Longitudinal Changes in the Retinal Microstructures of Eyes With Chiasmal Compression

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Abstract

Objective
To test the hypothesis that there was a temporal change in the retinal microstructure after decompression surgery for chiasmal compression, the 1-year longitudinal changes in the inner and outer retinal thickness after decompression surgery were analyzed using spectral-domain optical coherence tomography (SD-OCT) with linear mixed-effects models.

Methods
SD-OCT was obtained from 87 eyes with chiasmal compression and compared to 100 healthy controls. The preoperative and 1-year postoperative longitudinal changes in the retinal layer thickness were measured. The thickness of each of the following retinal layers was analyzed: the macular retinal nerve fiber layer (RNFL), the ganglion cell layer (GCL), the inner plexiform layer (IPL), the inner nuclear layer, the outer plexiform layer, the outer nuclear layer, and the photoreceptor layer.

Results
The RNFL, GCL, and IPL showed thinning at a rate of 1.068 μm/y (95% confidence interval [CI], 0.523, 1.613), 1.189 μm/y (95% CI 0.452, 1.925), and 1.177 μm/y (95% CI 0.645, 1.709), respectively, after decompression surgery. The preoperative thickness of the intraretinal layer was associated with postoperative visual field recovery (RNFL, odds ratio [OR] 1.221, 95% CI 1.058, 1.410; GCL, OR 1.133, 95% CI 1.024, 1.254; and IPL, OR 1.174, 95% CI 1.002, 1.376).

Conclusions
The changes in retinal microstructure persisted and progressed in eyes with chiasmal compression after decompression surgery. The findings provide insight into the biological and anatomical sequelae following chiasmal compression. The preoperative thickness of the inner retinal layers was associated with postoperative visual field recovery.

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Visual dysfunction due to chiasmal compressive lesions is characterized by decreased visual acuity, visual field (VF) defects, and a loss of color vision. These symptoms occur as a result of axonal injury due to optic chiasmal compression. After decompression surgery, the recovery of functional measures depends on the degree of the previous axonal injury. Optical coherence tomography (OCT) of eyes with permanent hemianopia in optic chiasmal compression showed thinning of the retinal nerve fiber layer (RNFL) and the ganglion cell layer (GCL) in previous studies. Axonal damage and retrograde degeneration of ganglion cells result in inner retinal thinning. Animal studies demonstrated an extended delay between axonal injury and the loss of retinal ganglion cells (RGCs). A time discrepancy was also reported between VF recovery and GCL thickness changes after decompression surgery in one longitudinal study in patients with chiasmal compression. The study analyzed the changes in RNFL thickness and ganglion cell layer complex (GCC) area in 19 patients with chiasmal compression over 6 months after decompression surgery. The results showed a significant decrease in the RNFL thickness and GCC area 3 months postoperatively, whereas a significant improvement in VF defects was observed immediately after surgery.

Few studies have reported longitudinal changes in the intraretinal thickness after decompression surgery in chiasmal compression, and no study has analyzed the longitudinal changes in the retinal microstructure of the whole layers. Cross-sectional studies reported that various retinal layers, such as the inner nuclear layer (INL), the inner plexiform layer (IPL), and the photoreceptor layer (PRL), were also affected in eyes with chiasmal compression. Monteiro et al. demonstrated that the INL, as well as the RNFL and GCL in eyes with band atrophy due to chiasmal compression, were significantly altered compared to healthy controls. Another study of 43 eyes diagnosed with permanent hemianopia also reported a reduction in the RNFL, GCL, and IPL thickness in all sectors of the macula. In that study, the PRL thickness increased in the nasal hemiretina of patients with chiasmal compression.

In this study, we evaluated the longitudinal changes in both the inner and outer retinal microstructures using OCT autosegmentation software and analyzed the factors affecting postoperative VF recovery.

**Methods**

**Study Participants**

This retrospective cohort study involved 87 patients with chiasmal compression and 100 healthy controls at the Neuro-ophthalmology Department of Samsung Medical Center between January 2015 and October 2018. Some of the patients participated in a cross-sectional study in the same department. Patients with chiasmal compression who underwent trans-sphenoidal surgical decompression and visited the Department of Neuro-ophthalmology Outpatient Clinic were screened using our outpatient log. Among patients who underwent trans-sphenoidal surgical decompression, they were considered for inclusion in this study when all the following criteria were met: (1) age 20 years or more; (2) preoperative VF defects with or without decreased visual acuity; (3) preoperative MRI evidence of mass lesions that compress the optic chiasm; (4) preoperative and postoperative comprehensive ophthalmic examinations, including spectral-domain OCT (SD-OCT, Spectralis, Heidelberg Engineering, Heidelberg, Germany) at each visit; (5) postoperative follow-up visits after surgery. Patients with any of the following conditions were excluded: any neurologic disorder other than mass lesions that compress the optic chiasm, systemic vasculitis, ocular pathology that could affect visual functions or OCT measures (glaucoma, refractive error greater than +6.0 diopters of spherical equivalent or less than −6.0 diopters of spherical equivalent, astigmatism of 3.0 diopters or more, amblyopia, epiretinal membrane, age-related macular degeneration, diabetic retinopathy, retinal artery/vein occlusion, or optic neuropathy other than compressive optic neuropathy due to chiasmal compression), or previous retinal surgery that affected the thickness of the intraretinal layer.

The onset time was defined as the time when the patient first noticed VF defects or experienced decreased vision related to chiasmal compression. In patients who did not notice visual symptoms, the onset time refers to the time when the VF defects were first detected by formal ocular examination. All patients underwent trans-sphenoidal surgical decompression. The patients visited the clinic preoperatively and 3, 6, and 12 months postoperatively, and underwent ophthalmic examinations. For subgroup analysis, all patients were categorized into 2 groups: those with complete recovery of VF defects and those with partial or no recovery of VF defects. Complete recovery of the VF was defined by the absence of clusters of 3
or more non-edge points with $p < 0.05$, the absence of 1 or more points with $p < 0.01$ in the pattern deviation probability plot, a pattern standard deviation within 95% confidence limits, and a glaucoma hemifield test result within normal limits.\textsuperscript{9,10}

Controls recruited in another OCT study for suprasellar tumors were utilized in this study for comparison purposes.\textsuperscript{8} However, previous measurement data were not duplicated. All measurements were newly performed. In the previous study, controls were prospectively recruited from staff and healthy volunteers who visited for routine eye examination.\textsuperscript{8} Informed consent was obtained from all participants. This process was approved by the Institutional Review Board of Samsung Medical Center (Seoul, Republic of Korea). The healthy controls were required to have normal visual acuity, normal intraocular pressure $\leq 21$ mm Hg, and normal optic discs. The following categories of healthy controls were excluded: those with any neurologic disorder, systemic vasculitis, ocular pathology that could affect visual functions or OCT measures (glaucoma, a refractive error greater than $+6.0$ diopters of spherical equivalent or less than $−6.0$ diopters of spherical equivalent, astigmatism of $3.0$ diopters or more, amblyopia, epiretinal membrane, age-related macular degeneration, diabetic retinopathy, retinal artery/vein occlusion, or optic neuropathy), or previous retinal surgery that affected the thickness of the intraretinal layer.

**Standard Protocol Approvals, Registrations, and Patient Consents**

This retrospective study was approved by the Institutional Review Board of Samsung Medical Center (Seoul, Republic of Korea) and conducted according to the tenets of the Declaration of Helsinki. Informed consent was waived for the patients with chiasmal compression.

**Ophthalmic Examinations**

All participants were scanned using fundus color photography and SD-OCT. The VF perimetry of the patients was measured with a Humphrey Field Analyzer using the 30-2 SITA-standard protocol (Humphrey 740 Visual Field Analyzer, Carl Zeiss Meditec Inc., Dublin, CA). Only reliable VFs ($\leq 33\%$ false-positives and false-negatives; fixation losses <20%) were used in the study. The mean deviation (MD) was used for the analysis.

**OCT Analysis and Segmentation**

In patients with chiasmal compression, we obtained SD-OCT images preoperatively and at 3, 6, and 12 months postoperatively. Only a single eye showing the worse preoperative VF defects in each patient was selected for the analysis, except when the data quality of the worse eye was inappropriate. In the healthy controls, only the right eye data were analyzed, except when the data quality of the right eye was inappropriate for the analysis of the retinal layer thickness and the data quality of the left eye was appropriate. High-resolution retinal imaging was performed by SD-OCT. The raster scan was composed of 25 B-scans covering an area of $20° \times 15°$. Each B-scan consisted of 512 A-lines 6.0 mm in length, spaced 240 $\mu$m apart. The automatic real-time mode using active eye-tracking software for automated eye alignment (TruTrack Active Eye Tracking; Heidelberg Engineering) to improve the quality and accuracy of segmentation was used to obtain the retinal scans, including 19 single horizontal axial scans in the macular area. All OCT images fulfilled the OSCAR-IB quality control criteria for retinal OCT scans. The 9-point advised protocol for OCT study terminology and elements (Advised Protocol for OCT Study Terminology and Elements [APOSTEL] recommendations) is presented in table e-1 (data available from Dryad: doi.org/10.5061/dryad.dncjsxkwn).

The thickness of each of the 7 layers between the vitreoretinal interface and the outer border of the retinal pigment epithelium was measured via automated segmentation using Spectralis software, with manual correction as needed. The entire retinal layer was segmented into the following 7 retinal layers: the RNFL, the GCL, the IPL, the INL, the outer plexiform layer (OPL), the outer nuclear layer (ONL), and the PRL. Following the automated segmentation of each retinal layer, the thickness of each retinal layer in the 3- and 6-mm subfields, as defined by the Early Treatment Diabetic Retinopathy Study grid, was automatically measured using Spectralis mapping software (figure 1). The average thickness of the 4 macular quadrants measured within the 3-mm and 6-mm zones was calculated for each layer. The segmentation was based on a validated algorithm\textsuperscript{11} used to measure the average thickness values within a $3 \times 3$ mm circle and a $6 \times 6$ mm area centered at the fovea. The foveal region, consisting of a $1 \times 1$ mm circle, was excluded from the analysis. The quality of all the images was reviewed by 2 independent masked graders (G.-L.L., K.Y.S.). We manually corrected any errors in the automated segmentation as reported previously by Oberwahrenbrock et al.\textsuperscript{12}

**Statistical Analysis**

The data are presented as the mean ± SD and the best-corrected visual acuity (BCVA) was converted to a logarithmic scale (logMAR). The Wilcoxon rank-sum test was used to compare age, spherical equivalent refractive errors (SER), BCVA, the preoperative MD of the VF, and preoperative peripapillary RNFL (pRNFL) thickness between the patients with chiasmal compression and the healthy controls. The $\chi^2$ test was used to compare categorical variables such as sex between the groups. The Wilcoxon rank-sum test was also used to compare the preoperative MD of the VF and the postoperative MD of the VF in the patient group. A $p$ value of less than 0.05 was considered statistically significant.

The preoperative intraretinal layer thickness of the patients was compared with that of the healthy controls using a 2-sample $t$ test. The longitudinal changes in the average thickness of the retinal layers were analyzed using a linear mixed-effects model after adjusting for patient age and refractive errors to eliminate the effect of potential confounders.
In the model, a random effect was assumed for the subject variable to account for repeated measures across multiple time points. Subgroup analysis was also performed according to the presence of complete VF recovery after decompression surgery. The logistic regression model was used to analyze the association between the preoperative retinal layer thicknesses and the postoperative VF recovery status after adjustment for measures that included patient age, sex, SER, preoperative VF defects, and visual acuity. The area under the receiver operating characteristic curve (AUROC) was calculated to investigate the predictive value of preoperative retinal thicknesses for VF recovery. The 95% confidence interval (CI) was used to define statistical significance.

All statistical analyses were performed with SAS version 9.4 (SAS Institute, Cary, NC) and R 3.5.1 (Vienna, Austria; R-project.org/).

Data Availability
Anonymized data will be shared upon request from any qualified investigator.

Results
A total of 178 patients with chiasmal lesions who underwent trans-sphenoidal surgical decompression and visited the Department of Neuro-ophthalmology Outpatient Clinic preoperatively and postoperatively were screened using our
outpatient log. Of these 178 patients, 110 patients met the inclusion criteria. Of these 110 patients, 3 patients with neurologic disorder other than chiasmal lesions and 20 patients with ocular pathology that could affect visual functions or OCT measures were excluded from this study. A total of 87 patients with chiasmal compression were included in this study. Among these 87 included patients, 64 patients were followed up for 1 year or more postoperatively. There were 70 patients with pituitary adenomas, 7 patients with craniopharyngiomas, 4 patients with Rathke cleft cyst, and 6 patients with meningiomas in this study. Complete VF recovery after decompression surgery was seen in 29 out of 70 patients with pituitary adenomas, 3 out of 7 patients with craniopharyngiomas, 2 out of 4 patients with Rathke cleft cysts, and no patient with meningioma (Fisher exact test, \( p = 0.1990 \)).

Table 1 displays the baseline characteristics of the eyes with chiasmal compression and healthy controls. The average age of the patients at the preoperative OCT examination and that of the healthy controls during the OCT examination was 52 ± 13 years and 50 ± 14 years, respectively (\( p = 0.3740 \)). The group with chiasmal compression included 36 men (41%) and the control group included 49 men (49%) (\( p = 0.3200 \)). The mean duration from symptom onset to decompression surgery was 8 ± 19 months (range, 1–156 months) in the patient group. The BCVA with LogMAR scale in patients and healthy controls was 0.41 ± 0.65 and 0.01 ± 0.03, respectively (\( p < 0.0001 \)). The average MD of the VF in patients and healthy controls was −13.12 ± 8.16 dB and −0.32 ± 1.48 dB, respectively (\( p < 0.0001 \)). The MD of the VF improved significantly from −13.12 ± 8.16 dB before surgery to −5.78 ± 8.21 dB 1 year after surgery (\( p < 0.0001 \)). The average pRNFL thickness of the patient group and healthy controls was 84.26 ± 16.92 µm and 102.41 ± 9.94 µm, respectively (\( p < 0.0001 \)).

At the preoperative visit, the macular RNFL, GCL, and IPL showed significant thinning in the patient group compared to the healthy controls after adjusting for age and SER (table 2 and figure 2). The mean difference in the macular RNFL, GCL, and IPL thickness between the patients and healthy controls was −4.532 (standard error [SE], 0.701; 95% CI −5.915, −3.150) µm, −7.700 (SE, 0.789; 95% CI −9.263, −6.138) µm, and −4.506 (SE, 0.485; 95% CI −5.465, −3.548) µm, respectively.

In terms of the annualized rate of change, the RNFL, GCL, and IPL showed thinning rates of 1.068 (SE, 0.278; 95% CI 0.523, 1.613) µm/y, 1.189 (SE, 0.376; 95% CI 0.452, 1.925) µm/y, and 1.177 (SE, 0.271; 95% CI 0.645, 1.709) µm/y, respectively, by the linear mixed-effects model after adjustment for age and SER. No significant changes were observed in other retinal layers (INL, OPL, ONL, and PRL) over time (table 3 and figure 3). In the subgroup analysis, the group of patients with complete VF recovery showed no significant changes in retinal layer thickness over time. In contrast, the group of patients without complete VF recovery showed significant annual changes in RNFL (−1.634 µm/y; 95% CI −2.374, −0.895), GCL (−2.099 µm/y; 95% CI −3.100, −1.097), and IPL (−1.805 µm/y; 95% CI −2.522, −1.087) thickness during the 1-year follow-up after decompression surgery (table e-2, data available from Dryad; doi.org/10.5061/dryad.dncjsxkwn).

In the logistic regression analysis of the association between preoperative intraretinal layer thicknesses and postoperative

### Table 1 Baseline Characteristics of Eyes with Chiasmal Compression and Healthy Controls

| Variables                        | Patients with chiasmal compression, n = 87, mean ± SD | Controls, n = 100, mean ± SD | p Value |
|----------------------------------|-------------------------------------------------------|-----------------------------|---------|
| Sex, male/female                 | 36/51                                                 | 49/51                       | 0.3200a |
| Age, y                           | 52 ± 13                                               | 50 ± 14                     | 0.3740b |
| BCVA, logMAR                     | 0.41 ± 0.65                                           | 0.01 ± 0.03                 | <0.0001c |
| Spherical equivalent refractive errors, diopters | −0.77 ± 1.95                                         | −0.58 ± 1.45                | 0.8620a |
| Symptom duration, mo (range)     | 7.78 ± 18.50 (1–156)                                  | NA                          |         |
| Follow-up duration, mo (range)   | 11.38 ± 4.68 (6–20)                                   | NA                          |         |
| Visual field, d, MD (median)     |                                                       |                             |         |
| Preoperative                     | −13.12 ± 8.16 (−12.66)                                | −0.32 ± 1.48 (−0.43)        | <0.0001c |
| Postoperative                    | −5.78 ± 8.21 (−3.07)                                  |                             |         |
| Peripapillary RNFL thickness, µm | 84.26 ± 16.92                                         | 102.41 ± 9.94               | <0.0001c |

Abbreviations: BCVA = best-corrected visual acuity; MD = mean deviation; NA = not applicable; RNFL = retinal nerve fiber layer.

*χ² test.

†Wilcoxon rank-sum test.

‡Statistically significant.

§Humphrey Field Analyzer using the 30-2 SITA-standard protocol.
VF recovery, the thickness of the RNFL (odds ratio [OR], 1.221; 95% CI 1.058, 1.410), GCL (OR, 1.133; 95% CI 1.024, 1.254), and IPL (OR, 1.174; 95% CI 1.002, 1.376) was associated with postoperative VF recovery after adjustment for age, sex, SER, preoperative visual acuity, and preoperative VF defects (table 4). AUROC analysis with adjustment for age, sex, SER, preoperative visual acuity, and preoperative VF defects demonstrated that the RNFL (area under the curve [AUC] 0.785; 95% CI 0.688, 0.882), GCL (AUC 0.780, 95% CI 0.683, 0.877), and IPL (AUC 0.760, 95% CI 0.659, 0.860) were excellent predictors of complete VF recovery after decompression surgery. The combined RNFL, GCL, and IPL thickness was also an excellent predictor of complete VF recovery (AUC 0.790; 95% CI 0.695, 0.885).

**Table 2** Comparison of Preoperative Intraretinal Layer Thickness Between Patients and Healthy Controls

| Layer     | Patients with chiasmal compression (n = 87), μm | Controls (n = 100), μm | Mean differences* (SE), μm | 95% CI of Mean differences |
|-----------|-----------------------------------------------|------------------------|----------------------------|----------------------------|
| RNFL      | 26.514 ± 4.278                                | 31.049 ± 5.297         | −4.532 (0.701)b            | −5.915, −3.150b            |
| GCL       | 36.894 ± 6.647                                | 44.596 ± 3.396         | −7.700 (0.789)b            | −9.268, −6.138b            |
| IPL       | 31.553 ± 3.992                                | 36.062 ± 2.723         | −4.506 (0.485)b            | −5.465, −3.548b            |
| INL       | 37.460 ± 2.846                                | 37.037 ± 3.116         | 0.425 (0.439)              | −0.441, 1.291              |
| OPL       | 30.567 ± 3.007                                | 31.496 ± 3.912         | −0.926 (0.507)             | −1.926, 0.074              |
| ONL       | 65.314 ± 7.956                                | 62.714 ± 7.025         | 2.602 (1.095)b             | 0.441, 4.763b              |
| PRL       | 66.238 ± 2.477                                | 66.526 ± 2.314         | −0.288 (0.351)             | −0.979, 0.404              |

Abbreviations: CI = confidence interval; GCL = ganglion cell layer; INL = inner nuclear layer; IPL = inner plexiform layer; ONL = outer nuclear layer; OPL = outer plexiform layer; PRL = photoreceptor layer; RNFL = retinal nerve fiber layer

* 2-sample *t*-test.

b Statistically significant.

**Figure 2** Preoperative Retinal Layer Thickness in Patients with Chiasmal Compression Compared to the Controls

Box plots of preoperative thicknesses of the 7 retinal layers (retinal nerve fiber layer [RNFL], A; ganglion cell layer [GCL], B; inner plexiform layer [IPL], C; inner nuclear layer [INL], D; outer plexiform layer [OPL], E; outer nuclear layer [ONL], F; photoreceptor layer [PRL], G) in patients with chiasmal compression and healthy controls by a 2-sample *t*-test. The central bars indicate the median values, the boxes indicate interquartile ranges, and the whiskers extend to the highest and lowest values. The values that extended more than two-thirds of the interquartile range from the edge of the box were excluded. Open circles indicate mean values. *Statistically significant differences between the 2 groups. Mean differences and standard error in the thickness between the 2 groups. CI = confidence interval.
### Table 3  Estimated Annualized Rate of Change and Random Effect Variance in the Intraretinal Layer Thickness Following Surgical Decompression of Pituitary Tumors

|             | Annualized rate of change, μm/y (SE) | 95% CI | Random effect variancea |
|-------------|---------------------------------------|--------|------------------------|
| RNFL        | -1.068 (0.278)b                        | -1.613, -0.523b | 19.059b 2.380b |
| GCL         | -1.189 (0.376)b                        | -1.925, -0.452b | 48.633b 3.455b |
| IPL         | -1.177 (0.271)b                        | -1.709, -0.645b | 17.028b 1.648b |
| INL         | 0.068 (0.169)                          | -0.264, 0.399 | 8.957 0.918 |
| OPL         | -0.462 (0.308)                         | -1.064, 0.141 | 5.386 2.875 |
| ONL         | -0.551 (0.446)                         | -1.424, 0.323 | 54.477 5.952 |
| PRL         | -0.328 (0.211)                         | -0.741, 0.084 | 4.310 1.558 |

Abbreviations: CI = confidence interval; GCL = ganglion cell layer; INL = inner nuclear layer; IPL = inner plexiform layer; ONL = outer nuclear layer; OPL = outer plexiform layer; PRL = photoreceptor layer; RNFL = retinal nerve fiber layer; SE = standard error.

*Linear mixed-effects model adjusting for age and spherical equivalent refractive errors and accounting for repeated measurements over time.

(figure e-1 [data available from Dryad: doi.org/10.5061/dryad.dncjsxkwn]).

### Discussion

Thinning of the retinal layers observed in chiasmal compression also occurs in other ocular pathologies, such as ischemic optic neuropathy or inflammatory optic neuropathies, depending on the course of the disease. Retinal layer thinning in chiasmal compression and other optic neuropathies occurs due to retrograde degeneration. In studies involving monkeys, a complete loss of ganglion cells was observed in the medial retina, and cystic degeneration in the INL was found after axonal injury. Retrograde degeneration of the RGCs reported in animal experiments has also been confirmed by OCT analyses in humans. OCT analysis has been widely used to monitor anatomical changes in the eyes of patients with chiasmal compression. OCT measurement was considered more sensitive than VF perimetry in chiasmal compression without definitive VF defects. Previously, Akashi et al. demonstrated that GCC thinning on the nasal hemiretina was diagnostic of band atrophy of the optic nerve head in patients with chiasmal compression. To date, few reports have analyzed changes in the respective retinal layers due to chiasmal compression. In this study, thinning of the pRNFL and macular RNFL, GCL, and IPL was already detected at the preoperative stage compared to healthy controls, which is consistent with previous studies that reported preoperative thinning of the peripapillary and macular RNFL and GCC. Despite the relatively short symptom duration, lasting an average of 8 months in this study population, the structural changes in the retina found by OCT had already occurred at presentation. The association between the duration of symptoms at presentation and the preoperative functional and structural changes in chiasmal compression has been inconsistently reported in previous studies. Although several studies reported a significant correlation between the duration of symptoms and preoperative changes, including VF defects, decreased visual acuity, decreased color vision, or development of optic disc pallor, other studies reported no correlation between the duration of symptoms and the degree of visual impairment. The discrepancies associated with the duration of symptoms may be related to the timing of visual symptom recognition, which varies greatly between individuals. These differences are attributed to a wide range of factors, including individual age, sex, cultural differences, and individual dispositions. Considering that the mean duration of symptoms in our study was only 8 months and the pRNFL thickness was significantly lower than that of the control group, a significant difference may have occurred in the time between disease onset and symptom recognition in our study population.

In this study, the results of OCT autosegmentation over 1 year after surgery revealed serial postoperative changes in the thickness of each retinal multilayer in patients with chiasmal compression. The inner retinal layers, including the RNFL, GCL, and IPL, showed progressive thinning after decompression up to 1 year. The annualized rate of change in the RNFL, GCL, and IPL thickness was 1.068 (95% CI 0.523, 0.051 μm/y, 0.523, 1.709) μm/y, and 1.177 (95% CI 0.452, 1.925) μm/y, respectively. As in the brain, axons in the eyes are lost in the normal aging process. Therefore, the normal decline of neurons in the eyes must be taken into account when interpreting pathologic changes in the retinal microstructures over time. Previously, Ooto et al. reported a linear decrease with aging of 0.05 μm/y, 0.07 μm/y, and 0.05 μm/y in RNFL, GCL, and IPL thickness, respectively, using Topcon 3D OCT (OCT-1000; Topcon, Tokyo, Japan) in 256 healthy volunteers. Nieves-Morenover et al. also reported thickness losses in the RNFL, GCL, and IPL of 0.012 (95% CI –0.008, 0.032) μm/y, 0.051 μm/y, and 0.008, 0.032 μm/y, respectively.
They used SD-OCT (Spectralis, Heidelberg Engineering) to measure the retinal layer thicknesses, as in the present study. Although direct comparison is impossible, the annual rate of thinning in the RNFL, GCL, and IPL in the patient group in our study was greater than the average normal aging changes in previous reports.

Moon et al. previously reported the postoperative changes of RNFL thickness and GCC area in 18 patients with chiasmal compression for 3 to 6 months. Both the RNFL thickness and the GCC area were decreased 3 months postsurgery but were increased 6 months after decompression surgery. However, the RNFL and GCL thickness showed prolonged retrograde degeneration up to 1 year after decompression surgery in our study. Interestingly, our study also showed a tendency toward continuous thinning of
Table 4 Logistic Regression Model of Preoperative Intraretinal Layer Thickness Associated With Visual Field Recovery in Patients With Chiasmal Compression

| Preoperative intraretinal layer | OR* | 95% CI* |
|--------------------------------|-----|--------|
| RNFL                          | 1.221b | 1.058, 1.410b |
| GCL                           | 1.133b | 1.024, 1.254b |
| IPL                           | 1.174b | 1.002, 1.376b |
| INL                           | 0.833 | 0.680, 1.019 |
| OPL                           | 1.006 | 0.853, 1.187 |
| ONL                           | 0.960 | 0.901, 1.023 |
| PRL                           | 0.913 | 0.743, 1.122 |

Abbreviations: CI = confidence interval; GCL = ganglion cell layer; INL = inner nuclear layer; IPL = inner plexiform layer; ONL = outer nuclear layer; OPL = outer plexiform layer; OR = odds ratio; PRL = photoreceptor layer; RNFL = retinal nerve fiber layer.

* Logistic regression model adjusting for age, sex, spherical equivalent refractive errors, preoperative visual acuity, and visual field defects.

**Statistically significant.

The subgroup analysis based on complete VF recovery demonstrated that the group with only partial or no recovery showed a significant decrease in the macular RNFL, GCL, and IPL over time after decompression surgery. Postoperative changes in the retinal structure were greater when the functional outcome was poor in this study. There has been no previous study that specifically demonstrated changes involving each retinal layer over time according to VF recovery in patients with chiasmal compression. Based on our study results, we postulate that more severe preoperative chiasmal compression decreased the likelihood of postoperative VF recovery and may also lead to more severe and chronic changes in the retinal structure.

There were several limitations associated with this study. First, this study was confined to a single center with a population of Asian ethnicity. Some of the results may not apply to other ethnic groups. Further larger-scale and longitudinal studies investigating diverse ethnic groups are needed to confirm the serial changes involving the retinal microstructure of patients with chiasmal compression.

We report the longitudinal changes in retinal microstructures over a 1-year period in eyes with chiasmal compression after decompression surgery. Retinal microstructural changes persisted and progressed in eyes with chiasmal compression even after successful decompression surgery. The preoperative thickness of the inner retinal layers was associated with postoperative VF recovery. These findings shed light on the biological and anatomical sequelae following chiasmal compression. Further functional studies are needed to elucidate the clinical implications of these longitudinal microstructural changes.

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Disclosure

The authors report no disclosures relevant to the manuscript.

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Publication History

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Appendix

Authors

| Name                  | Location                     | Contribution                                                      |
|-----------------------|------------------------------|-------------------------------------------------------------------|
| Ga-In Lee, MD         | Samsung Medical Center, Seoul, Korea | Drafted and revised the manuscript, acquired and analyzed the data |
| Ki Young Son, MD      | Samsung Medical Center, Seoul, Korea | Revised the manuscript, acquired and analyzed the data            |
| Kyung-Ah Park, MD, PhD | Samsung Medical Center, Seoul, Korea | Designed, drafted, conceptualized, and revised the manuscript, acquired and analyzed data, provided critical revision to the manuscript, supervised the study |
| Doo-Sik Kong, MD, PhD  | Samsung Medical Center, Seoul, Korea | Supervised the study, acquired and analyzed the data              |
| Sei Yeul Oh, MD, PhD   | Samsung Medical Center, Seoul, Korea | Designed and conceptualized manuscript for content, performed critical revisions of the manuscript, supervised the study |

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