INTRODUCTION

Scanning laser polarimetry (SLP) is an objective and quantitative method for assessing the polarization of the retinal nerve fiber layer. Since the retardation of the polarized signal is assumed to be related to the amount of nerve fibers, the method has already been applied to glaucoma diagnosis\(^1\)\(^-\)\(^8\). The usefulness of SLP for the diagnosis of glaucoma has been reported\(^2\), however, the correlation between the retinal nerve fiber layer thickness (NFLT) and the field defects has been demonstrated only in the inferonasal area\(^1\),\(^3\) of the retina. In comparison between histological NFLT measurement and SLP, each NFLT at the temporal side of optic disc had a lower correlation than those at the superior or inferior area\(^9\). We also reported that the SLP measurement of NFLT in the area temporal or nasal to the optic disc were greatly influenced by the corneal compensator in SLP\(^10\).

Using SLP, glaucoma-associated thinning of the nerve fiber layers has not been demonstrated in the area temporal to the optic disc corresponding to the papillomacular bundle.

While thinning and irregular thickness of the whole neurosensory retina in the macular area have been demonstrated with a Retinal Thick-
ness Analyzer in eyes with glaucoma, we reported that the evaluation of parafoveal NFLT using SLP was difficult. Difficulty in clinical application of parafoveal SLP for glaucoma diagnosis results from great inter-individual variability of the measurement, which is thought to derive from the inter-individual variability of the axis of corneal birefringence reported by Greenfield and other investigators.

In the 6th European Glaucoma Society meeting in London (26, 6, 2000), we reported the new parameter: the ratio of the parafoveal retardation value between sectors on the opposite sides of the fovea, in normal eyes, and found this parameter was independent of the changing corneal birefringence which was intentionally made by authors (unpublished data). In this present study we applied this parameter to eyes with early glaucoma to study whether the ratio could discriminate them from normal control eyes.

**MATERIALS AND METHODS**

**Subjects**

Fourteen eyes of 14 patients with early glaucoma (age: 48.7 ± 11.2 years old) and 14 eyes of 14 normal controls (age: 50.6 ± 21.5 years old) were enrolled in this study. The criteria for glaucoma included one or more points with 6 dB or greater decrease in pattern deviation within central 10-degree-area in Humphrey Field Analyzer program central 30–2 (HFA30–2) and corrected visual acuity of 20/30 or better. The criteria for normal eyes are: free from any ocular disease, and corrected visual acuity of 20/20 or better. Eyes were excluded when they had cataract, corneal opacity or vitreous opacity, when the pupil diameter was 2 mm or less, when they had ocular diseases other than glaucoma (i.e. Age related macular degeneration or Soft drusen), or when the stage of glaucoma was severe enough that mean deviation (MD) of HFA 30–2 was −8 dB or less.

Averaged mean deviation and corrected pattern standard deviation of the HFA 30–2 were −3.74 ± 2.72 dB (ranging from +0.53 dB to −7.45 dB) and 5.17 ± 3.07 dB (ranging from 0.55 dB to 10.43 dB) respectively in eyes with glaucoma. The refractive error in eyes with glaucoma and in normal control eyes was −0.5 ± 2.6 D (ranging from −7.0 D to +3.25 D) and −1.0 ± 2.2 D (ranging from −6.0 D to +1.75 D), respectively.

**Scanning laser polarimetry**

The nerve fiber layer thickness or Henle’s fiber layer thickness was measured without pupillary dilation using SLP (Nerve Fiber Analyzer II, Ver. 2.1.17 beta, Laser Diagnostic Technologies, San Diego, CA, U. S. A.)16-20). Fundus image of 15 degrees of field were obtained 3 times. The image consisted of 256 x 256 pixels. The retinal nerve fiber profile was obtained along a circle 90 pixels in diameter around the fovea with a 5-pixels of width (Fig. 1). This 90 pixel-circle is approximately equivalent to 1.5 mm or 5.3 degrees on the retina. The measured ring was divided into 12 sectors. The retardation of each of the six sectors in the superior hemisphere was compared with that of the sector on the opposite side of the fovea and the ratio (S/I ratio) was evaluated (Fig. 2). The retardation map where we could not identify the fovea on the original laser fundus image was not included.

**RESULTS**

The six ratios by 12 sectors of parafoveal retardation are shown in table 1. The glaucoma eyes had smaller ratios (p = 0.0004, Student-t
test). Three of six ratios (Ratio No.4, 5 and 6) were significantly smaller in eyes with glaucoma than in those of normal controls ($p = 0.0129, 0.0068, 0.043)$; Scheffe’s multiple comparison test). It means that there is a thinning of superior or temporal retinal NFLT because thinning of
NFLT is more common than thickening of NFLT in an eye with glaucoma. Fig. 3 shows the distribution of glaucoma eyes and normal controls with this parameter. Variability of the ratio of NFLT in the sectors of No. 1 and 2 is greater in an eye with glaucoma than normal control eyes. It shows that the irregularity of the parafoveal NFLT in glaucoma eye.

Table 1. Parafoveal retardation ratio

<table>
<thead>
<tr>
<th>Parameters (Ratio Number)</th>
<th>Normal eyes (mean±1SD)</th>
<th>Glaucoma eyes (mean±1SD)</th>
<th>p value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>No 1</td>
<td>0.944±0.088</td>
<td>0.977±0.143</td>
<td>0.4728</td>
</tr>
<tr>
<td>No 2</td>
<td>0.958±0.094</td>
<td>0.949±0.135</td>
<td>0.8444</td>
</tr>
<tr>
<td>No 3</td>
<td>0.947±0.076</td>
<td>0.913±0.092</td>
<td>0.2981</td>
</tr>
<tr>
<td>No 4</td>
<td>0.933±0.093</td>
<td>0.840±0.091</td>
<td>0.0129</td>
</tr>
<tr>
<td>No 5</td>
<td>1.004±0.133</td>
<td>0.838±0.164</td>
<td>0.0068</td>
</tr>
<tr>
<td>No 6</td>
<td>1.086±0.163</td>
<td>0.915±0.162</td>
<td>0.043</td>
</tr>
</tbody>
</table>

*Scheffe’s multiple comparison test

DISCUSSION

As well as sensitivity in static perimetry, the NFLT has commonly been compared between values at corresponding points across the horizontal line. In this study, however, we evaluated the ratio between retardations in areas located in the opposite sides of the fovea because the effect of corneal birefringence on several retinal points on the same meridian line may be equal and thus the ratio would evaluate the difference of birefringence in the nerve fiber minimizing the effect of that in the cornea. In our previous study, the retardation maps of a single eye were taken through 4 different corneal locations with a dilated pupil. Each different corneal location has a different corneal birefringence. The fluctuations between retardation maps in same retina are caused by differences in corneal birefringence. While the mean coefficient variance of raw data was 0.281, the mean coefficient in the variance of the ratios between diagonal areas was 0.085 (unpublished data). The values of this parameter were approximately 1.0 in all areas, which fits the anatomy of nerve fibers around fovea which is almost flat. It means that this parameter avoids corneal artifact and is reliable. Evaluations using the ratio of the parafoveal retardations in the present study, successfully detected the difference between eyes with early glaucoma and normal controls.

In our previous study[12], we compared the retardation of advanced glaucoma eyes and normal controls using parafoveal SLP. The differences between advanced glaucoma eyes and normal controls were not significant. It might be caused by corneal birefringence and generalized decreased NFLT. The corneal birefringence influences exact retardation value on SLP but the ratio between retardation values in areas
located in the opposite sides of the fovea. The present study shows a significant difference of parafoveal retardation between an early glaucoma eye and a normal eye. Although it is not common to evaluate glaucoma damages in the parafoveal area, the thinning of whole retina of glaucoma eyes had been reported\textsuperscript{11).} This report supports present results.

The measurement of parafoveal retardation using SLP is advantageous because the area around the fovea has fewer vessels that affect the obtained image of the nerve fiber layers, and it is exempt from atrophy or other myopic changes frequently seen around the optic disc.

Present study suggests the possibility of glaucoma detection not only around optic disc but also in the macular area using SLP. A combination of conventional SLP and parafoveal SLP is a possible improved method for detection of glaucomatous changes associated with central visual dysfunction and could provide us with a more sensitive and specific measure for diagnosing glaucoma than the present testing only around optic disc. In this study, it is not determined how we combined parafoveal SLP with conventional SLP. A further study is required to show how we could utilize the parafoveal SLP for glaucoma diagnosis.

**REFERENCES**


