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GLAUCOMA

Comparison of ganglion cell and retinal nerve fiber layer thickness in primary open-angle glaucoma and normal tension glaucoma with spectral-domain OCT

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Abstract
Background The aim of this study was to evaluate the macular thickness (MT), ganglion cell complex (GCC), and circum-papillary retinal nerve fiber layer (RNFL) thickness in primary open-angle glaucoma (POAG) and normal tension glaucoma (NTG) with spectral domain optical coherence tomography (SD-OCT).
Methods A total of 169 subjects were enrolled: 52 normal subjects, 61 with POAG, and 56 with NTG. Spectral-domain optical coherence tomography (SD-OCT) was used to analyze MT, GCC, and RNFL thickness. To compare the discrimination capabilities between the MT, GCC, and RNFL thickness measurements, we analyzed the areas under the receiver operating characteristic (ROC) curves (AUCs). The relationships between GCC and RNFL measurement and also the relationships of the groups, with age, gender, GCC, and RNFL thickness were assessed.
Results Normal subjects showed the thickest superior and inferior GCC, followed by in order NTG and POAG ($p<0.05$). While there was a statistically difference in MT value of the normal subjects and the glaucoma patients ($p<0.05$), MT value did not differ between POAG and NTG ($p<0.05$). RNFL thickness parameters were significantly greater in normal subjects, followed in order by the NTG, and POAG ($p<0.05$). Between the normal and entire glaucoma groups, all GCC and RNFL parameters showed the similar discrimination power. RNFL thickness parameters correlated significantly with all GCC thickness ($p<0.05$). Superior RNFL thickness was the only independent variable between the POAG and NTG patients (odds ratio (OR) 0.942, $p=0.004$, 95 %CI 0.905–0.981).
Conclusions SD-OCT evaluation results suggest higher GCC and RNFL parameters for NTG than POAG.

Keywords Primary open-angle glaucoma · Normal tension glaucoma · Ganglion cell complex · Retinal nerve fiber layer thickness · Spectral optical coherence tomography

Introduction

Glaucoma is a progressive optic neuropathy characterized by gradual degeneration of neuronal tissue in which retinal ganglion cells (RGCs) are injured, leading to loss of the visual field. The disease is usually characterized by an increase in intraocular pressure (IOP), which is treated with ocular hypotensive agents. However, both RGC apoptosis and optic nerve atrophy, associated with glaucoma, can occur independently of IOP. Normal tension glaucoma (NTG) has been considered a subset of primary open-angle glaucoma (POAG), sharing many similar characteristics [1]. A normal IOP level is not the only difference between NTG and POAG. Although POAG has a progressive nature, NTG seems to be non-progressive or to progress only very slowly over time [2]. Many studies have demonstrated thinner neuroretinal rims, deeper and steeper-sided visual field defects, and greater prevalence of disc hemorrhages in

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NTG patients compared with POAG patients [3–5]. Considering NTG to be a simple subset of POAG, therefore, can be a mistake in managing and treating the disease. It is important to note the difference between NTG and POAG. After Zeimer et al. [6] reported on the thinning of the macula and its association with glaucomatous field defect, many studies were conducted to measure macular thickness and retinal nerve fiber layer (RNFL) in glaucoma [7–9]. However, recent studies have shown that ganglion cell loss is the main cause of thinning in macular thickness. This thinning is attributed mainly to the thinning of the macular nerve fiber layer, ganglion cell layer, and inner plexiform layer, collectively known as the ganglion cell complex (GCC) and inner nuclear layer [10]. Spectral-domain optical coherence tomography (SD-OCT) enables the measurement of GCC.

GCC analysis is useful in assisting the clinician's early detection of glaucoma [11]. A wide area map (9 mm ×9 mm) enables an observation of GCC status, even in the peripheral area.

Recent studies have separately demonstrated a reduction in macular retinal thickness and in the retinal nerve fibers in both POAG and NTG [11, 12]. Seong et al. demonstrated that in early-stage NTG, macular GCC thickness showed a strong correlation with RNFL thickness [12]. However, there have yet to be any reports regarding the comparison of macular thickness (MT), GCC, and RNFL between POAG and NTG with an RS-3000 RetinaScan at an early stage. Therefore, the aim of this study was to examine whether there is a difference in MT, GCC thickness, and RNFL thickness in early-stage POAG and NTG with SD-OCT.

Methods

Subjects

This was a prospective, cross-sectional study including 169 eyes of 169 subjects: 52 normal, 61 with POAG, and 56 with NTG. In each of the subjects, one eye was randomly selected for study. The study was conducted in accordance with the ethical standards stated in the Declaration of Helsinki, and approved by our institutional ethics board. Informed consent was obtained from all recruited individuals. Informed consent was in written form and obtained from all recruited individuals prior to the first intervention of the study.

Each subject underwent a full ophthalmic examination, including best-corrected visual acuity, IOP measurement with a Goldmann applanation tonometry, slit-lamp biomicroscopy, gonioscopy, stereoscopic fundus evaluation on the slit lamp using a 90 diopter lens, the Humphrey Field Analyzer (HFA) (Humphrey-Zeiss Systems, Dublin, CA, USA) Swedish Interactive Threshold Algorithm (SITA) 30–2 test, and RS-3000 OCT RetinaScan scanning (Nidek Inc., Fremont, CA, USA). IOP measurement and fundus examinations were performed by the same investigator (Dr. PF).

The POAG group inclusion criteria were (1) IOP higher than 21 mmHg before treatment on three different visits, (2) best-corrected VA of 20/25 or better, with a spherical equivalent within ±5 D and a cylinder correction within +3 D, and (3) open angle confirmed by gonioscopy. Glaucomatous optic disc damage was defined as the presence of glaucomatous optic neuropathy, such as rim thinning (diffuse or local), cupping, notching, and a cup/disc ratio >0.3 and 0.2 of the difference between the two eyes. All patients underwent at least three visual field tests within a month, at intervals of approximately 1 week. To minimize learning effect, only the results of the last visual field test were used in the analysis. The results of the visual field tests were considered reliable when fixation losses were less than 20 %, and false positive and false negative rates were less than 15 %. A widely used set of criteria was set by Hodapp et al. [13], according to which all of the three following criteria should be met to define a visual field abnormality: (1) a cluster of ≥3 non-edge points (on the 30–2 strategy) in either hemifield on the pattern deviation plot, demonstrating an abnormal sensitivity at $p<5$ %, with at least one of the points having $p<1$ %, (2) pattern standard deviation (PSD) <5 %, and (3) an abnormal glaucomatous hemifield test. Based on the HFA results, patients with a mean deviation (MD) value between −0.01 and −6.0 dB were classified as having early glaucoma. Subjects with any retinal disease, diabetes mellitus, or neurological disease, or who had undergone ocular surgery or laser procedures, were excluded. In addition, subjects with pseudoexfoliation glaucoma, pigmentary glaucoma, or other types of secondary glaucomas were excluded.

NTG patients were included if they exhibited the same optic disc and visual field criteria as the POAG patients, with the exception that their IOP was ≤21 mmHg on three separate visits, without any glaucomatous treatment.

The control group was comprised of age- and sex-matched normal subjects from patients referred for routine ophthalmic examination and hospital staff who had no ocular disease and who had not undergone ocular surgery or laser procedures. The subjects in the control group had a normal anterior segment, open angles, and normal posterior segment findings, as well as a normal optic nerve head appearance in their ophthalmic examinations. IOP measurements were lower than 21 mmHg without any medication, and full-threshold 30–2 HFA were within normal limits in the control group.

RS-3000 OCT RetinaScan measurements

The macular thickness, ganglion cell thickness, and RNFL thickness measurements were performed with an RS-3000 OCT RetinaScan, which is a high-speed spectral-domain

optical coherence tomography (OCT)/confocal ophthalmoscope system. It provides 53,000 A-scans/s with an OCT digital resolution of 4 μm, thereby revealing the discrete retinal layers. Real-time, high-contrast, and wide-view (40° ×30°) confocal scanning laser ophthalmoscope (SLO) imaging ensures OCT scanning accuracy of the pathological target. OCT scanning position is precisely matched with the SLO fundus image. The RS-3000 provides an overall view of the macula and the GCC of the right and left eyes. Despite these properties, the RS-3000 SD-OCT does not have an eye tracker, which improves the measurement quality and reproducibility [14].

For all subjects in this study, the "Glaucoma Combo" scanning protocol was performed. In this protocol, there are six maps: a macula map x-y, a disc circle, a disc map x-y, a macula radial 12, a disc radial 6, and a disc radial 12. We used signal strength index which is a quality criterion of the SD-OCT device in software. Images with SSI score 50 and above were used for the study. In a very small number of our patients, we could not reach the image quality because they moved their eyes. After explaining again and again, measurements were repeated and the appropriate image quality was obtained. Average, superior and inferior hemiretinal RNFL and superior and inferior GCC values were used for analysis. A superiority of RNFL is that while GCC was analyzed only in the hemifields, RNFL was analyzed both for hemifield and for the overall mean. In addition, central MT and MT values of 3 and 6 mm zone of four quadrants for analyzed.

Statistical analysis

Statistically analyses were performed using SPSS v.16 (SPSS Inc, Chicago, IL, USA). The Shapiro–Wilk test was used to test distribution of numerical data. Non-normally distributed data of groups were compared by the Kruskal–Wallis H test. Multiple comparisons were carried out using the Conover test. The Chi-square test was used to compare categorical data. The relationships among GCC, and RNFL measurements were assessed by Pearson's correlation analysis for each group. To compare the discrimination capabilities between the MT, GCC, and RNFL thickness measurements in normal subjects and the POAG and NTG groups, we analyzed the areas under the receiver operating characteristics (ROC) curves (AUCs). An AUC of 1.0 represented perfect discrimination, whereas an AUC of 0.5 represented chance discrimination. AUC values were compared based on z statistic.

In addition, the relationships of the groups and age, gender, superior GCC (SGCC), inferior GCC (IGCC), superior RNFL (SRNFL), inferior RNFL (IRNFL), and average RNFL thicknesses were assessed by binary logistic regression modeling.

Forty-five patients (15 patients in each group) provided consent for multiple examinations to be performed to ensure the reproducibility of the measurements. Intra-visit reproducibility was assessed using the results of two scanning sessions in the same day with a break of 15–30 min by one operator (Dr. PF).To assess the inter-visit reproducibility, the findings obtained on the first scanning session on the first day were compared with the results of an additional scan obtained by the same operator a week later.

In all statistical analyses, $p<0.05$ was considered statistically significant.

Results

Patients who fulfilled the entry criteria were enrolled in the study. There were no significant differences in age, gender, or refractive error among the groups (Table 1). Although the MD and pattern standard deviation (PSD) were significantly different between the normal subjects and those with POAG or NTG, there were no significant differences in MD and PSD among the POAG and NTG patients. Table 2 shows a summary of the results of the SD-OCT parameter measurements. The mean values of the superior and inferior GCC measurements were significantly different among the three groups. The normal subjects showed the thickest superior and inferior GCC measurements, followed, in order, by the NTG and POAG patients. In addition, the mean values of RNFL thickness (μm) for average, superior, and inferior hemiretina were significantly greater in the normal subjects, followed, in order, by the NTG and POAG patients. There were no statistically significant differences among the groups for MT values of central 1.5 mm zone. The mean MT values of 3- and 6-mm zones of the superior, inferior, nasal, and temporal quadrants showed statistically significant differences between the normal group and all glaucomas. However, there were no statistically significant differences in mean MT values of 3- and 6-mm zones of the four quadrants between the POAG and NTG groups.

Table 1 Baseline characteristics of the groups

	Normal (n=52)	POAG (n=61)	NTG (n=56)	P
Age (years)	52.8±8.4	52.9±11.1	51.4±9.2	0.630
Gender (male/female)	24/28	31/30	28/28	0.624*
Refractive error, (D)	0.27±1.02	0.09±0.86	0.14±0.73	0.313
MD (db)	1.30±1.02	−1.98±1.29[a]	−2.49±1.47[a]	<0.0001
PSD (dB)	1.47±1.1	3.43±1.12[a]	3.04±1.62[a]	<0.0001

POAG primary open-angle glaucoma, *NTG* normotensive glaucoma, *D* diopters, *db* decibels, *μm* micrometre. Data are expressed as the mean ± SD. *P*: one-way ANOVA. *: Chi-Square test. [a]: statistically different from normal subjects ($p<0.005$)

Table 2 MT, GCC and RNFL thickness of the groups

	Normal (n=52)	POAG (n=61)	NTG (n=56)	P
MT, central (μm)	266.5 (230–323)	265 (125–310)	261 (206–298)	0.80
MT, 3 mm				
Superior	355.5 (302–381)	341 (71–372)[a]	337 (299–362)[a]	0.0001
Inferior	351.5 (298–378)	333 (71–369)[a]	337.5 (305–364)[a]	0.0001
Nasal	352.5 (296–387)	338 (68–378)[a]	336 (263–369)[a]	0.0001
Temporal	337 (290–365)	325 (63–360)[a]	325 (33–359)[a]	0.0001
MT, 6 mm				
Superior	307.5 (278–336)	295 (67–331)[a]	299 (246–382)[a]	0.0001
Inferior	301 (274–342)	288 (58–328)[a]	287 (269–312)[a]	0.0001
Nasal	324.5 (268–359)	309 (68–356)[a]	310 (185–338)[a]	0.0001
Temporal	297 (262–340)	281 (43–335)[a]	281 (228–310)[a]	0.0001
GCC (μm)				
Superior	109 (92–124)	93 (55–107)[a,b]	97 (69–115)[a,b]	<0.0001
Inferior	110 (99–124)	98 (59–109)[a,b]	99.5 (70–120)	<0.0001
RNFL (μm)				
Average	112 (98–132)	95 (62–107)[a,b]	100 (78–123)[a,b]	<0.0001
Superior	116 (97–142)	98 (65–110)[a,b]	105 (77–130)[a,b]	<0.0001
Inferior	108.5 (94–124)	93 (60–106)[a,b]	96 (76–119)[a,b]	<0.0001

MT macular thickness, *GCC* ganglion cell complex, *RNFL* retinal nerve fiber layer, *POAG* primary open-angle glaucoma, *NTG* normotensive glaucoma, *μm* micrometer. Data are expressed as the median (min-max). *P*: Kruskal–Wallis H tes., [a]statistically significant with the normal group ($p<0.05$), [b]: statistically significant with each other ($p<0.05$)

Table 3 shows the AUCs for the SD-OCT parameters used to compare the discriminating power of the MT, GCC and RNFL thicknesses in the POAG and NTG groups. AUC values were compared using z statistic. According to the z

Table 3 The AUC for the MT, GCC and RNFL parameters of SD-OCT

	Normal vs NTG	95 % confidence interval		p value	Normal vs POAG	95 % confidence interval		p value	Normal vs NTG and POAG	95 % confidence interval		P value
		Lower bound	Upper bound			Lower bound	Upper bound			Lower bound	Upper bound	
MT, Central	0.620	0.514	0.726	0.032	0.584	0.476	0.691	0.127	0.601	0.508	0.694	0.036
MT, 3 mm												
Superior	0.762	0.671	0.853	<0.001	0.703	0.606	0.801	<0.001	0.731	0.645	0.818	<0.001
Inferior	0.733	0.639	0.827	<0.001	0.687	0.589	0.784	0.001	0.709	0.626	0.792	<0.001
Nasal	0.737	0.643	0.830	<0.001	0.689	0.591	0.787	0.001	0.712	0.628	0.795	<0.001
Temporal	0.729	0.633	0.825	<0.001	0.675	0.576	0.775	0.001	0.701	0.615	0.787	<0.001
MT, 6 mm												
Superior	0.676	0.575	0.777	<0.001	0.734	0.640	0.828	<0.001	0.706	0.622	0.790	<0.001
Inferior	0.762	0.672	0.851	<0.001	0.715	0.621	0.808	<0.001	0.737	0.656	0.818	<0.001
Nasal	0.721	0.624	0.817	<0.001	0.691	0.590	0.791	<0.001	0.705	0.615	0.795	<0.001
Temporal	0.729	0.633	0.825	<0.001	0.705	0.610	0.800	<0.001	0.716	0.632	0.801	<0.001
GCC												
Superior	0.846	0.771	0.921	<0.001	0.928	0.882	0.974	<0.001	0.889	0.835	0.942	<0.001
Inferior	0.837	0.761	0.914	<0.001	0.941	0.903	0.980	<0.001	0.892	0.843	0.940	<0.001
RNFL												
Average	0.829	0.753	0.904	<0.001	0.939	0.900	0.978	<0.001	0.886	0.838	0.935	<0.001
Superior	0.794	0.712	0.877	<0.001	0.918	0.870	0.966	<0.001	0.859	0.801	0.916	<0.001
Inferior	0.807	0.726	0.888	<0.001	0.919	0.873	0.966	<0.001	0.866	0.813	0.918	<0.001

AUC areas under the receiver operating characteristic curve, *GCC* ganglion cell complex, *RNFL* retinal nerve fiber layer, *POAG* primary open-angle glaucoma, *NTG* normotensive glaucoma

Table 4 Correlation between superior GCC (SGCC) and inferior GCC (GCC) and RNFL

	Normal				POAG				NTG			
	SGCC		IGCC		SGCC		IGCC		SGCC		IGCC	
	r value	*p* value	*r* value	*p* value	*r* value	*p* value	*r* value	*p* value	*r* value	*p* value	*r* value	*p* value
RNFL												
Average	0.128	0.366	0.454*	0.001	0.681*	<0.001	0.685*	<0.001	0.450*	0.001	0.577*	<0.001
Superior	0.036	0.800	0.238	0.089	0.702*	<0.001	0.650*	<0.001	0.476*	<0.001	0.574*	<0.001
Inferior	0.187	0.184	0.523*	<0.001	0.580*	<0.001	0.635*	<0.001	0.370*	<0.001	0.497*	<0.001

*Pearson's correlation coefficient

GCC ganglion cell complex, *RNFL* retinal nerve fiber layer, *POAG* primary open-angle glaucoma, *NTG* normotensive glaucoma

statistic results, there were no statistically significant differences between all GCC and RNFL values' discrimination power. However, there were statistically significant differences between both the GCC and MT values' AUC values and the RNFL and MT values.

The results of the binary logistic regression analysis showed that the superior RNFL thickness was the only independent relationship between the POAG and NTG patients (odds ratio (OR) 0.942, p=0.004, 95 %CI 0.905–0.981).

In the normal subjects, the average and inferior RNFL correlated significantly with the inferior GCC thickness. In the POAG group, all three RNFL thicknesses (average, superior, and inferior) parameters correlated significantly with all GCC thickness parameters. Similarly, in the NTG group, all three RNFL thickness parameters correlated significantly with all GCC thickness (Table 4).

The reproducibility of measurements is shown in Table 5. The demographic characteristics of the patients in reproducibility of measurements are shown in Table 6.

Discussion

Over the past few years, SD-OCT has become more popular, due to its remarkable advantages in the diagnosis and follow-up of glaucoma [15]. With the development of SD-OCT, it is possible to image and measure macular GCC. In glaucomatous eyes, reduction in macular thickness is more significant, and loss of GCC is the main reason. Therefore, it becomes more important to measure GCC than macular thickness. Many studies have demonstrated the predictive value of GCC measurement in the diagnosis of glaucoma [12, 16]. In this study, using SD-OCT, MT, GCC, and RNFL thickness measurements were obtained from POAG and NTG patients, as well as normal subjects. All of the OCT parameters, including superior and inferior GCC, average, superior, and inferior RNFL thickness, and MT in 3- and 6-mm of four quadrants were significantly lower in the POAG and NTG patients than in the normal subjects. Only the central 1.5-mm MT was not different between the groups. This finding suggests loss of MT, GCC, and RNFL

Table 5 Reproducibility of the measurements

Diagnostic parameters	Normal (n=15)						POAG (n=15)						NTG (n=15)					
	Intraobserver			Interobserver			Intraobserver			Interobserver			Intraobserver			Interobserver		
	95 % confidence interval			95 % confidence interval			95 % confidence interval			95 % confidence interval			95 % confidence interval			95 % confidence interval		
	ICC	Lower bound	Upper bound	ICC	Lower bound	Upper bound	ICC	Lower bound	Upper bound	ICC	Lower bound	Upper bound	ICC	Lower bound	Upper bound	ICC	Lower bound	Upper bound
SGCC	0.917	0.748	0.975	0.961	0.875	0.988	0.939	0.810	0.982	0.915	0.742	0.942	0.930	0.784	0.979	0.924	0.769	0.977
IGCC	0.905	0.715	0.971	0.901	0.705	0.970	0.939	0.812	0.982	0.900	0.701	0.970	0.985	0.951	0.996	0.982	0.941	0.995
Average RNFL	0.922	0.763	0.977	0.955	0.857	0.987	0.991	0.972	0.997	0.984	0.948	0.995	0.969	0.901	0.991	0.955	0.859	0.987
SRNFL	0.935	0.799	0.981	0.921	0.760	0.976	0.964	0.885	0.989	0.962	0.879	0.989	0.997	0.991	0.999	0.996	0.986	0.999
IRNFL	0.991	0.969	0.997	0.981	0.938	0.994	0.982	0.941	0.995	0.981	0.939	0.995	0.971	0.907	0.991	0.964	0.884	0.989

SGCC superior ganglion cell complex, *IGCC* inferior ganglion cell complex, *RNFL* retinal nerve fiber layer, *SRNFL* superior retinal nerve fiber layer, *IRNFL* inferior retinal nerve fiber layer, *POAG* primary open-angle glaucoma, *NTG* normotensive glaucoma. *ICC* intraclass correlation coefficient

Table 6 Demographic characteristics of patients in reproducibility study

	Normal (n=15)	POAG (n=15)	NTG (n=15)
Age (years)	51.16±3.32	49.75±5.51	49.58±9.85
Gender(male/female)	8/7	9/6	7/8
Refractive error (D)	0±1.05	0.14±0.55	0.12±0.74
MD (db)	1.65±1.08	−2.07±1.25	−2.32±5.35

POAG primary open-angle glaucoma, *NTG* normotensive glaucoma, *D* diopters, *db* decibels. Data are expressed as the mean ± SD

thickness in POAG and NTG. Quantitative measurements showed a significantly thicker superior and inferior GCC in the NTG patients compared with the POAG patients. In many studies, MT was shown to be decreased in glaucoma patients[12, 17, 18]. The results of our study are consistent with the results of these studies. The difference with our study was that we compared the MT value in patients with POAG and NTG, and we did not find any statistically significant difference among the groups. However, there is some disagreement in the literature with regard to RNFL thickness in high-tension glaucoma versus NTG. In the present study, we found that average, superior, and inferior RNFL thicknesses were higher in the NTG patients than in the POAG patients. Mok et al. [19] and Konstantakopoulou et al. [20] found no statistically significant differences between high-tension glaucoma and NTG for OCT RNFL parameters. In these studies, NTG patients were compared with individuals with high-tension glaucoma rather than primary open-angle glaucoma. The different results found in the present study may be attributable to the use of different devices and study designs.

In the literature, there is no quantitative comparison of GCC thickness between POAG and NTG with an RS-3000 RetinaScan. The present study showed significantly higher GCC thicknesses in the NTG patients compared with the POAG patients. In the light of these results, it seems that GCC and RNFL is thinner in POAG compared to NTG patients, whereas MT remains same. There was less GCC and RNFL loss in the NTG patients, but both the NTG and POAG patients exhibited similar perimetric damage based on the MD and PSD values (Figs. 1 and 2). A possible explanation for this difference can be the different sensitivities of the techniques to detect the defects. Although the HFA is the gold standard for detecting functional defects, it is well-known that visual field defects are detected after significant retinal ganglion cell damage has occurred.

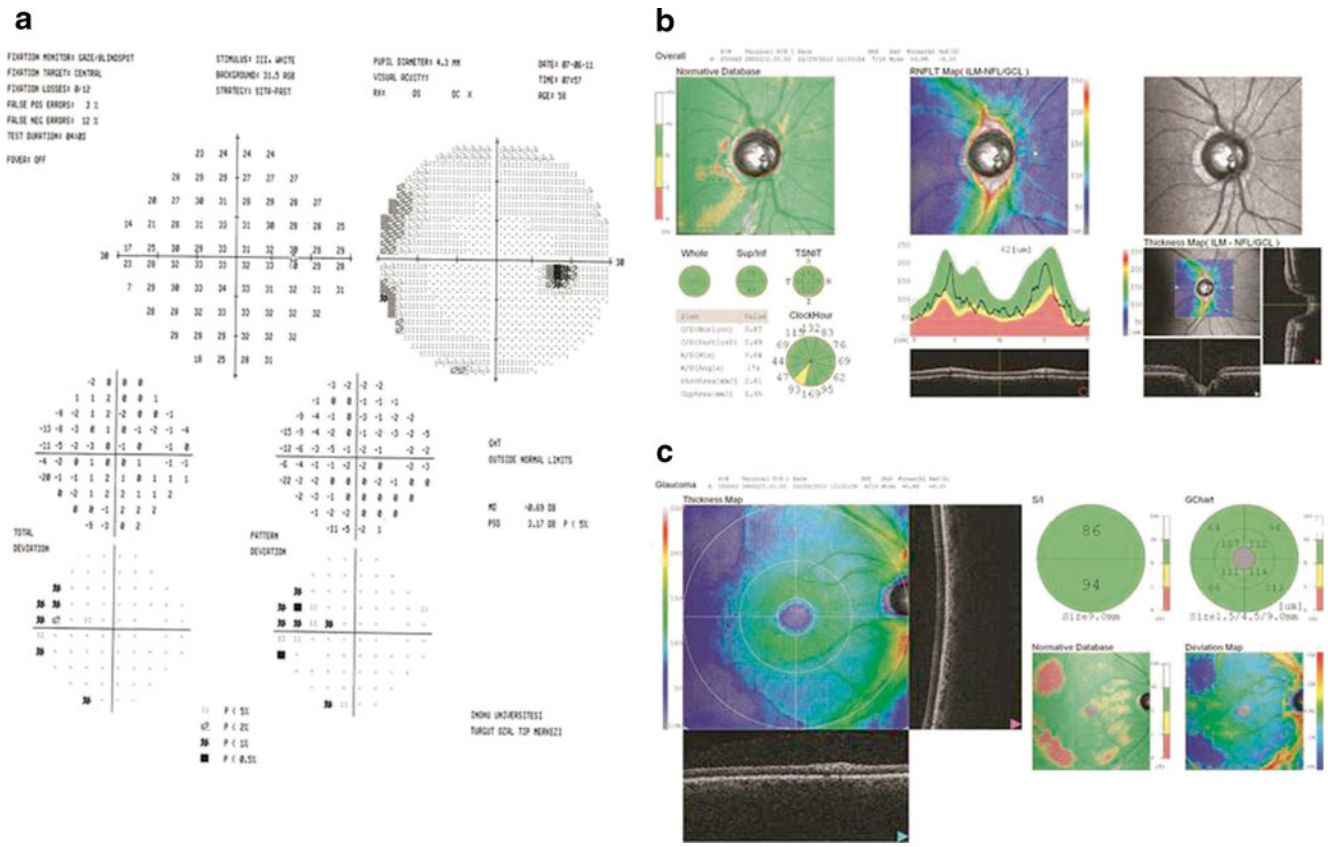

Fig. 1 **a** Humphrey Field Analysis showing a nasal defect from a 58-year-old patient with POAG. **b** Disc Map Analysis from SD-OCT and **c** Macula Map Analysis from SD-OCT of the same patient

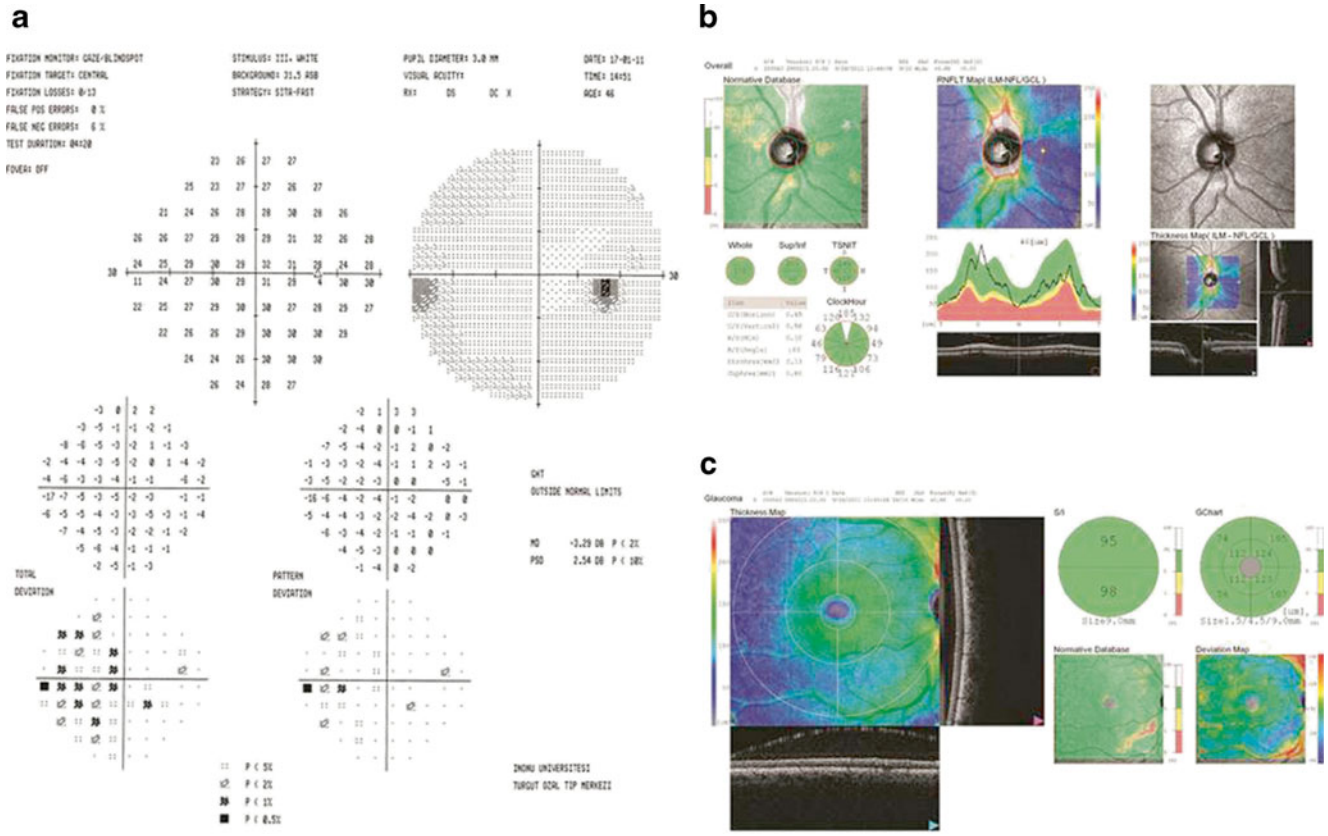

Fig. 2 **a** Humphrey Field Analysis showing a nasal defect from a 46-year-old patient with NTG. **b** Disc Map Analysis from SD-OCT and **c** Macula Map Analysis from SD-OCT of the same patient

Because of different types and locations of the retinal ganglion cells, correlation with the perimetry is not simple. A 20 % loss of large ganglion cells in the central 30° of the retina correlated with a 5-dB sensitivity loss, whereas a 40 % loss corresponded with a 10-dB loss, and some ganglion cells remained in areas with 0 dB sensitivity [21]. Therefore, the same MD values would not be the same type and stage of retinal nerve fiber nerve loss in glaucoma.

Measured macular area is an important parameter for the performance of this study, because recent studies showed that the peripheral macular region was more severely affected in glaucoma [7, 10, 22]. Smaller scan areas result in limited diagnostic ability of the macular structures [23]. In support of this finding, we did not find any difference between the groups for central 1.5 mm MT. However, for the 3×3 and 6×6 mm zones, there were differences between the normal subjects and all the glaucomas with regard to the importance of area that was analyzed. For GCC measurement, we evaluated a 9×9 mm macular area, and there were statistically significant differences in GCC thicknesses between the POAG and NTG patients. In addition to the RNFL and GCC parameters evaluated, the wide macular area measured is a valuable parameter of current study.

We used ROC curves and AUCs for discriminating healthy eyes from glaucomatous eyes. According to our results, all GCC thickness parameters showed similar diagnostic abilities with RNFL thickness parameters, suggesting that GCC thickness is a valuable parameter for the diagnosis of glaucoma. Similar to recent studies with SD-OCT [24, 25] our study suggests that the ability to detect glaucoma with GCC parameters was similar with RNFL parameters. An additional attempt was made to study the relationships of POAG and NTG with age, gender, superior GCC, inferior GCC, superior RNFL, inferior RNFL, and average RNFL thickness, by binary logistic regression modeling. Based on the results of the binary logistic regression analysis, the superior RNFL thickness was the only independent relationship between the POAG and NTG patients. Thinning of the superior RNFL in the POAG patients was significantly greater than in the NTG patients. This result is consistent with the report of Kubota et al., who noted that high- and low-tension glaucoma exhibit different patterns of RNFL change. Although a reduction in the thickness of the RNFL is symmetric in the superior and inferior quadrants in high-tension glaucoma, NTG patients display more localized defects on the inferior RNFL [26].

Measurement reproducibility is an essential quality in determining the value of a device for clinical practice. The SD-OCT system has high axial resolution and sensitivity, resulting in good reproducibility in eyes with glaucoma. Mori et al. reported excellent reproducibility in glaucomatous eyes with the RTVue-100, which is an SD-OCT [23]. The reproducibility of our measurements with the RS-300 RetinaScan was also excellent.

A limitation of this study is that we evaluated the GCC and RNFL of early-stage glaucoma, and moderate and severe glaucoma may represent different GCC and RNFL patterns.

In conclusion, we used SD-OCT to investigate the MT, GCC, and RNFL thickness parameters in POAG and NTG patients to determine whether there were any diagnostic differences between the two diseases. We found that all GCC and RNFL parameters were greater in NTG patients than in POAG patients, and that the superior RNFL has the highest diagnostic ability for discriminating NTG from POAG.

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