center. Another factor that reflects the RNFL thickness profile is the extending pattern of major retinal blood vessels. Recent studies have found that the locations of peak RNFL thicknesses in RNFL profiles largely correlate with the angles of major retinal blood vessels. Further, Kozulin et al. showed that, during eye development, the growth patterns of retinal nerve fibers and retinal blood vessels are induced by the same genes. Thus, the present findings can give us a hint of how to estimate whether the RNFL thickness profile of a patient deviates from the normative profile. Patients who have myopia, increased axial length, and temporally deviating blood vessels are likely to have temporally deviating RNFL thickness profiles.

As shown in Figure 9, data from the eyes with temporally or nasally deviating RNFL thickness profiles differed from the normative reference provided with the Cirrus HD OCT scanner. Patients with such RNFL thickness profiles tend to be misdiagnosed with glaucoma or suspected glaucoma, despite having no abnormality in visual function. To avoid such misdiagnoses, the variations in the RNFL thickness profiles should be taken into account during RNFL thickness profile analysis, and new normative RNFL profiles for subjects with temporally or nasally deviated RNFL thickness profiles should be established to improve the sensitivity and specificity of glaucoma diagnosis.

References


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