• Clinical Research •

Diagnostic capability of peripapillary retinal nerve fiber layer parameters in time-domain versus spectral-domain optical coherence tomography for assessing glaucoma in high myopia

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Abstract

• AIM: To evaluate and compare the diagnostic capabilities of peripapillary retinal nerve fiber layer (p-RNFL) parameters of Spectralis optical coherence tomography (OCT) versus Stratus OCT to detect glaucoma in patients with high myopia.

• METHODS: This is a retrospective, cross-sectional study. Sixty highly myopic eyes of 60 patients were enrolled, with 30 eyes in the glaucoma group and 30 eyes in the control group. All eyes received peripapillary imaging of the optic disc using Stratus and Spectralis OCT. Areas under the receiver operating characteristic curve (AUROC) and the sensitivity at specificity of >80% and >95% for p-RNFL parameters obtained using the two devices to diagnose glaucoma were analysed and compared.

• RESULTS: In Spectralis OCT, p-RNFL thickness parameters with the largest AUROC were the temporal-inferior sector (0.974) and the inferior quadrant (0.951), whereas in Stratus OCT, the best parameters were the 7-o'clock sector (0.918) and the inferior quadrant (0.918). Compared to the Stratus OCT parameters, the Spectralis OCT parameters demonstrated generally higher AUROC; however, the difference was not statistically significant.

• CONCLUSION: The best p-RNFL parameters for diagnosing glaucoma in patients with high myopia were the temporal-inferior sector on Spectralis OCT and the 7-o'clock sector on Stratus OCT. There were no significant differences between the AUROCs for Spectralis OCT and Stratus OCT, which suggest that the glaucoma diagnostic capabilities of these two devices in patients with high myopia are similar.

• **KEYWORDS:** diagnostic capability; glaucoma; high myopia; optical coherence tomography; retinal nerve fiber layer

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INTRODUCTION

Glaucoma is an optic neuropathy that is characterised by the selective loss of retinal ganglion cells and their axons, which manifests as the loss of the retinal nerve fiber layer (RNFL)[1]. Numerous studies have shown that the extent of RNFL damage correlates with the severity of functional deficit in the visual field (VF), and that RNFL measurement by optical coherence tomography (OCT) has good sensitivity for the detection of glaucoma[2-4].

High myopia is a known risk factor for open angle glaucoma[5]. Clinical diagnosis of glaucoma in this group of patients is often difficult because of the variation in the sizes, shapes, tilt of the optic nerve head, and the presence of large peripapillary atrophy (PPA) in these eyes. In high myopia, RNFL loss also occurs more frequently in a generalized or diffuse pattern rather than in a localised pattern. These characteristics of highly myopic eyes make it difficult to accurately determine the cup-to-disc ratio and the extent of RNFL damage in susceptible patients[6-9].

Previous studies on patients without high myopia have shown that time-domain optical coherence tomography (TD-OCT), such as Stratus OCT may have limited diagnostic capability for identifying localised RNFL defects, particularly in the early stages of glaucoma[10-12]. Spectralis OCT, on the other hand, is a spectral-domain optical coherence tomography (SD-OCT), with an acquisition speed of 40 000 A-scans/s, which

is 100 times faster than a Stratus OCT. Moreover, it has axial resolutions that are almost twice as high (5-7 μm) as those of Stratus OCT (approximately 8-10 μm) and has reduced speckle noise to drastically improve the clarity of boundaries between inner retinal layers and to facilitate visualization of small pathologic changes[13-17]. The improvements in the newer SD-OCT technology have been shown to be useful in providing a better diagnostic performance in glaucoma patients within the normative refractive range of between ±5 diopter (D) in several studies. Nukada *et al*[18] reported that Spectralis OCT had better diagnostic capability than single-scan TD-OCT for detecting localised RNFL defects in perimetric glaucoma, while Jeoung *et al*[19] recently also demonstrated that Spectralis OCT was better than TD-OCT at detecting preperimetric localised RNFL defects.

However, it would be important to apply these technology advantages towards not only a non-myopic or moderately myopic population, but also towards a highly myopic population. High myopia has not only been shown to be a risk factor for glaucoma[20-21], it is also currently a major public health concern particularly in the east and southeast Asian countries. Population-based studies have found the prevalence of high myopia to be 2.1%-4.2% in the general population[22], and can be as high as 20% in high school graduates[23]. Yet, all of the previous studies comparing SD-OCT to TD-OCT have been conducted on patients with refractions of >-6 D, and not on highly myopic patients, and whether the advantages of SD-OCT over TD-OCT in diagnosing glaucoma are also present in patients with high myopia remains unclear. Therefore, the purpose of this study is to evaluate and compare whether there are any differences in the diagnostic capabilities of Spectralis SD-OCT and Stratus TD-OCT to detect glaucoma in patients with high myopia.

SUBJECTS AND METHODS

This retrospective, cross-sectional study included patients who presented to the Outpatient Department of Kaohsiung Chang Gung Memorial Hospital, Kaohsiung, Taiwan, between May 2014 and April 2015. The study was approved by the Ethics Committee of Chang Gung Memorial Hospital. The methods applied in the study adhered to the tenets of the Declaration of Helsinki for the use of human subjects in biomedical research. Informed consent was obtained from all of the patients.

All of the patients enrolled in this study underwent a complete ophthalmic examination, including best-corrected visual acuity, refraction, slit-lamp biomicroscopy, gonioscopy, Goldmann applanation tonometry, dilated stereoscopic examination of the optic disc, colour disc photography and red-free fundus photography (TOPCON TRC-50EX, Japan), VF examination by using Humphrey Field Analyzer Swedish interactive threshold algorithm standard 30-2 test (Carl Zeiss Meditec, Dublin, CA, USA), and peripapillary RNFL (p-RNFL) thickness measurement by using Stratus OCT (Model 3000, software version 4.0, Carl Zeiss Meditec, Dublin, CA, USA) and Spectralis OCT (software version 5.6, Heidelberg Engineering, Dossenheim, Germany). OCT imaging with the two devices was performed either on the same day or at separate visits within a 6-month period.

The inclusion criteria were as follows: spherical equivalent (SE) of ≤-6.0 D, best-corrected visual acuity of 20/40 or better, a healthy anterior segment on slit-lamp biomicroscopy, open angles on gonioscopy, clear ocular media, and reliable VF test results. The results of VF tests were considered reliable when fixation losses were less than 20%, and false-positive and false-negative rates were less than 15%, with reproducible VF result on at least two reliable examinations. The OCT images with signal strength of at least 7 on Stratus OCT and image quality of at least 20 on Spectralis OCT were used for this study.

Patients were excluded if they had SE <-15.00 D, or had large PPA that extended outside the peripapillary scanning circle on OCT. In addition, patients with any evidence of intraocular surgery, laser history, or evidence of eye trauma, uveal, retinal, or macular pathology, and those with systemic diseases or neurological disorders that could produce VF defects that might be confused with glaucoma were excluded. Patients with pseudoexfoliation glaucoma, pigmentary glaucoma, or other secondary glaucomas were also excluded. If both eyes of a patient were eligible for the study, only one eye was randomly chosen for analysis.

In this study, the patients were categorised into two groups: glaucoma group (GG) and control group (CG). The GG included patients with glaucomatous VF defects confirmed by two reliable VF examinations that corresponded with a glaucomatous disc appearance (notching or diffuse thinning of the neuroretinal rim) and/or RNFL defects, irrespective of the level of intraocular pressure (IOP). A glaucomatous VF defect was defined as a cluster of three or more non-edge points with a probability of less than 5%, including at least one point with a probability of less than 1% on a pattern deviation map and glaucoma hemi-field test result outside normal limits.

The patients in the CG were age- and SE-matched to the patients in the GG. The CG included highly myopic patients without any other ocular diseases or ocular medications, had IOP <21 mm Hg, normal posterior segment findings, and normal VF or any VF depressions that did not fulfil the criteria for a glaucomatous VF defect.

Optical Coherence Tomography Measurements For Stratus OCT, a scan circle with a diameter of 3.46 mm was manually positioned with the optic disc at its centre; the fast RNFL scan protocol was used for measurement. This protocol consisted ofthree consecutive peripapillary scans, with each image consisting of 400 A-scans. The device's built-in software calculated the mean p-RNFL thickness of average,

Table 1 Demographic data of study subjects *n*=30

Parameters	Glaucoma group	Control group	[2]*P*
Age (a)[1]	42.4±8.6	39.7±10.9	0.292
Sex ratio (M:F)	18:12	10:20	0.038
Laterality (right:left)	12:18	14:16	0.602
Spherical equivalent (Diopters)[1]	-8.8±2.5	-7.9±2.1	0.148
Mean deviation (dB)[1]	-6.4±4.1	-3.0±1.9	0.0004
Pattern standard deviation (dB)[1]	6.9±4.5	3.4±2.2	0.001

[1]Values are expressed as mean±standard deviation; [2]Continuous data were analysed using the independent *t*-test and categorical data by using the Chi-square test.

Table 2 The mean peripapillary retinal nerve fibre layer thickness measured by Stratus and Spectralis OCT

Groups	Location	Thickness parameter (μm)		Mean difference[1]	[2]*P*
		Stratus[1]	Spectralis[1]		
Glaucoma group (*n*=30)	Average	73.1±14.2	63.6±14.7	9.5±7.3	<0.0001
	Superior	93.6±20.8	83.9±23.2	9.7±12.5	0.0007
	Temporal	62.8±23.6	60.9±25.2	1.9±11.7	0.419
	Inferior	74.5±19.5	66.0±18.7	8.4±10.1	0.0002
	Nasal	59.4±14.2	43.7±15.7	15.7±11.0	<0.0001
Control group (*n*=30)	Average	91.5±12.6	86.1±10.6	5.4±10.7	0.054
	Superior	111.8±28.5	102.1±19.1	9.7±20.8	0.072
	Temporal	97.6±13.7	93.5±24.2	4.1±18.2	0.364
	Inferior	107.7±11.6	106.0±12.4	1.7±7.7	0.377
	Nasal	52.9±10.0	38.2±17.6	14.8±17.3	0.003

[1]All values are expressed as mean±standard deviation; [2]Comparison between the thicknesses measured using two devices was performed using the paired *t*-test.

four quadrants (superior, inferior, nasal, and temporal), and 12 clock-hour sectors. The p-RNFL thickness profiles were plotted in a clockwise direction for right eyes and an anticlockwise direction for left eyes. Thus, the 3-o'clock sector of the peripapillary scan represented the nasal optic disc side of both eyes.

For Spectralis OCT, a scan circle with a diameter of 3.46 mm was manually positioned with the optic disc at its centre while the eye-tracking system was activated. This enabled real-time three-dimensional tracking of eye movements with real-time averaging of multiple B-scans acquired at an identical location of the retina to reduce speckle noise. For this study, 100 images were acquired at the scan circle under high-resolution settings (40 000 A-scans) and were averaged automatically by the software. The device's built-in software calculated the mean p-RNFL thickness of global average four quadrants (superior, inferior, nasal, and temporal) and sectors (nasal-superior, temporal-superior, temporal-inferior, and nasal-inferior). The same experienced operators performed all of the OCT scans under standardised mesopic lighting conditions.

Statistical Analysis Comparisons between the GG and CG were performed using the independent *t*-test for continuous variables and Chi-square test for categorical variables. The comparison of average and four quadrants p-RNFL thickness measurements obtained using the two OCT devices were analysed using paired *t*-tests. To evaluate the diagnostic ability of the p-RNFL thickness parameters in diagnosing glaucoma, area under the receiver operating characteristics curve (AUROC) values were calculated. The AUROC was calculated using the standard formula[24]. An AUROC of 1.0 represented perfect discrimination, whereas an AUROC of 0.5 represented chance discrimination. AUROC values of comparable parameters obtained using the two devices were compared using Chi-square tests. The sensitivities were calculated at specificities >80% and >95%. All analyses were performed using SPSS Version 21.0 (SPSS Inc., Chicago, IL, USA) and SAS 9.3 for Windows (SAS Institute Inc., Cary, NC, USA). A *P* value of <0.05 was considered statistically significant.

RESULTS

The study enrolled 60 highly myopic eyes from 60 Chinese patients (32 females and 28 males). Mean age was 41.0±9.8y (range: 21 to 63y); mean SE was -8.3±2.2 D (range: -6.00 to -15.00 D). Thirty eyes of 30 patients were categorized into the GG and 30 eyes of 30 patients into the CG. The characteristics of participants in both groups are summarised in Table 1. There was a slight female predominance in the CG, but there was no significant difference between the two groups in laterality, mean age, and SE.

Table 2 shows the mean p-RNFL thickness measured by Stratus OCT and Spectralis OCT. For both study groups,

Table 3 Areas under the receiver operating characteristic curves and sensitivities at fixed specificities for the average and quadrant parameters in Spectralis and Stratus OCT

Parameters	AUROC (SE)		*P*	Sensitivity/Specificity			
				Specificity >80.0%		Specificity >95%	
	Spectralis	Stratus		Spectralis	Stratus	Spectralis	Stratus
Average	0.893 (0.049)	0.840 (0.061)	0.301	75.0/81.5	78.3/82.1	29.2/96.3	47.8/96.4
Superior	0.744 (0.078)	0.704 (0.092)	0.584	50.0/81.5	52.2/82.1	16.7/100.0	34.8/96.4
Temporal	0.933 (0.035)	0.815 (0.074)	0.09	75.0/81.5	82.6/85.7	45.8/96.3	60.9/96.4
Inferior	0.951 (0.030)	0.918 (0.041)	0.157	87.5/85.2	91.3/82.1	58.3/96.4	60.9/96.4
Nasal	0.575 (0.092)	0.597 (0.089)	0.828	8.3/81.5	4.3/89.3	8.3/92.6	4.3/96.4

AUROC: Area under the receiver operating characteristic curve; SE: Standard error. AUROC values of comparable parameters obtained using the two devices were compared using Chi-square tests.

the average and quadrant p-RNFL thickness measured by Spectralis OCT was thinner than that measured by Stratus OCT, and the difference was more pronounced in the glaucoma group than in the control group.

Table 3 shows the AUROC values and sensitivities at fixed specificities for the p-RNFL average and quadrant parameters in Spectralis OCT and Stratus OCT. The parameters of Spectralis OCT demonstrated generally higher AUROC values than did the parameters of Stratus OCT; however, the difference was not statistically significant. Both OCT devices had the largest AUROC at the inferior quadrant, and the value was higher in Spectralis OCT (0.951) than in Stratus OCT (0.918), but there was no significant difference (P=0.157). For Stratus OCT, the sensitivity of the inferior quadrant parameter was 91.3% at a specificity of 82.1% and 60.9% at a specificity of 96.4%. For Spectralis OCT, the sensitivity of the inferior quadrant parameter was 87.5% at a specificity of 85.2%, and 58.3% at a specificity of 96.4%.

Table 4 indicates the AUROC values and sensitivities at fixed specificities for the p-RNFL sector parameters in Spectralis OCT and p-RNFL clock-hour parameters in Stratus OCT. In Spectralis OCT, the parameter with the highest AUROC was the temporal-inferior sector (0.974), with a sensitivity of 95.8% at 85.2% specificity and 66.7% at 96.3% specificity. In Stratus OCT, the parameter with the highest AUROC was the 7-o'clock sector (0.918), with a sensitivity of 91.3% at 82.1% specificity and 73.9% at 96.4% specificity. The AUROC for the best parameter from Spectralis OCT was higher than that for the best parameter from Stratus OCT (0.974 *vs* 0.918, P=0.120), but the difference was not statistically significant.

Table 4 Areas under the receiver operating characteristic curves and sensitivities at fixed specificities for the sector parameters in Spectralis and Stratus OCT

Parameters	AUROC (SE)	Sensitivity/Specificity	
		Specificity >80.0%	Specificity >95%
Spectralis OCT (sectors)			
Temporal-superior	0.885 (0.052)	62.5/81.5	41.7/96.3
Nasal-superior	0.502 (0.094)	4.2/81.5	0/96.3
Nasal-inferior	0.648 (0.089)	37.5/81.5	25.0/96.3
Temporal-inferior	0.974 (0.020)	95.8/85.2	66.7/96.3
Stratus OCT (clock hours)			
12 superior	0.627 (0.098)	43.5/82.1	39.1/96.4
11	0.842 (0.061)	73.9/82.1	56.5/96.4
10	0.779 (0.080)	78.3/82.1	47.8/96.4
9 temporal	0.772 (0.074)	60.9/82.1	21.7/96.6
8	0.840 (0.060)	69.6/82.1	39.1/96.4
7	0.918 (0.042)	91.3/82.1	73.9/96.4
6 inferior	0.878 (0.053)	87.0/82.1	34.8/96.4
5	0.551 (0.093)	17.4/82.1	13.0/96.4
4	0.584 (0.090)	13.0/82.1	0/96.4
3 nasal	0.689 (0.084)	8.7/85.7	0/96.4
2	0.634 (0.089)	17.4/82.1	4.3/96.4
1	0.513 (0.099)	30.4/82.1	17.4/96.4

AUROC: Area under the receiver operating characteristic curves; OCT: Optical coherence tomography; SE: Standard error.

DISCUSSION

Diagnosing glaucoma in myopic eyes can be challenging, mainly because of the morphologic changes in the optic disc, such as PPA related to myopia, and atypical VF defects such as an enlarged blind spot, temporal peripheral defect, or generalised reduction in sensitivity. Thus, true glaucomatous eyes can sometimes be misdiagnosed with conventional diagnostic tools such as fundus examinations or VF testing. With improvements in technology, ophthalmic imaging, such as OCT, has been found to be important adjunct to clinical diagnosis of glaucoma[9,25-26].

Compared to the older TD-OCT, the newer SD-OCT technology in Spectralis OCT offers the advantages of multiple B-scan averaging, in which studies have shown to be able to improve the clarity of boundaries between inner retinal layers[15-16], and may provide a significant advantage over the older time-domain technology in diagnosing glaucoma. Nukada *et al*[18] reported that Spectralis OCT had a better diagnostic capability than single-scan Stratus OCT to detect localised RNFL defects in patients with perimetric glaucoma. Jeoung *et al*[19] also demonstrated that Spectralis OCT was better than Stratus OCT in detecting preperimetric localised RNFL defects. Both of these studies found that with the use of technology to reduce

speckle noise, Spectralis OCT has an improved capability to detect localised RNFL defects before disruption of its reflectivity, and proposed that a device having higher accuracy to detect the RNFL would have higher diagnostic performance in detecting RNFL defects[18-19]; however, all of these studies have excluded patients with a refraction of <-6 D. In an era of growing prevalence in high myopia[23], it would be important to also assess whether these technological advances may provide an advantage in this group of patients. While none of the previous studies have directly compared whether SD-OCT would also offer a diagnostic advantage over TD-OCT in the diagnosis of glaucoma in patients with high myopia, our studys pecifically compared the glaucoma diagnostic capabilities of Spectralis OCT and Stratus OCT in highly myopic patients (Table 1).

In the present study, we found that the thickness measurements of p-RNFL in patients with high myopia from Spectralis OCT were generally thinner than that measured by Stratus OCT, and the difference in thickness was more pronounced in the GG (Table 2). Our results are consistent with a previous study that also found the average RNFL thickness in patients with open-angle glaucoma to be lower when measured using Spectralis OCT than using Stratus OCT[27]. This difference in thickness measurements obtained using the two devices might be explained by the differences in their segmentation algorithms. The RNFL thickness is generated in Spectralis OCT by setting its posterior border to the bottom part of the RNFL, whereas in Stratus OCT, the posterior border of the RNFL is set to be the top layer of the ganglion cell layer, thereby resulting in a possibly thicker measurement on Stratus OCT.

Although no studies have directly compared the glaucoma diagnostic capabilities of Spectralis SD-OCT versus Stratus TD-OCT in patients with high myopia, several studies have evaluated the diagnostic performances of various SD-OCT devices in highly myopic patients. Shoji *et al*[28] evaluated the diagnostic capability of p-RNFL parameters in patients with high myopia [SE=-8.9±3.1 D; mean deviation (MD)=-8.1±7.7 dB] using RTVue SD-OCT and found that the largest AUROC was obtained for average p-RNFL thickness (0.826), followed by the inferior quadrant (0.811). Kim *et al*[29] also performed a similar study using RTVue SD-OCT in patients with high myopia (SE=-9.25±3.70 D; MD=-8.56±5.82 dB) and found that the parameter with the largest AUROC was the inferior p-RNFL thickness (0.881), followed by the average p-RNFL thickness (0.825). In the study by Akashi *et al*[30] p-RNFL in patients with high myopia (SE=-7.87±1.34 D; MD=-7.36±6.52 dB) was measured using Cirrus SD-OCT, RTVue SD-OCT, and 3D OCT; they found that the largest AUROC values were the average p-RNFL thickness (0.969, 0.975, and 0.957, respectively) and inferior p-RNFL thickness (0.944, 0.953, and 0.964, respectively). Using Cirrus SD-OCT, Choi *et al*[31] also found that in patients with high myopia (SE=-8.70±3.11 D; MD=-7.44±4.85 dB), the p-RNFL parameter with the largest AUROC was the inferior RNFL thickness (0.906), followed by the average RNFL thickness (0.899) and the 7-o'clock sector (0.840). Our results are consistent with the previous studies regarding the diagnostic capability of SD-OCT in highly myopic glaucoma, and found that Spectralis OCT also demonstrated good to excellent diagnostic capability for glaucoma in patients with high myopia (Tables 3, 4). In our study, the SD-OCT p-RNFL parameters with the best ability for discriminating highly myopic patients with and without glaucoma were the temporal-inferior sector (0.974) and the inferior quadrant (0.951).

Recent studies on non-highly myopic patients that have directly compared between the Cirrus SD-OCT and Stratus TD-OCT foundthat glaucoma detection capabilities were significantly better for SD-OCT[18-19], although some of the earlier studies have suggested otherwise[12,32]. In the current study on highly myopic patients, which compared the glaucoma diagnostic performance of Spectralis SD-OCT and Stratus TD-OCT, we foundthat on Spectralis OCT, the temporal-inferior sector (AUROC=0.974) and the inferior quadrant (AUROC=0.951) parameters performed the best, whereas for Stratus OCT, the 7-o'clock sector (AUROC=0.918) and inferior quadrant (AUROC=0.918) performed the best. Spectralis OCT had generally higher AUROC values than Stratus OCT, although the differences were not statistically significant.

However, the patient population in the study design may affect the comparison between these two OCT devices. Our study evaluated only highly myopic controls and patients with mild to moderate glaucoma (MD=-6.4±4.1 dB). RNFL thickness has been shown to be increasingly thinned as myopia increases[33], and since the patients in our glaucoma group only had mild to moderate glaucoma, the RNFL thickness differences in the control group versus the glaucoma group may not be pronounced enough to highlight a significant difference in diagnostic capabilities of these two devices. In addition to the thickness of RNFL, glaucoma severity may also affect its reflectivity[18,34]. As the reflectivity of RNFL decreases with worsening glaucoma, differentiation between the border of the RNFL and the ganglion cell layer may be increasingly difficult, and may result in misidentification of the RNFL layer by the OCT segmentation software. Therefore, in patients with moderate to severe glaucoma and markedly reduced reflectivity of RNFL, the reduced speckle noise technology in Spectralis OCT may have a greater advantage in having a better visualization of the boundaries between the inner retinal layers over Stratus OCT[18], and thus possibly offering a better diagnostic capability.

Two additional explanations might account for the lack of diagnostic advantage of Spectralis OCT over Stratus OCT in patients with high myopia. First, small, focal, and narrow RNFL defects <10° may be masked by the averaging of the thickness values in the sectors or quadrants; thus, if the RNFL defects were very narrow, then they would likely be difficult to detect using either device. Jeoung *et al*'s[10,12,19] previous studies found that for localised defects with angular widths <10°, the sensitivities of Spectralis and Stratus OCT were similar at 46.2% and 38.5%, respectively; however, when the defects had angular widths of 20° to 30°, the sensitivity was 81.8% for Spectralis OCT and 63.6% for Stratus OCT. A second possible explanation for the lack of differences between the diagnostic capabilities of these two devices is that the present study included only highly myopic eyes. Glaucomatous RNFL damage may appear as both localised defects and diffuse RNFL atrophy, but the latter is more common in high myopia. Compared with localised RNFL defects, diffuse RNFL atrophy may be more difficult to detect[7-8]. A previous study by Kim *et al*[35] also found that the Stratus and Cirrus OCT devices did not differ significantly in their capability to detect diffuse RNFL atrophy. The results of our study suggest that even with the advances and improvements in SD-OCT imaging technology, the glaucoma diagnostic capabilities of these two devices are similar in patients with high myopia.

Our study has some limitations. First, the differences in the sensitivity of imaging devices would depend on the severity of glaucomatous damage, referral source for study patients, and criteria used to define glaucoma. In this study, the definition of glaucoma was based on both functional deterioration in glaucomatous VF defects as well as structural changes in the optic disc and RNFL. The diagnostic accuracy of OCT has been evaluated only for perimetric glaucoma. Some eyes with very early optic nerve structural abnormality or with functional damage not apparent on VF testing may have been categorised in the control group, thereby affecting our results. Furthermore, since the results of our study showed that the glaucoma diagnostic capability of Stratus OCT and Spectralis OCT appear to be similar in highly myopic patients with mild to moderate glaucoma, it would be important in a future study to include highly myopic glaucoma patients at different glaucoma stages to clarify whether Spectralis OCT would perform better than Stratus OCT in patients with more severe glaucoma and decreased RNFL reflectivity. Second, we excluded patients with large PPA that extended outside the measurement circle of the OCT in order to decrease the number of scans with artefacts. Exclusion of these patients could have created a potential selection bias, as PPA is considered an optic disc characteristic of myopia. However, we undertook a within-patient comparison to ensure this selection bias did not alter the conclusions.

In conclusion, this study found that the peripapillary RNFL thickness parameters with the highest AUROC for diagnosing glaucoma in patients with high myopia were the temporal-inferior sector on Spectralis SD-OCT and the 7-o'clock sector on Stratus TD-OCT. These parameters could be useful in distinguishing highly myopic patients with and without glaucoma. However, there were no significant differences between the AUROCs for Spectralis SD-OCT and Stratus OCT, which suggest that the glaucoma diagnostic capabilities of these two devices in patients with high myopia are similar.

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REFERENCES

1 Weinreb RN, Khaw PT. Primary open-angle glaucoma. *Lancet* 2004;363(9422):1711-1720.

2 Leung CK, Chan WM, Yung WH, Ng AC, Woo J, Tsang MK, Tse RK. Comparison of macular and peripapillary measurements for the detection of glaucoma: an optical coherence tomography study. *Ophthalmology* 2005;112(3):391-400.

3 Hoffmann EM, Medeiros FA, Sample PA, Boden C, Bowd C, Bourne RR, Zangwill LM, Weinreb RN. Relationship between patterns of visual field loss and retinal nerve fiber layer thickness measurements. *Am J Ophthalmol* 2006;141(3):463-471.

4 Medeiros FA, Zangwill LM, Bowd C, Weinreb RN. Comparison of the GDx VCC scanning laser polarimeter, HRT II confocal scanning laser ophthalmoscope, and stratus OCT optical coherence tomograph for the detection of glaucoma. *Arch Ophthalmol* 2004;122(6):827-837.

5 Chen SJ, Lu P, Zhang WF, Lu JH. High myopia as a risk factor in primary open angle glaucoma. *Int J Ophthalmol* 2012;5(6):750-753.

6 Chang RT, Singh K. Myopia and glaucoma: diagnostic and therapeutic challenges. *Curr Opin Ophthalmol* 2013;24(2):96-101.

7 Tuulonen A, Airaksinen PJ. Initial glaucomatous optic disk and retinal nerve fiber layer abnormalities and their progression. *Am J Ophthalmol* 1991;111(4):485-490.

8 Jonas JB, Dichtl A. Optic disc morphology in myopic primary open-angle glaucoma. *Graefes Arch Clin Exp Ophthalmol* 1997;235(10):627-633.

9 Hsu CH, Chen RI, Lin SC. Myopia and glaucoma: sorting out the difference. *Curr Opin Ophthalmol* 2015;26(2):90-95.

10 Jeoung JW, Park KH, Kim TW, Khwarg SI, Kim DM. Diagnostic ability of optical coherence tomography with a normative database to detect localized retinal nerve fiber layer defects. *Ophthalmology* 2005;112(12):2157-2163.

11 Kim TW, Park UC, Park KH, Kim DM. Ability of Stratus OCT to identify localized retinal nerve fiber layer defects in patients with normal standard automated perimetry results. *Invest Ophthalmol Vis Sci* 2007;48(4):1635-1641.

12 Jeoung JW, Park KH. Comparison of Cirrus OCT and Stratus OCT on the ability to detect localized retinal nerve fiber layer defects in preperimetric glaucoma. *Invest Ophthalmol Vis Sci* 2010;51(2):938-945.

13 Hangai M, Yamamoto M, Sakamoto A, Yoshimura N. Ultrahigh-resolution versus speckle noise-reduction in spectral-domain optical coherence tomography. *Opt Express* 2009;17(5):4221-4235.

14 Mumcuoglu T, Wollstein G, Wojtkowski M, Kagemann L, Ishikawa H, Gabriele ML, Srinivasan V, Fujimoto JG, Duker JS, Schuman JS. Improved visualization of glaucomatous retinal damage using high-speed ultrahigh-resolution optical coherence tomography. *Ophthalmology* 2008;115(5):782-789.

15 Sander B, Larsen M, Thrane L, Hougaard JL, Jorgensen TM. Enhanced optical coherence tomography imaging by multiple scan averaging. *Br J Ophthalmol* 2005;89(2):207-212.

16 Sakamoto A, Hangai M, Yoshimura N. Spectral-domain optical coherence tomography with multiple B-scan averaging for enhanced imaging of retinal diseases. *Ophthalmology* 2008;115(6):1071-1078.

17 Byeon SH, Chu YK, Lee H, Lee SY, Kwon OW. Foveal ganglion cell layer damage in ischemic diabetic maculopathy: correlation of optical coherence tomographic and anatomic changes. *Ophthalmology* 2009; 116(10):1949-1959.

18 Nukada M, Hangai M, Mori S, Nakano N, Nakanishi H, Ohashi-Ikeda H, Nonaka A, Yoshimura N. Detection of localized retinal nerve fiber layer defects in glaucoma using enhanced spectral-domain optical coherence tomography. *Ophthalmology* 2011;118(6):1038-1048.

19 Jeoung JW, Kim TW, Weinreb RN, Kim SH, Park KH, Kim DM. Diagnostic ability of spectral-domain versus time-domain optical coherence tomography in preperimetric glaucoma. *J Glaucoma* 2014; 23(5):299-306.

20 Mitchell P, Hourihan F, Sandbach J, Wang JJ. The relationship between glaucoma and myopia: the Blue Mountain Eye Study. *Ophthalmology* 1999;106(10):2010-2015.

21 Xu L, Wang Y, Wang S, Wang Y, Jonas JB. High myopia and glaucoma susceptibility - the Beijing Eye Study. *Ophthalmology* 2007;114(2):216-220.

22 Verkicharla PK, Ohno-Matsui K, Saw SM. Current and predicted demographics of high myopia and an update of its associated pathological changes. *Ophthalmic Physiol Opt* 2015;35(5):465-475.

23 Lin LL, Shih YF, Hsiao CK, Chen CJ. Prevalence of myopia in Taiwanese schoolchildren: 1983 to 2000. *Ann Acad Med Singap* 2004;33(1):27-33.

24 Obuchowski NA. ROC analysis. *AJR Am J Roentgenol* 2005;184(2): 364-372.

25 Grewal DS, Tanna AP. Diagnosis of glaucoma and detection of glaucoma progression using spectral domain optical coherence tomography. *Curr Opin Ophthalmol* 2013;24(2):150-161.

26 Bussel II, Wollstein G, Schuman JS. OCT for glaucoma diagnosis, screening and detection of glaucoma progression. *Br J Ophthalmol* 2014;98(Suppl 2):ii15-19.

27 Toteberg-Harms M, Sturm V, Knecht PB, Funk J, Menke MN. Repeatability of nerve fiber layer thickness measurements in patients with glaucoma and without glaucoma using spectral-domain and time-domain OCT. *Graefes Arch Clin Exp Ophthalmol* 2012;250(2):279-287.

28 Shoji T, Nagaoka Y, Sato H, Chihara E. Impact of high myopia on the performance of SD-OCT parameters to detect glaucoma. *Graefes Arch Clin Exp Ophthalmol* 2012;250(12):1843-1849.

29 Kim NR, Lee ES, Seong GJ, Kang SY, Kim JH, Hong S, Kim CY. Comparing the ganglion cell complex and retinal nerve fibre layer measurements by Fourier domain OCT to detect glaucoma in high myopia. *Br J Ophthalmol* 2011;95(8):1115-1121.

30 Akashi A, Kanamori A, Nakamura M, Fujihara M, Yamada Y, Negi A. The ability of macular parameters and circumpapillary retinal nerve fiber layer by three SD-OCT instruments to diagnose highly myopic glaucoma. *Invest Ophthalmol Vis Sci* 2013;54(9):6025-6032.

31 Choi YJ, Jeoung JW, Park KH, Kim DM. Glaucoma detection ability of ganglion cell-inner plexiform layer thickness by spectral-domain optical coherence tomography in high myopia. *Invest Ophthalmol Vis Sci* 2013;54(3):2296-2304.

32 Sehi M, Grewal DS, Sheets CW, Greenfield DS. Diagnostic ability of fourier-domain vs time-domain optical coherence tomography for glaucoma detection. *Am J Ophthalmol* 2009;148(4):597-605.

33 Oner V, Aykut V, Tas M, Alakus MF, Iscan Y. Effect of refractive status on peripapillary retinal nerve fibre layer thickness: a study by RTVue spectral domain optical coherence tomography. *Br J Ophthalmol* 2013;97(1):75-79.

34 van der Schoot J, Vermeer KA, de Boer JF, Lemij HG. The effect of glaucoma on the optical attenuation coefficient of the retinal nerve fiber layer in spectral domain optical coherence tomography images. *Invest Ophthalmol Vis Sci* 2012;53(4):2424-2430.

35 Kim KE, Kim SH, Jeoung JW, Park KH, Kim TW, Kim DM. Comparison of ability of time-domain and spectral-domain optical coherence tomography to detect diffuse retinal nerve fiber layer atrophy. *Jpn J Ophthalmol* 2013;57(6):529-539.