Differentiation by imaging of superior segmental optic hypoplasia and normal-tension glaucoma with inferior visual field defects only

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Differentiation by imaging of superior segmental optic hypoplasia and normal-tension glaucoma with inferior visual field defects only

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Abstract

Purpose: To differentiate superior segmental optic hypoplasia (SSOH) from normal-tension glaucoma (NTG) with inferior visual field defects only. Methods Eighteen eyes with SSOH (SSOH group) and 19 eyes with NTG (NTG group) were examined by optical coherence tomography (OCT), Heidelberg retina tomography (Heidelberg Retinal Tomograph II, HRT II) and standard automated perimetry.

Results: Retinal nerve fiber layer thickness (RNFLT) based on OCT measurements was significantly reduced (thinner) in the superior to superonasal sectors and significantly greater (thicker) in the inferotemporal sector in the SSOH group than in the NTG group. The cup was significantly smaller and the rim significantly larger in the superotemporal and temporal sectors in the SSOH group than in the NTG group based on HRT II measurements. The greatest area under the receiver operating characteristic curve for discrimination of SSOH from NTG by OCT and HRT II was for the RNFLT ratio of 1 +2 o'clock/10 +11 o'clock (0.985) and for the ratio of the superonasal to superotemporal sector of rim to disc area ratio and cup to disc area ratio (0.955), respectively. The frequent location of the inferior visual field defects corresponded to the difference in structural changes in both groups.

Conclusions: Comparison of the superonasal to superotemporal sectors by OCT and HRT II were useful in differentiating SSOH from NTG with only inferior visual field defects.

Keywords Superior segmental optic hypoplasia, Normal-tension glaucoma, Optical coherence tomography, Heidelberg Retina Tomograph II , Visual field

Introduction

In recent years, A form of segmental optic nerve hypoplasia, called superior segmental optic hypoplasia (SSOH), has been reported in recent years, mainly in Asia [1–7]. SSOH eyes usually have visual field defect in the lower hemifield corresponding to optic disc hypoplasia of the superior to nasal segment [1–7]. Although SSOH has a much lower prevalence than glaucoma [3, 4] and an essentially different pathology from the latter, it should be included in the list of differential diagnoses of normal-tension glaucoma (NTG), especially when the visual field defects are located predominantly in the inferior visual field. In our daily clinical practice, we often see cases in which SSOH is misdiagnosed and treated as NTG. A number of researchers have compared the structural characteristics of eyes of normal subjects with those of patients with SSOH using optical coherence tomography (OCT) [5, 6]. Unoki et al. [5] report that circular OCT scans of the peripapillary retina showed a decrease in the thickness of the retinal nerve fiber layer (RNFL) in the superior quadrants of SSOH eyes. Lee et al. [6] found that even

though the eyes of their patients with SSOH had a significantly thinner RNFL than those of the control subjects in all segments except for the papillomacular bundle area, the area under the receiver operating characteristic curve (AROC) was greatest for the RNFL thickness of the superonasal one o'clock segment measured by OCT. They also report that the rim area of the superonasal segment had the greatest AROC among all HRT parameters. Hayashi et al. [7] demonstrated the characteristics of the optic nerve head configuration of SSOH using spectral-domain OCT. However, structural differences between SSOH and NTG have not been elucidated by any imaging device. Here we report our investigation of whether imaging devices are useful in the differentiation of SSOH from NTG with inferior visual field defects only.

Materials and methods

Subjects

A retrospective study was conducted on patients who were examined at the Department of othalmology at Kanazawa University Hospital between March 2003 and March 2009 and met the definition of either SSOH or NTG with only inferior visual field defects as described below. Healthy volunteers were recruited as normal controls. All volunteers underwent a complete ophthalmic examination. The inclusion criteria for the normal control group were normal ophthalmic findings, an intraocular pressure (IOP) of < 20 mmHg and normal reliable standard automated perimetry (SAP). We defined the visual fieldwhich did not meet Anderson's criteria [8] as normal. Exclusion criteria were as follows: a previous history of intraocular surgery, including laser treatment, other ocular diseases, disorders of the central nervous system, corrected decimal visual acuity of <0.9, myopia of more than -7D or astigmatism of >3D and an age of ≤18 years.

This study met the Helsinki Declaration guidelines and was approved by the Ethical Committee of Kanazawa University Graduate School of Medical Science. Informed consent was obtained from each subject.

Definition of SSOH in this study Patients were diagnosed with either SSOH with only inferior visual field defect when they met the four criteria listed below.

1. The optic disc had the characteristic features of SSOH, i.e., relative superior entrance of the central etinal artery, superior double ring sign (a hallmark of optic hypoplasia) [9–11] and thinning of the superior RNFL.
2. A visual field test revealed inferior altitudinal or sector visual field defect by Goldmann perimetry.
3. IOP measurements had a peak of ≤21 mmHg based on Goldmann applanation tonometry measurements.
4. The eyes demonstrated a gonioscopically normal open angle; the eye which was suspected to have glaucomatous optic neuropathy was excluded.

Definition of NTG with only inferior visual field defects in this study Patients were diagnosed with NTG with only inferior visual field defects when they met the four criteria listed below.

1. Goldmann applanation tonometry in both eyes repeated more than five times without any glaucoma medication showed an IOP with a peak of 21 mmHg or less.
2. Both eyes demonstrated a gonioscopically normal open angle.
3. The vertical cup-to-disc ratio of the optic nerve head was $\geq$ 0.7, or the rim width at the superior portion (11–1 o'clock) or the inferior portion (5–7 o'clock) was $\leq$0.1 of the disc diameter, or the difference of the vertical cup-todisc ratio between both eyes was $\geq$0.2, or the existence of optic disc rimthinning with a corresponding retinal nerve fiber layer defect (RNFLD) was established.
4. In SAP (described in following text), a hemifield was judged to be abnormal when the pattern deviation probability plot showed an abnormal cluster of $\geq$3 non-edge contiguous points, having a sensitivity probability of <5 % in the lower hemifield, including at least 1 point with a probability of <1 %, but no abnormal cluster in the upper hemifield.

Optical coherence tomography

The fast RNFL thickness (3.4) scan mode was used in Stratus OCT (Carl Zeiss Meditec, Dublin, CA). Peripapillary RNFL thickness parameters were automatically calculated by the existing Stratus OCT software (ver. 4.0). Cases were selected if the signal strength, an indicator of scan quality, was $\geq$ 7. The circle was divided into four or twelve sectors by the existing software. The 256 measurement points' value of the OCT RNFL thickness around the optic disc was redivided into six sectors corresponding to the six Heidelberg retina tomography (HRT II; Heidelberg Retinal Tomograph II; Heidelberg Engineering, Dossenheim, Germany) sectors. The mean RNFL thickness of each sector was used for analysis.

Heidelberg Retina Tomograph II

An HRT II with software version 1.7–3.1 was used to obtain three-dimensional (3D) topographic images of the optic nerve head; version 3.1 of the same software was used in the analysis. The topographic images were obtained, combined and automatically aligned to generate one mean topographic image for analysis. The same examiner (M.Y.) drew the contour lines for all subjects. Cases were excluded if the topography standard deviation (SD), indicating image quality, exceeded 40 lm. Sectors were defined as superotemporal (46° –90°), superonasal (91° –135°), nasal (136° –225°), inferonasal (226° –270°), inferotemporal (271° –315°) and temporal (1° –45° and 316° –360°). The following measurements were used for the analysis of the optic disc parameters: disc area, cup area, cup volume, rim area and rim volume. In the HRT II, sector-based analysis was performed for each parameter. In addition, the diagnostic classification performance of the Moorfields regression analysis (MRA) was

assessed. The outcomes of the 'outside normal limits' were defined as abnormal. The frequencies of the outside normal limits were calculated by the sector.

Evaluation of visual field

Standard automated perimetry measurements were obtained using the Humphrey visual field test (central 30-2 Swedish interactive threshold algorithm standard); the tests were performed multiple times within 6 months of the initial examination. We set the reliability criteria at a fixation loss of<33 % and false-positive and false-negative values of <15 %. The SAP measurement showing the highest reliability, except the initial test, was analyzed. If a test point was at the p<0.5 % level on the total deviation probability plot, its location was established as the site of the visual field defect. The frequencies of occurrence were examined for such defects. Patients were excluded from the analysis if there were abnormal clusters of ≥3 non-edge contiguous points having a sensitivity with a probability of <5 % in the upper hemifield in SAP in both the SSOH and the NTG eyes.

Garway-Heath et al. [12] report on the correspondence between the six visual field sectors and six optic nerve head sectors in HRT II on the basis of known anatomy [13] (Fig. 1). Similarly, we also evaluated the correspondence of the visual field damage and parameters of HRT II and OCT based on the six optic nerve head sectors.

Data analysis

One eye per subject was selected. If both eyes were eligible, the eye with the worse mean deviation (MD) was selected. The left eye was the mirror image of the right eye in the analysis. The Kruskal–Wallis test was used to compare the parameters between the patients with SSOH or NTG and the control subjects. Dunn's test was used for post hoc comparisons. Sex distribution among the groups was evaluated with the v_2 test. Fisher's test was used to compare the frequencies of outside normal limits by MRA between the SSOH and NTG groups. These statistical analyses were performed using Stat Mate III software (ATOMS Co., Ltd., Tokyo, Japan). We used ROC curves to describe the diagnostic ability of each OCT and HRT II parameter to differentiate SSOH eyes from NTG eyes and to differentiate these from the eyes of the normal control subjects. The AROC was calculated using SPSS ver. 18.0 software (SPSS Inc., Chicago, IL). We also examined the nasal/temporal ratio and superior/ inferior ratio of each OCT and HRT II parameter. A p value of <0.05 was considered to be statistically significant.

Results

During the enrollment period, SSOH was diagnosed in 33 patients. Fifteen of these patients were subsequently excluded from this study: two patients did not meet the refraction criterion, five patients did not meet the age criterion, one patient had brain tumor surgery, five patients had abnormalities in the upper hemifield based on SAP results and glaucoma was suspected in two patients because one had

progressive visual field defects and the other had inferior RNFLD. Therefore, 18 eyes of 18 patients with SSOH were included in this study (SSOH group). We reviewed the database of glaucoma patients at Kanazawa University Hospital and chose eligible subjects for this study according to the inclusion and exclusion criteria. A total of 32 patients were identified who had NTG with only inferior visual field defects; 13 of these patients were excluded from this study due to not meeting the refraction criterion (5 patients), not meeting the visual field test reliability criterion (6 patients), or having a history of cataract surgery (2 patients). Nineteen eyes of 19 patients with NTG who had only inferior visual field defects were included in this study (NTG group). The control group included 33 eyes of 33 volunteers (control group).

Table 1 shows the demographics and ocular characteristics of the 18 subjects with SSOH, 19 subjects with NTG and the 33 normal control subjects. The SSOH group was significantly younger than the NTG and control groups ($p<0.001$). There were no significant differences between the SSOH and NTG groups in any other outcomes, including the severity of visual field defects [MD and pattern SD (PSD)].

Table 2 shows the peripapillary RNFL thickness measured by OCT. The RNFL thickness was significantly thinner in the superior, nasal and inferior quadrants in the SSOH group than in the controls. The RNFL thickness in the NTG group was significantly thinner than that in the controls in all quadrants. Compared to the NTG group, the RNFL thickness in the SSOH group was significantly thinner at the 12 o'clock ($p<0.05$), 1 o'clock ($p<0.001$) and 2 o'clock positions ($p<0.01$) and was thicker at the 7 o'clock position ($p<0.05$).

Table 3 shows the peripapillary RNFL thickness determined by OCT divided into six sectors corresponding to the six HRT II sectors. The RNFL thickness at the superonasal sector was significantly thinner in the SSOH group than in the NTG group.

Table 4 shows the disc parameters of the eyes with SSOH and NTG and those of the normal controls measured by HRT II. There were no significant differences between the three groups in the disc area and in any of the six sectors of the disc area. When the parameters were examined by sector, the SSOH group had a significantly larger rim area and rim volume in the temporal and superotemporal sectors than the NTG group. The SSOH group had a significantly smaller cup area than the NTG group except for the superonasal and nasal sectors.

Table 5 shows the percentages of outside normal limit by MRA of HRT II in the SSOH and NTG patients. Although the frequency of the outside normal limit was significantly higher in the NTG group compared with the SSOH group at the superotemporal sector ($p = 0.003$), it was not significantly different between the SSOH and the NTG groups at the superonasal and nasal sectors.

The largest AROC discriminating SSOH from NTG was for the RNFL thickness of the one o'clock segment measured by OCT [AROC 0.975, 95 % confidence interval (CI) 0.932–1.000]. Among the quadrant parameters, the thickness of the superior quadrant RNFL was the parameter that best differentiated the SSOH eyes from the NTG eyes as measured by OCT (AROC 0.803, 95 % CI 0.656–

0.949). The HRT parameters showed a relatively lower AROC than the OCT parameters. When the nasal/temporal ratio was determined, the largest AROC value for distinguishing the SSOH eyes from the NTG eyes was the RNFL thickness ratio of the superonasal 1 + 2 o'clock segment to the superotemporal 10 + 11 o'clock segment (AROC 0.985, 95 % CI 0.958– 1.000), as measured by OCT. For most HRT parameters, the AROC values distinguishing the SSOH eyes from the NTG eyes were largest for the ratio of the superonasal to superotemporal segments: cup/disc area ratio (AROC 0.955, 95 % CI 0.881–1.000), rim area (AROC 0.935, 95 % CI 0.843–1.000), rim volume (AROC 0.890, 95 % CI 0.749–1.000) and rim/disc area ratio (AROC 0.955, 95 % CI 0.881–1.000). Among these, the AROC values were the largest for the ratio of rim/disc area ratio and the cup/disc area ratio.

Figure 2 shows the frequency of points with $p<0.5$ % on the total deviation probability plots of the SAP measurments in the SSOH and NTG groups. The frequency of visual field defects was significantly higher in the SSOH group than in the NTG group from the temporal sector to the inferior sector which leads to the Mariotte blind spot (Fig. 2a). This area corresponds to the superonasal disc area according to the diagram (Fig. 1) by Garway-Heath et al. [12]. The frequency of the inferior visual field defects in the nasal sector and in the Bjerrum's area was higher in the NTG group than in the SSOH group (Fig. 2b). This area corresponds to the superotemporal disc sector according to the diagram by Garway-Heath et al. [12] (Fig. 1).

Discussion

In our OCT analysis, the RNFL was significantly thinner in the SSOH group than in the NTG group from the superior to the superonasal sectors (12–2 o'clock). A similar result was also found when the eyes with SSOH were compared with those of the control subjects: the thickness of the RNFL of the eyes with SSOH was generally reduced; these differences were significant with the exception of the 4, 7, 8 and 9 o'clock segments. Unoki et al. [5] found that RNFL thickness as determined by OCT was significantly thinner in SSOH eyes compared with normal eyes in the 11 and 12 o'clock sectors based on a 12-sector analysis and in the superior quadrant based on a 4-quadrant sector analysis. Lee et al. [6] reported that the RNFL thickness of SSOH eyes was significantly thinner than that of the eyes of normal subjects except for the 8 and 9 o'clock segments. Lee et al. also found that the greatest AROC difference between the SSOH eyes and normal eyes was for the RNFL thickness of the 1 o'clock segment (AROC 0.991), leading them to suggest that this value can be a useful tool for diagnosing SSOH. In our study, the 1 o'clock segment showed the greatest AROC values (AROC 0.995, 95 % CI 0.983–1.000) to distinguish the SSOH eyes from those of the normal controls and also the greatest AROC values (AROC 0.975, 95 % CI 0.932–1.000) to distinguish the SSOH eyes from NTG eyes with only inferior visual field defects among the 12 sectors. Our results are consistent with those of Lee et al. [6], and we also demonstrated that the RNFL thickness of the 1 o'clock segment is a useful parameter for distinguishing SSOH from NTG patients with inferior visual field defect. Furthermore, in distinguishing SSOH from

NTG eyes, an RNFL thickness ratio of the 1 + 2 o'clock to 10 + 11 o'clock showed an even greater AROC (AROC 0.985, 95 % CI 0.958–1.000). If the cut-off value of the RNFL thickness ratio of the 1 + 2 o'clock to 10 + 11 o'clock was set at 0.312, the sensitivity was 100 % and specificity 94.4 %. Similarly, the greatest AROC was for the ratio of the superonasal to superotemporal sectors for the rim-to-disc ratio and cup-todisc ratio (AROC 0.955, 95 % CI 0.881–1.000) in HRT II parameters. We therefore consider that obtaining the ratios of the superonasal to superotemporal sectors (1 + 2 o'clock to 10 + 11 o'clock) would provide a useful parameter for differentiating SSOH and NTG.

Our OCT and HRT II sector-based analysis showed that the NTG group had suffered significantly more damage to the inferior RNFL and the inferior part of the optic disc than the SSOH group. This reflected the generalized glaucomatous damage involving the inferior part of the RNFL and optic disc from the early stage of glaucoma [14, 15] even though the corresponding part of the visual field seemed to be intact [16]. In this regard, Nagai-Kusuhara et al. reported that HRT is able to detect glaucomatous damage in areas where visual field defects were undetected in eyes with either upper or lower visual hemifield defects [16].

Although disc area has been reported to be in close correlation with other HRT parameters [17], our HRT II examination revealed no significant difference in terms of disc area between the three groups. Based on this result, disc size should have had no influence on the differences in the HRT parameters between the three groups. In our study, we also found no significant difference between the three groups in terms of the disc areas of the six sectors, including the superonasal and nasal areas where hypoplasia was expected in SSOH eyes. We speculate that HRT II is unable to detect any sector hypoplasia because HRT II divides the optic disc into six sectors around the center of gravity.

In our study, the visual field sectors which were more frequently damaged in the SSOH group than in the NTG group corresponded to the superonasal and nasal sectors of the optic disc. The thickness of the RNFL, determined by OCT, was significantly thinner at the superonasal sector in the SSOH group than in the NTG group. Thus, the sectors determined to predominantly damaged in the SSOH eyes relative to the NTG eyes in the visual field were matched those identified in the OCT analysis. In contrast, all HRT II parameters and the MRA failed to detect the difference between the SSOH and NTG groups at these sectors. On the other hand, based on the HRT II results, the sectors in which the visual field was predominantly more damaged in the NTG eyes than in the SSOH eyes corresponded to the superotemporal sector of the optic disc, where the cup area was significantly larger and the rim area and volume were significantly smaller in the NTG eyes than in the SSOH eyes. Thus, the sectors predominantly damaged in the NTG eyes relative to the SSOH eyes in the visual field matched those displayed in the HRT analysis. In contrast, the results of the OCT analysis of the RNFL thickness at the superotemporal sector were not significantly different between the SSOH and NTG groups. These findings indicate that the sites of visual field damage characteristic of SSOH and NTG match those of structural abnormalities predominant in SSOH eyes and NTG eyes, but that OCT and HRT are

complementary in the detection of the structural differences between SSOH and NTG eyes.

Our study has a number of limitations. First, the SSOH group was significantly younger than the NTG and control groups. The young age of the SSOH patients reduces the possibility that SSOH and NTG co-exist to that of unlikely because glaucoma is relatively uncommon among the young. The RNFL is reported to become thinner with aging [18, 19]. Parikh et al. reported that the change in average RNFL thickness as measured by OCT due to age is -0.16 lm/year in normal eyes [18]. The temporal quadrant average, superior quadrant average, nasal quadrant average and inferior quadrant average had a negative slope of -0.20, -0.23, -0.12 and -0.08 lm/year, respectively, in their study [18]. When these authors compensated for the difference in age between the SSOH and NTG groups (26.3 years), the corrected RNFL thickness of the SSOH eyes was 69.1 ± 17.2 lm in the temporal, 52.2 ± 15.9 in the superior, 43.8 ± 13.2 lm in the nasal and 109.4 ± 17.9 lm in the inferior quadrants. The correction of RNFL thickness did not change the results of the RNFL thickness analysis except for the inferior quadrant and at 7 o'clock, where the thickness difference between the two groups became insignificant [18]. We also calculated the corrected RNFL thickness to fit the age of the controls into the SSOH group. The corrected RNFL thickness of the controls did not change the results of the RNFL thickness analysis except for those at the 4 o'clock position, where the thickness difference between the two groups became insignificant. The correlation between age and HRT parameters remains controversial [20–22], with some researchers reporting age-related optic nerve head changes in cross-sectional and longitudinal studies [20, 21] and others finding no correlation between age and HRT parameters in a cross-sectional study [22]. Second, only a small number of SSOH and NTG subjects were enrolled in our study. However, our results show significant differences between SSOH and NTG eyes in many parameters of OCT, HRT II and SAP, indicating that OCT, HRT II and SAP are useful in distinguishing between SSOH and NTG eyes. Further studies with more cases and with new devices, such as Fourier-domain OCT, are necessary to provide a more detailed difference between SSOH and NTG eyes.

In conclusion, we quantitatively analyzed the structural abnormalities in SSOH and NTG eyes with only inferior visual field defects by OCT and HRT II and found differences in the locations of abnormalities in the optic disc and RNFL between the two conditions. Our comparison of onboard parameters revealed that the OCT parameters of the superior to superonasal segment had a higher AROC value than that of the HRT parameters. The calculated ratio of the superonasal to superotemporal sectors was markedly different in SSOH eyes and NTG eyes in both the OCT and HRT analyses. The location of the inferior visual field defects differed in SSOH eyes and NTG eyes, with the differences corresponding to differences in the location of the structure abnormalities between the SSOH and NTG eyes. Based on our results, OCT and HRT can be used as complementary tools for detecting the structural differences between SSOH and NTG eyes.

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Table 1 Demographics and ocular characteristics of superior segmental optic hypoplasia, normal-tension glaucoma and normal control

	SSOH eyes (n=18)	NTG eyes (n=19)	Control (n=33)	p value	p value SSOH-NTG	p value SSOH-control	p value NTG-control
Age (years)	31.5 ± 11.0	57.4 ± 8.5	50.5 ± 13.8	＜0.001*†	＜0.001* §	＜0.001* §	ns §
Gender (M:F)	4:14	10:9	20:13	0.030‡	0.117‡	0.020*‡	0.788‡
SE (D)	-3.7 ± 2.6	-3.6 ± 2.7	-0.9 ± 2.1	0.0003*†	ns §	＜0.01* §	＜0.01* §
IOP (mmHg)	15.3 ± 2.7	15.4 ± 3.0	13.8 ± 2.2	0.061 §	ns §	ns†	ns §
HFA							
MD (dB)	-4.8 ± 2.5	-5.5 ± 4.3	0.35 ± 1.2	＜0.001*†	ns §	＜0.001* §	＜0.001* §
PSD (dB)	10.2 ± 5.1	10.4 ± 5.4	1.5 ± 0.2	＜0.001*†	ns §	＜0.001* §	＜0.001* §

SSOH, superior segmental optic hypoplasia; NTG, normal-tension glaucoma; M, male; F, female; SE, spherical equivalent; IOP, intraocular pressure; HFA, Humphrey Field Analyzer; MD, mean deviation ; PSD, pattern standard deviation.

Values are means ± standard deviation. P values for comparison among, SSOH, NTG and control groups. † Kruskal-Wallis test; ‡ χ^2 exact test; § Dunn's test (*significant values).

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Table 2 Comparison of the peripapillary retinal nerve fiber layer thickness parameters measured by optical coherence tomography among subjects with superior segmental optic hypoplasia, normal-tension glaucoma and normal control

parameter	SSOH eyes (n=18)	NTG eyes (n=19)	Control (n=33)	p value†	p value‡ SSOH-NTG	p value‡ SSOH-control	p value‡ NTG-control
Average	72.7 ± 11.5	76.2 ± 9.8	102.0 ± 9.1	< 0.001*	ns	< 0.001*	< 0.001*
Quadrant							
Temporal	74.3 ± 18.4	66.1 ± 13.3	82.4 ± 13.4	0.002	ns	ns	< 0.01*
Superior	58.1 ± 15.9	77.5 ± 16.8	123.8 ± 16.4	< 0.001*	ns	< 0.001*	< 0.001*
Nasal	47.0 ± 13.1	57.8 ± 11.3	69.9 ± 11.1	< 0.001*	ns	< 0.001*	< 0.01*
Inferior	111.5 ± 17.9	103.9 ± 12.9	131.7 ± 18.3	< 0.001*	ns	< 0.01*	< 0.001*
Clock hour							
1	41.3 ± 12.1	84.0 ± 20.8	108.3 ± 23.8	< 0.001*	< 0.001*	< 0.001*	＜0.05*
2	40.6 ± 9.6	64.1 ± 17.3	83.6 ± 18.2	< 0.001*	< 0.01*	< 0.001*	＜0.05*
3	41.1 ± 13.5	50.8 ± 13.5	57.3 ± 10.1	0.0003	ns	< 0.001*	ns
4	58.9 ± 21.0	56.6 ± 12.6	68.7 ± 12.9	0.006	ns	ns	＜0.05*
5	84.2 ± 24.2	85.3 ± 14.2	105.5 ± 22.9	0.0006	ns	＜0.05*	< 0.01*
6	113.3 ± 25.8	106.6 ± 19.0	142.6 ± 28.7	< 0.001*	ns	＜0.01*	< 0.001*
7	137.2 ± 23.3	118.7 ± 22.2	147.0 ± 18.9	0.0002	＜0.05*	ns	< 0.001*
8	86.1 ± 23.5	78.9 ± 15.8	86.0 ± 18.3	0.530	ns	ns	ns
9	60.3 ± 15.3	56.7 ± 12.3	66.3 ± 10.0	0.023	ns	ns	＜0.05*
10	76. 4± 24.0	62.7 ± 19.4	95.0 ± 17.8	< 0.001*	ns	＜0.05*	< 0.001*
11	83. 5± 29.0	67.9 ± 23.3	140.0 ± 18.7	< 0.001*	ns	< 0.001*	< 0.001*
12	49.7 ± 16.5	80.0 ± 23.5	123.4 ± 26.0	< 0.001*	＜0.05*	< 0.001*	< 0.001*

SSOH, superior segmental optic hypoplasia; NTG, normal-tension glaucoma.

Clock-hour thickness values from the left eyes were converted into the right eyes format.

Values are means ± standard deviation.

P values for comparison among, SSOH, NTG and control groups. †Kruskal-Wallis test; ‡Dunn's test (*significant values).

Table 3 Comparison of the peripapillary retinal nerve fiber layer thickness parameters measured by optical coherence tomography divided into six sectors among subjects with superior segmental optic hypoplasia, normal-tension glaucoma and normal control

	SSOH eyes (n=18)	NTG eyes (n=19)	Control (n=33)	p value†	p value‡ SSOH-NTG	p value‡ SSOH-control	p value‡ NTG-control
T	73.5 ± 19.9	64.4 ± 14.6	81.1 ± 13.7	0.003	ns	ns	＜0.01*
ST	74.1 ± 22.4	64.4 ± 18.6	137.6 ± 17.5	＜0.001*	ns	＜0.001*	＜0.001*
SN	43.7 ± 11.7	79.2 ± 22.0	108.8 ± 22.6	＜0.001*	＜0.001*	＜0.001*	＜0.01*
N	46.8± 11.6	57.9 ± 12.1	70.4 ± 12.6	＜0.001*	ns	＜0.001*	＜0.05*
IN	89.0 ± 23.1	95.4 ± 13.2	115.4 ± 25.8	0.0002	ns	＜0.001*	＜0.01*
IT	133.0 ± 21.4	119.8 ± 20.5	146.8 ± 18.6	0.0002	ns	ns	＜0.001*

SSOH, superior segmental optic hypoplasia; NTG, normal-tension glaucoma; T, temporal; ST, superotemporal;I, inferior; SN, superonasal; N, nasal; IN, inferonasal; IT, inferotemporal.

Values are means ± standard deviation. P values for comparison among, SSOH, NTG and control groups. †Kruskal-Wallis test; ‡Dunn's test (*significant values).

Table 4 Comparison of disc parameters measured by Heidelberg Retina Tomograph II among subjects with superior segmental optic hypoplasia, normal-tension glaucoma and normal control

parameter	SSOH eyes (n=18)	NTG eyes (n=19)	Control (n=33)	p value†	p value‡ SSOH-NTG	p value‡ SSOH-control	p value‡ NTG-control
Disc area	1.843 ± 0.410	2.039 ± 0.606	1.981 ± 0432	0.602	ns	ns	ns
T	0.433 ± 0.106	0.461 ± 0.145	0.469 ± 0.115	0.795	ns	ns	ns
ST	0.258 ± 0.061	0.277 ± 0.089	0.255 ± 0.056	0.702	ns	ns	ns
SN	0.226 ± 0.056	0.276 ± 0.085	0.268 ± 0.06	0.097	ns	ns	ns
N	0.439 ± 0.103	0.466 ± 0.144	0.467 ± 0.111	0.842	ns	ns	ns
IN	0.244 ± 0.055	0.260 ± 0.084	0.251 ± 0.056	0.843	ns	ns	ns
IT	0.244 ± 0.059	0.296 ± 0.092	0.269 ± 0.053	0.273	ns	ns	ns
Cup area	0.557 ± 0.378	0.945 ± 0.539	0.515 ± 0.350	0.009*	ns	ns	＜0.01*
T	0.176 ± 0.115	0.293 ± 0.141	0.243 ± 0.117	0.036*	＜0.05*	ns	ns
ST	0.084 ± 0.065	0.168 ± 0.093	0.069 ± 0.052	0.0006*	＜0.05*	ns	＜0.001*
SN	0.091 ± 0.067	0.121 ± 0.090	0.040 ± 0.046	0.0005*	ns	＜0.05*	＜0.01*
N	0.129 ± 0.102	0.148 ± 0.144	0.060 ± 0.081	0.004*	ns	＜0.05*	＜0.05*
IN	0.031 ± 0.024	0.074 ± 0.052	0.028 ± 0.033	0.001*	＜0.05*	ns	＜0.001*
IT	0.047 ± 0.033	0.142 ± 0.081	0.074 ± 0.062	0.0008*	＜0.001*	ns	＜0.05*
Cup volume	0.148 ± 0.174	0.217 ± 0.192	0.123 ± 0.140	0.085	ns	ns	ns
T	0.036 ± 0.046	0.056 ± 0.051	0.053 ± 0.055	0.143	ns	ns	ns
ST	0.023 ± 0.030	0.040 ± 0.034	0.020 ± 0.021	0.05	ns	ns	ns

SN	0.028 ± 0.032	0.033 ± 0.032	0.011 ± 0.016	0.01*	ns	ns	＜0.05*
N	0.044 ± 0.062	0.037 ± 0.042	0.016 ± 0.025	0.021*	ns	ns	＜0.05*
IN	0.006 ± 0.009	0.020 ± 0.021	0.006 ± 0.011	0.002*	＜0.05*	ns	＜0.01*
IT	0.008 ± 0.011	0.032± 0.025	0.017 ± 0.024	0.001*	＜0.001*	ns	＜0.05*
Rim area	1.286 ± 0.407	1.092 ± 0.354	1.466 ± 0.269	0.0005*	ns	ns	＜0.001*
T	0.257 ± 0.130	0.168 ± 0.068	0.226 ± 0.075	0.013*	＜0.05*	ns	＜0.05*
ST	0.174 ± 0.067	0.105 ± 0.064	0.186 ± 0.038	＜0.001*	＜0.01*	ns	＜0.001*
SN	0.136 ± 0.059	0.156 ± 0.061	0.229 ± 0.043	＜0.001*	ns	＜0.001*	＜0.001*
N	0.309 ± 0.098	0.319 ± 0.133	0.406 ± 0.083	0.0004*	ns	＜0.01*	＜0.01*
IN	0.212 ± 0.052	0.187 ± 0.072	0.223 ± 0.047	0.059	ns	ns	ns
IT	0.198 ± 0.052	0.155 ± 0.051	0.196 ± 0.048	0.014*	ns	ns	＜0.05*
Rim volume	0.351 ± 0.147	0.279 ± 0.110	0.407 ± 0.128	0.005*	ns	ns	＜0.01*
T	0.030 ± 0.022	0.015 ± 0.008	0.024 ± 0.014	0.007*	＜0.01*	ns	＜0.05*
ST	0.045 ± 0.025	0.019 ± 0.021	0.051 ± 0.022	＜0.001*	＜0.01*	ns	＜0.001*
SN	0.038 ± 0.028	0.046 ± 0.031	0.076 ± 0.028	＜0.001*	ns	＜0.001*	＜0.01*
N	0.104 ± 0.049	0.092 ± 0.040	0.127 ± 0.041	0.018*	ns	ns	＜0.05*
IN	0.077 ± 0.029	0.066 ± 0.028	0.080 ± 0.028	0.197	ns	ns	ns
IT	0.053 ± 0.024	0.042 ± 0.026	0.048 ± 0.021	0.256	ns	ns	ns

SSOH, superior segmental optic hypoplasia ; NTG, normal-tension glaucoman; T, temporal; ST, superotemporal SN, superonasal; N, nasal; IN, inferonasal; IT, inferotemporal.
Values are means ± standard deviation. P values for comparison among, SSOH, NTG and control groups. †Kruskal-Wallis test; ‡Dunn's test (*significant values).

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Table 5 Comparisons of frequency of outside normal limits by Moorfield regression analysis between subjects with superior segmental optic hypoplasia and subjects with normal-tension glaucoma

	SSOH eyes (n=18)	NTG eyes (n=19)	p value
T	0%	5.3%	0.978
ST	5.5%	47.4%	0.003*
SN	38.9%	36.8%	0.833
N	27.8%	15.8%	0.627
IN	0%	15.8%	0.248
IT	0%	10.5%	0.491

SSOH, superior segmental optic hypoplasia ; NTG, normal-tension glaucoman; T, temporal; ST, superotemporal SN, superonasal; N, nasal; IN, inferonasal; IT, inferotemporal.
Stastical significances was tested using the Fisher's exact test (*significant values).

Table 6 Area under the receiver operator curves for discrimination of superior segmental optic hypoplasia from normal-tension glaucoma and control subject by optical coherence tomography

AROC of OCT RNFL thickness parameter					
parameter	SSOH-NTG	SSOH-control	parameter	SSOH-NTG	SSOH-control
Average RNFL	0.528	0.990	Clock hour		
			1	0.975*	0.995
Quadrant			2	0.889	0.973
Temporal	0.645	0.616	3	0.708	0.842
Superior	0.803	1.000*	4	0.510	0.680
Nasal	0.741	0.901	5	0.534	0.747
Inferior	0.694	0.783	6	0.599	0.768
N/T ratio	0.785	0.754	7	0.732	0.608
S/I ratio	0.876	0.990	8	0.613	0.530
			9	0.566	0.634
			10	0.652	0.711
			11	0.661	0.950
			12	0.883	0.994
			1/11 ratio	0.968	0.852
			2/10 ratio	0.901	0.859
			3/9 ratio	0.724	0.753
			4/8 ratio	0.594	0.608
			5/7 ratio	0.673	0.688
			12/6 ratio	0.885	0.970
			1+2/10+11ratio	0.985*	0.880

AROC, area under the receiver operative characteristic curve; OCT, optical coherence tomography; RNFL, retinal nerve fiber layer; SSOH, superior segmental optic hypoplasia ; NTG, normal-tension glaucoman; N, nasal; T, temporal; S, superior; I, inferior. Clock-hour thickness values from the left eyes were converted into the right eye format in OCT parameters.

Table 7 Area under the receiver operator curves for discrimination of superior segmental optic hypoplasia from normal-tension glaucoma and control subject by Heidelberg retina tomograph II

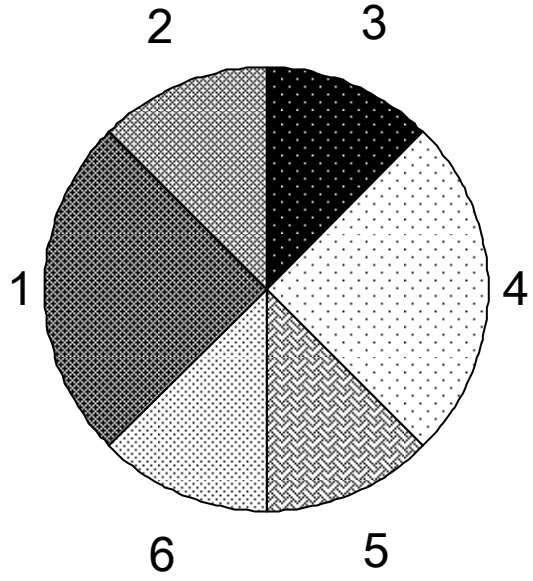
AROC of HRT parameter

parameter	SSOH-NTG	SSOH-control	parameter	SSOH-NTG	SSOH-control
Cup area	0.722	0.529	Rim area	0.646	0.688
T	0.732	0.647	T	0.743	0.546
ST	0.776	0.556	ST	0.803	0.586
SN	0.575	0.749	SN	0.637	0.891
N	0.510	0.726	N	0.513	0.787
IN	0.753	0.586	IN	0.637	0.562
IT	0.844	0.613	IT	0.713	0.509
SN/ST ratio	0.854	0.895	SN/ST ratio	0.935	0.951
N/T ratio	0.694	0.857	N/T ratio	0.808	0.829
IN/IT ratio	0.689	0.775	IN/IT ratio	0.601	0.618
SN+ST/IN+IT ratio	0.868	0.960	SN+ST/IN+IT ratio	0.713	0.989
Cup volume	0.640	0.500	Rim volume	0.637	0.636
T	0.667	0.643	T	0.760	0.567
ST	0.673	0.529	ST	0.794	0.566
SN	0.561	0.667	SN	0.592	0.852
N	0.513	0.675	N	0.556	0.648
IN	0.753	0.512	IN	0.614	0.527
IT	0.832	0.639	IT	0.658	0.524
SN/ST ratio	0.792	0.885	SN/ST ratio	0.890	0.836
N/T ratio	0.716	0.844	N/T ratio	0.706	0.664
IN/IT ratio	0.592	0.746	IN/IT ratio	0.668	0.718
SN+ST/IN+IT ratio	0.879	0.898	SN+ST/IN+IT ratio	0.518	0.955
Cup/disc area ratio	0.721	0.575	Rim/disc area ratio	0.721	0.575
T	0.759	0.637	T	0.759	0.637
ST	0.816	0.579	ST	0.816	0.579
SN	0.534	0.816	SN	0.525	0.816
N	0.525	0.759	N	0.534	0.759
IN	0.757	0.589	IN	0.757	0.589
IT	0.882	0.599	IT	0.882	0.599
SN/ST ratio	0.955*	0.996*	SN/ST ratio	0.955*	0.949
N/T ratio	0.706	0.852	N/T ratio	0.817	0.852

IN/IT ratio	0.559	0.732	IN/IT ratio	0.807	0.793
SN+ST/IN+IT ratio	0.838	0.960	SN+ST/IN+IT ratio	0.699	0.983

AROC, area under the receiver operative characteristic curve; HRT, Heidelberg retina tomography; T, temporal; ST, superotemporal SN, superonasal; N, nasal; IN, inferonasal; IT, inferotemporal. * highest AROC

a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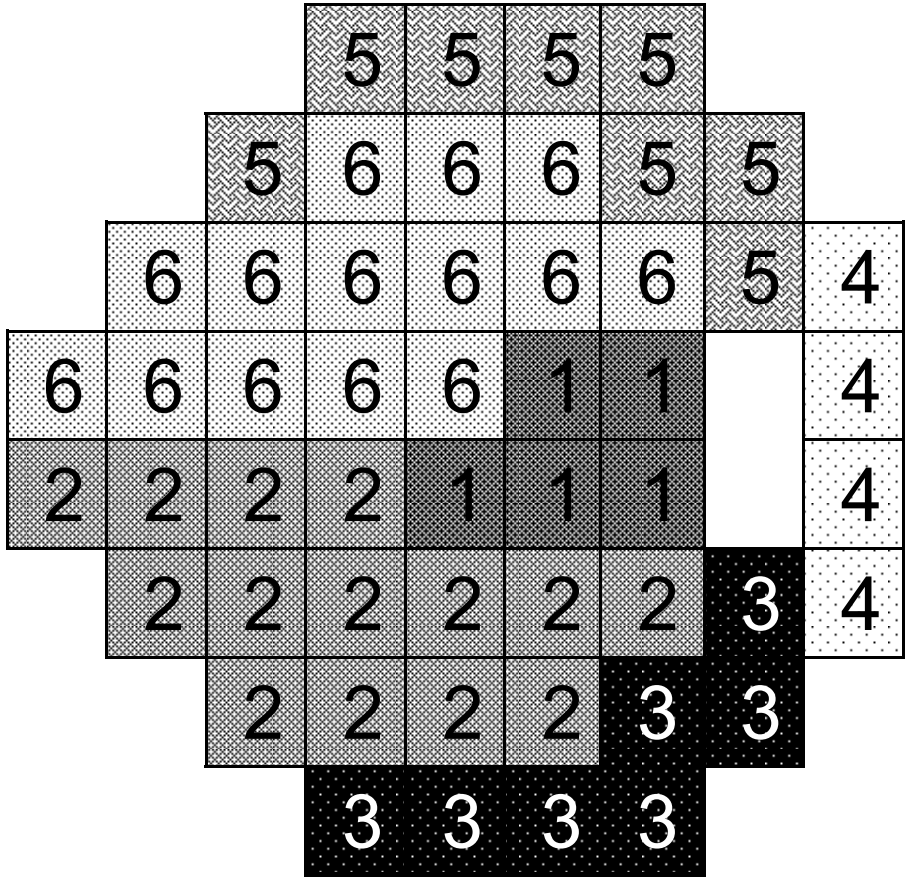
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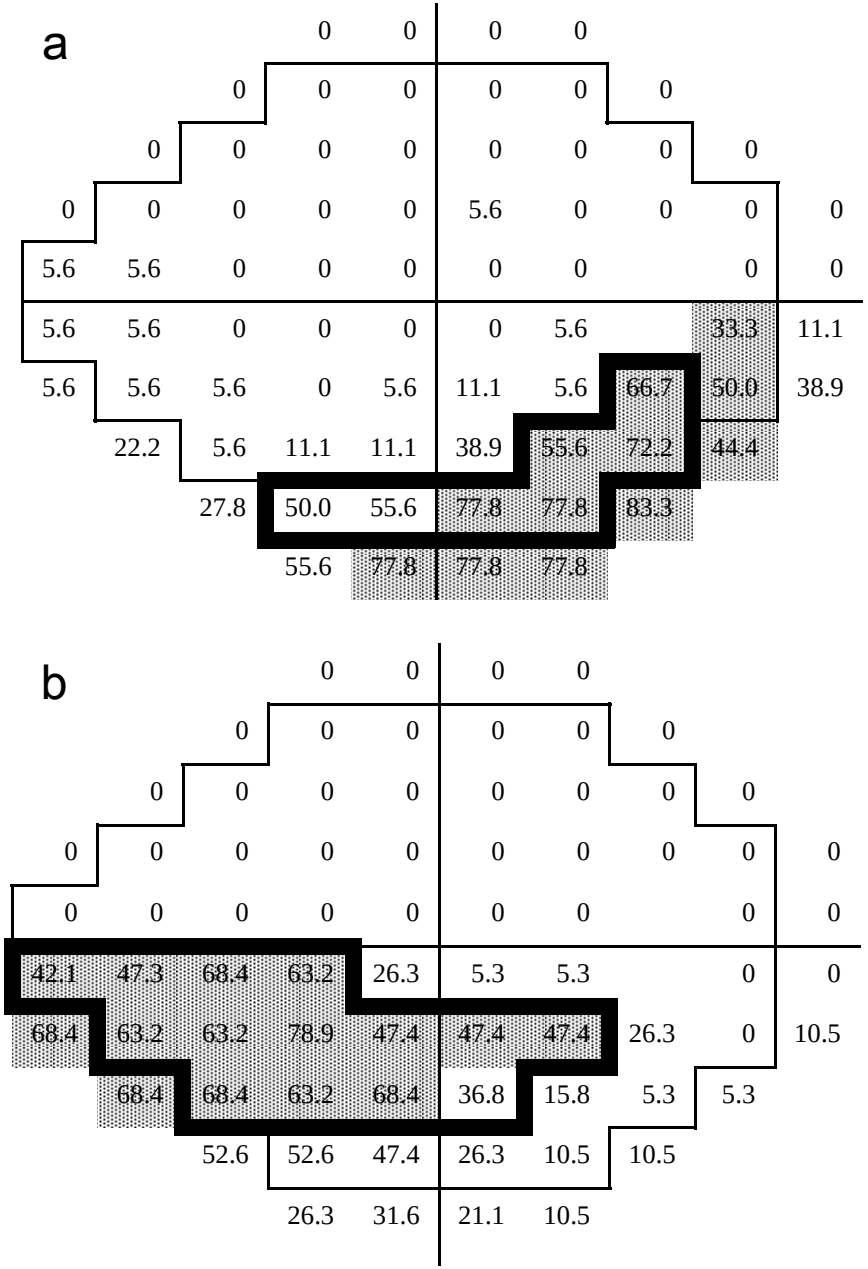
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