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Imaging of the retinal nerve fibre layer with spectral domain optical coherence tomography for glaucoma diagnosis

Kyung Rim Sung[1], **Jong S Kim**[2], **Gadi Wollstein**[2], **Lindsey Folio**[2], **Michael S Kook**[1], and **Joel S Schuman**[2]

[1]Department of Ophthalmology, Asan Medical Center, University of Ulsan, College of Medicine, Seoul, Korea

[2]Department of Ophthalmology, UPMC Eye Center, Eye and Ear Institute, Ophthalmology and Visual Science Research Center, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania, USA

Abstract

Optical coherence tomography (OCT) techniques have been applied to develop a new generation of the technology, called spectral domain (SD) or Fourier domain (FD) OCT. The commercially available SD-OCT technology offers benefits over the conventional time domain (TD) OCT such as a scanning speed up to 200 times faster and higher axial resolution (3 to 6 μm). Overall, SD-OCT offers improved performance in terms of reproducibility. SD-OCT has a level of discriminating capability, between healthy and perimetric glaucoma eyes similar to that obtained with TD-OCT. Furthermore, the capabilities and features of SD-OCT are rapidly evolving, mainly due to three-dimensional imaging and image rendering. More sophisticated approaches for macular and optic disc assessment are expected to be employed in clinical practice. Analysis software should be further refined for interpretation of SD-OCT images in order to enhance the sensitivity and specificity of glaucoma diagnostics. Most importantly for SD-OCT is determination of its ability to diagnostic structural glaucomatous progression. Considering the recent launch time of the commercially available SD-OCT and slow progressing characteristic of glaucoma, we must wait for longitudinal SD-OCT data, with a long enough follow-up, to become available.

INTRODUCTION

Optical coherence tomography (OCT) has undoubtedly and significantly improved the diagnostic paradigm for retinal and glaucoma clinical care. In glaucoma, the retinal nerve fibre layer (RNFL) thickness measured by OCT enables an objective and quantitative assessment of glaucomatous structural loss. Standard automated perimetry combined with optic nerve head (ONH) examination remains the gold standard for glaucoma diagnosis. However, non-contact and non-invasive OCT RNFL thickness measurements and diagnostic classifications such as ‘within normal limits,’ ‘borderline,’ and ‘outside normal limits’ derived from a normative database allow ophthalmologists to assess structural aspects of glaucomatous damage more efficiently. Numerous studies have shown the glaucoma

Correspondence to: Dr Kyung Rim Sung, Department of Ophthalmology, University of Ulsan, College of Medicine, Asan Medical Center, 388-1 Pungnap-2-dong, Songpagu, Seoul, Korea 138-736; sungeye@gmail.com.

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diagnostic capability of time domain (TD) OCT (Stratus OCT, Carl Zeiss Meditec, Dublin, California).[1–11]

OCT techniques have been applied to develop a new generation of the technology with outstanding performance relative to the conventional TD-OCT system, called spectral domain (SD) or Fourier domain (FD) OCT.[12, 13] The most obviously improved feature of SD-OCT technology compared with TD-OCT is scanning speeds up to 200 times faster. Employing a fast scanning speed with an OCT device is relatively more important than other imaging modalities because the human eye moves very fast involuntarily. Therefore, a faster scan speed allows the acquisition of data sets with less motion artefact. In addition, the higher sampling density of SD-OCT three-dimensional (D) cube data with a faster scan speed allows us to visualise pathophysiological features of the retina.[14–16] Another advantage of SD-OCT over TD-OCT is the improved axial resolution. Currently, SD-OCT has two to three times better axial resolution (3 to 6 μm) than TD-OCT (10 μm).

Needless to say, what glaucoma specialists as well as general ophthalmologists expect from the state-of-the-art SD-OCT technology is the enhancement of capabilities in glaucoma diagnoses and glaucoma progression detection. The purpose of this manuscript was to review recently published articles regarding the assessment of commercially available SD-OCT devices for glaucoma diagnosis.

Principle of SD OCT

The basic principles of SD-OCT have been well described.[17] Briefly, TD-OCT detects the echo time delay between the reference arm and the sample arm and the intensity of the back reflection. To achieve this, the reference arm of TD-OCT moves back and forth to obtain the echo time delay, which limits the maximal scanning speed. Alternatively, the reference mirror in SD-OCT remains fixed because the echo time delay is replaced by the simultaneous detection of frequency changes. In other words, instead of a moving reference mirror like that used in TD-OCT, the mirror remains stationary, and the interference pattern is split by a grating into its frequency components. All of these components are simultaneously detected by a charge-coupled device. Depth information in the retinal layer of each frequency component is obtained after a Fourier transform of the each received signal. This approach enables the fast scanning time of SD-OCT. The axial resolution of an OCT image is dependent on the coherent length of the light source, which is inversely proportional to the bandwidth of the light source. For the purpose of an improvement in axial resolution, broad-bandwidth light sources are employed in SD-OCT systems. This enables SD-OCT to achieve a resolution (3–6 μm) two to three times higher than that of commercially available TD-OCT (10 μm). Like TD-OCT, the main glaucoma diagnosis protocol in SD-OCT is peripapillary RNFL thickness assessment.

REPRODUCIBILITY

Measurement reproducibility is an important requirement for clinical utility of a diagnostic device. Several studies evaluated the reproducibility of RNFL thickness measurement from various SD-OCT devices, and those results are summarised in table 1.[18–25] Leung *et al* and Schuman each compared the reproducibility of SD-OCT and TD-OCT.[18, 19] Both study results indicated that measurement variability of sectoral RNFL thicknesses were significantly lower in SD-OCT compared with TD-OCT.[18, 19] Kim *et al* compared the reproducibility of TD-OCT with SD-OCT using an experimental methodology.[20] In this study, the 3D SD-OCT cube scan (200×200 A scans) was analysed in two ways. The ONH centre was defined on each image separately, and the ONH centre was defined on one image (ie, scan at the first visit) and exported to other images (ie, scans in different time points) after scan registration. After defining the ONH centre, a 3.4 mm diameter virtual circular

OCT B-mode image was obtained from the 3D SD-OCT cube scan to mimic the conventional TD-OCT circumpapillary scan. Their results indicated that the reproducibility of RNFL thickness measurements from the 3D SD-OCT cube data showed significantly better results in both methods than TD-OCT. Vizzeri *et al* and González-García *et al* showed excellent and similar reproducibility levels that can be obtained by different SD devices (Cirrus and RTVue OCT).[21, 22] Two data-acquisition modes, direct circular scanning like TD-OCTand resampling the data of interest from a 3D dataset are possible with SD-OCT. Shin *et al* tested RNFL thickness measurement reproducibility by two different techniques (NHM4 (resampling) vs RNFL 3.45 (direct circular scanning)) of the RTVue OCT and reported that both modes showed excellent measurement reproducibility.[25]

According to the above results, the commercialised SD-OCT devices by various manufacturers showed good RNFL measurement reproducibility and generally were reported to be better than or comparable with those obtained with TD-OCT. Sectoral RNFL measurements showed a higher variability than overall mean RNFL thickness measurements.[26] Sectoral measurements are more easily affected by inconsistent sampling circle placement or other confounding factors. The results suggesting SD-OCT can achieve better levels of reproducibility than TD-OCT, especially in sectoral measurement, are very encouraging. Glaucomatous structural damage usually starts as a localised defect; therefore, reproducible measurement of sectoral change is crucial for structural progression detection. Better reproducibility of sectoral RNFL thickness measurement in SD-OCT compared with TD OCT might be explained by the improved scan resolution and data-registration technology of SD-OCT.

STRUCTURE AND FUNCTION RELATIONSHIP

Since glaucoma is defined as a structural change in optic disc and RNFL with accompanying functional decay manifested by visual field (VF), the correlation of glaucomatous damage (structural loss) detected by SD-OCT with functional loss assessed with a VF test needs to be evaluated. Horn *et al* evaluated the correlation between local glaucomatous VF defects (functional loss) and RNFL thinning (structural damage) measured with SD-OCT and compared those results with scanning laser polarimetry (SLP; GD×VCC).[27] They found SD-OCT to be useful for determining the functional–structural relationship in peripapillary areas, where the association between perimetric defects and corresponding RNFL loss is stronger for SD OCT than for the present SLP. Similarly, Leung *et al* studied the structure–function relationship between SD-OCT and TD-OCT using mean RNFL thicknesses and VF mean deviations (MDs) fitted with the second-order regression equation.[18] They showed that there was no significant difference in the strength of structure–function association between SD-OCT (coefficient of determination (R^2) = 0.580) and TD-OCT (R^2 = 0.623; p = 0.918). Further research regarding the structure–function relationship using various commercialised SD-OCT devices is warranted.

GLAUCOMA DIAGNOSTIC CAPABILITY OF SD-OCT

A considerable number of studies regarding the glaucoma diagnostic capability of SD-OCT RNFL measurements have been published (table 2).[18, 28–37] Most of the studies compared the diagnostic capability of SD-OCT RNFL measurements with those of TD-OCT.[18, 29–33, 35, 37] Several publications have investigated the diagnostic capability of SD-OCT RNFL thickness measurements using an area-under-the-receiver-operating-characteristic curve (AUC) for discrimination between healthy and glaucomatous eyes.[18, 31–37] It is difficult to compare the AUC values directly among different studies, since AUC values can vary according to the glaucoma participant's stage of disease, and the disease characteristics of the subjects. However, all SD-OCT devices tested showed a good

glaucoma diagnostic capability. Additionally, most of the studies consistently showed no statistically significant differences in glaucoma diagnostic capability between SD-OCT and TD-OCT.[18, 31–33, 35, 37] Categorical classification of RNFL thickness measurements using terms such as 'outside normal limits,' 'borderline,' or 'within normal limits,' based on a comparison with a normative database, is another advantage helping clinicians to assess the structural status of glaucoma objectively and conveniently. Sung *et al* found that SD-OCT demonstrated a higher sensitivity than TD-OCT in an abnormal classification of mean RNFL thickness from glaucomatous eyes as defined by the VF test.[29] The authors hypothesised that the higher sensitivity of SD-OCT may be due to the higher scan resolution and more accurate data registration from the improved technology. They suggest that the racial distribution of the SD-OCT normative database may also add to the difference between the technologies. For example, 20% of the total population included in the Cirrus OCT normative database were Asian, while a relatively small number of Asian individuals (3%) were included in the TD-OCT normative database.[38] Moreover, Chang *et al* reported that the sensitivity and specificity of SD-OCT for classification of abnormal RNFL thickness for glaucoma detection were equivalent to those of TD-OCT.[30] Jeoung *et al* compared the diagnostic ability of SD-OCT and TD-OCT to detect localised RNFL defects in patients with normal standard automated perimetry (preperimetric glaucoma) and found that there was no statistically significant difference between the AUCs for the best parameters from both iterations of OCTs.[37]

Summarising the previously described studies regarding glaucoma diagnostic capability of SD-OCT, various SD-OCTs showed a similar level of glaucoma discriminating ability compared with TD-OCT. These results can be explained by several speculations. First, most of the current diagnostic studies are designed to evaluate whether or not RNFL measurements can identify perimetrically defined glaucoma. Glaucomatous structural damage is known to precede perimetrically assessed functional deficit.[39–41] Thus, most of the glaucomatous patients enrolled in studies already had considerable structural damage. Therefore, the superiority of one imaging device compared with another will be difficult to evaluate in structurally advanced cases. Obviously, if we intended to see diagnostic sensitivity of newly introduced SD-OCT, we should evaluate patients with preperimetric stages of glaucoma. However, there is no gold standard by which to define such preperimetric stages. Thus, there are some limitations in those studies comparing glaucoma diagnostic capability determined by VF. Second, although, SD-OCT employed new technology for data acquisition, most of the peripapillary RNFL data are analysed in the same location as TD-OCT, usually a concentric peripapillary circle with a diameter of 3.4 mm. This similar measurement location is familiar to most OCT users and makes it easy to compare SD-OCT data with TD-OCT data. However, this similarity of the scan location may contribute to a similar level of diagnostic capability; in other words, it may be difficult for SD-OCT to outperform TD-OCT if the measurements are limited by this similar location. Jeoung *et al* showed a focal RNFL defect in SD-OCT deviation map which was not detected by a Stratus OCT peripapillary circle with a diameter of 3.4 mm.[37] Thus, one can say that SD-OCT would enhance the diagnostic capability of glaucoma not by conventional peripapillary circular measurement with a diameter of 3.4 mm but by an RNFL thickness map from a 3D volumetric data set.

Comparison of glaucoma diagnostic capability between SD-OCT and other imaging devices is another valuable research area. The potential for multiple imaging devices to report similar findings can allow more confident glaucoma diagnostic decisions. Leung *et al* evaluated and compared the diagnostic capability of Spectralis OCT and Heidelberg Retinal Tomograph, and reported that Spectralis OCT RNFL measurements attained a higher sensitivity than the Heidelberg Retinal Tomograph optic disc measurements at a comparable

level of specificity.[36] More studies addressing this topic are expected to be reported in forthcoming reports.

AGREEMENT OF TD-OCT AND SD-OCT IN RNFL THICKNESS MEASUREMENT

Since glaucoma is a life-long disease for most patients, the structural and functional assessment of the patient should be traced longitudinally. Considering the rapid development of OCT technology and software, it seems that there will be many improved devices introduced during the lifetime of a given patient. Therefore, the comparability between different iterations of a device should be studied. Many researchers have investigated the agreement of various SD-OCTs with TD-OCT RNFL measurements.[21, 22, 29, 33, 42] All study results consistently showed that there was a good correlation between SD-OCT and TD-OCT RNFL measurements; however, systematic and statistically significant differences were reported between two iterations of the device.[21, 22, 29, 33, 42] Among SD-OCTs, Cirrus OCT tended to have thinner RNFL than TD-OCT, [21, 29, 42] whereas RTVue and SD-SLO/OCT tended to have a thicker RNFL than TD-OCT.[22, 33] However, both devices tended to have thicker RNFL measurements than TD-OCT in eyes with a very thin RNFL.

Overall, RNFL measurements by various SD-OCTs were well correlated with those obtained by TD-OCT. However, most of the precise RNFL thickness measurements by SD-OCTs differ significantly from those of TD-OCT. This may suggest that RNFL measurements between SD-and TD-OCT are not interchangeable, and there is a constant bias between two measurements. There was one report by Kim *et al* that intended to create a robust technique to make TD-OCT circular scan RNFL thickness measurements comparable with those obtained with 3D SD-OCT volumes.[43] Briefly, each eye was scanned multiple times with different scanning circles, and one 3D SD-OCT cube scan was obtained at the same visit. The matching location of the TD-OCT scanning circle was automatically detected within the corresponding 3D SD-OCT scan. The authors reported that scan location matching may bridge the gap in RNFL thickness measurements between TD-OCT circular scan data and 3D SD-OCT scan data, providing follow-up comparability across the two generations of OCTs. Therefore, conversion of TD-OCT data to SD-OCT data might be possible in the future, using either statistical modelling or image-processing techniques, to ensure that huge amounts of previously acquired TD-OCT data are not discarded. However, current research outcomes suggest that there should be caution when an individual undergoes a longitudinal follow-up with different OCTs, since data from TD- and SD-OCT are not clearly interchangeable.

MACULAR ASSESSMENT FOR GLAUCOMA

Previous reports have suggested that macular thickness assessment could be a valuable surrogate measure in the evaluation of glaucomatous structural change, because such damage occurs in retinal ganglion cells (RGCs), which are multilayered and most dense in the macular region.[3, 44–46] Total macular thickness may reduce the sensitivity of glaucoma. Thus, Ishikawa *et al* calculated the macular inner retinal layer (MIRL) thickness which was assumed to be more specific in glaucomatous damage by their own segmentation algorithm and showed a comparable glaucoma diagnostic capability of MIRL measurement to peripapillary RNFL measurement by use of TD-OCT. Instead of total macular thickness, SD-OCT can provide the ganglion cell layer thickness segmented from the total macular thickness with the help of improved resolution and the 3D cube scan. Using RTVue OCT, Tan *et al* measured macular retinal thickness and ganglion cell complex (GCC) thickness, defined as the combination of retinal nerve fibre, ganglion cell and inner plexiform layers.[47]

Here, they showed that the mean SD-OCT GCC had a significantly (p=0.02) higher diagnostic power (AUC=0.90) than macular retinal (AUC=0.85 for both SD-OCT and TD-OCT) in differentiating between perimetric glaucoma and normal eyes. They also reported that the diagnostic powers of the best GCC parameters were statistically equal to that of the TD-OCT RNFL mean. Seong *et al* compared the glaucoma discrimination ability of the MIRL thickness with that of peripapillary retinal nerve fibre layer (pRNFL) thickness measured by SD-OCT (RTVue OCT).[48] Here, they showed that the mean MIRL thickness had a strong correlation with pRNFL thickness, and MIRL thickness showed a glaucoma discrimination ability comparable with pRNFL thickness in early VF defect. In eyes with advanced or peripheral VF defect, pRNFL measurement showed a better glaucoma diagnostic ability than did MIRL measurement. The current study results suggest that GCC thickness assessed by SD-OCT has a comparable diagnostic capability with that of pRNFL thickness.[47, 48] It will be interesting to see what role macular GCC thickness will play in glaucoma diagnosis in the future.

RESEARCH APPROACH TOWARD OPTIC NERVE HEAD ANALYSIS

Traditionally, glaucomatous structural damage was defined as typical glaucomatous optic neuropathy, which included neuroretinal rim thinning and deepening of the optic disc cup. However, an optic disc analysis in TD-OCT was used less frequently than RNFL analysis in clinical practice. Several investigations were performed to enhance the utility of optic disc information in SD-OCT.[49–51] Strouthidis *et al* compared serial ONH histology with interpolated B-scans generated from 3D Spectralis OCT data.[49] They suggested that volumetric SD-OCT imaging of the ONH was capable of generating interpolated B-scans, which accurately matched serial histological sections. Chen correlated quantitative SD-OCT parameters with disc photography and VFs, and demonstrated an SD-OCT reference plane 139 μm above the retinal pigment epithelium yielded cup–disc.[50] Abràmoff *et al* developed an algorithm to determine the cup and rim in close-to-isotropic SD-OCT images of the ONH and showed that its performance for determining the cup and rim from SD-OCT images is similar to that of planimetry by glaucoma experts.[51] Further refined SD-OCT optic disc analysis might augment the diagnostic capability of RNFL analysis.

GLAUCOMATOUS PROGRESSION DETECTION

Progression detection remains the most challenging aspect of glaucoma management. Only a few studies regarding the glaucoma progression detection capability of OCT were reported at the time of writing this review.[52–54] Such problems may stem from the innate nature of the disease. Glaucoma progresses slowly, and the extent of progressive change is generally small, so the ability of detection of minute changes is essential in identifying progression. In order to identify changes in repetitive scans, the difference in the measured parameter has to exceed the inherent variability of the device. Therefore, the results of improved measurement reproducibility of SD-OCT compared with TD-OCT are very encouraging in terms of glaucoma progression detection. Improved reproducibility of SD-OCT RNFL measurements may enhance the ability to detect glaucomatous changes over time by enabling the detection of smaller changes than those required by TD-OCT. A higher scan sampling density and subsequent accurate data registration between measurements may play an important role for glaucoma progression detection. Considering the recent launch of the commercially available SD-OCT and the slowly progressive character of glaucoma, we must wait for longitudinal SD-OCT data with a long enough follow-up to become available.

IN THE FUTURE

SD-OCT imaging technology is rapidly evolving. New technologies such as swept source OCT,[55] SD-OCT integrated with adaptive optics[56] and polarisation-sensitive SD-OCT[57] are

currently under development. We hope to gain a better understanding of the structural status of glaucoma through future use of state-of-the-art technologies.

CONCLUSION

OCT employing SD technology is commercially available and in widespread clinical use. Unlike the dominance of a single brand in TD-OCT, multiple companies are producing SD-OCTs with different technical features. Unfortunately, clinical study outcomes regarding glaucoma diagnostic capability have concentrated on only two or three SD-OCTs at the time of writing this manuscript. SD-OCT performed better in terms of reproducibility but did not outperform TD-OCT for discriminating perimetrically proven glaucomatous from healthy eyes, possible reasons for which were explored above. Furthermore, SD-OCT is rapidly evolving, and unprecedented new features are becoming feasible with the help of 3D rendering. More sophisticated approaches for macular and optic disc evaluation are being developed. It is probable that SD-OCT will continue to integrate more accurate and attractive diagnostic strategies which are not currently available. There is also a need for analysis software to be further refined and tuned for interpretation of SD-OCT images to enhance glaucoma diagnostic capability. We need to take full advantage of the 3D data available with SD-OCT and go beyond TD-OCT's circum-papillary RNFL analysis. Finally, the most important issue for SD-OCT diagnostic ability is whether it can detect glaucomatous structural progression. Considering the recent launch time of commercially available SD-OCT and the slow progression characteristics of glaucoma, we may need to wait some time before this capability can be evaluated.

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Table 1

Spectral-domain (SD) optical coherence tomography (OCT) retinal nerve fibre layer (RNFL) thickness measurement reproducibility

Authors	SD-OCT device (company)	Study design	Main finding
Leung *et al*[18]	Cirrus OCT (Carl Zeiss Meditec)	Comparison with TD-OCT (Stratus)	Intravisit repeatability of Cirrus OCT ranged between 5.12 and 15.02 μm, intervisit reproducibility ranged between 4.31 and 22.01 μm
			The intervisit variabilities of sectoral and mean RNFL thicknesses were lower in Cirrus HD-OCT compared with TD-OCT (Stratus)
Schuman[19]	Cirrus OCT (Carl Zeiss Meditec) RTVue OCT (Optovue)	Comparison with TD-OCT (Stratus)	SD-OCT had a significantly better repro- ducibility in most RNFL sectoral measurements than TD-OCT
			No statistically significant differences in overall mean RNFL reproducibility between SD- and TD-OCT
Vizzeri *et al*[21]	Cirrus OCT (Carl Zeiss Meditec)	Reproducibility in healthy and glaucomatous eyes	The CV and ICC for mean RNFL thickness were 1.5% and 0.96 in healthy eyes, and 1.6% and 0.98, in patient eyes
González-García *et al*[22]	RTVue OCT (Optovue)	Reproducibility in healthy and glaucomatous eyes	The CV and ICC for mean RNFL thickness were 1.54% and 0.97 in healthy eyes, and 1.9% and 0.97 in patient eyes
Garas *et al*[23]	RTVue OCT (Optovue)	Influence of various factors on reproducibility	The intrasession CV and ICC for mean RNFL thickness were 2.2% and 0.99 in undilated status
			Pupil dilation, age and experience in imaging examinations did not influence reproducibility in a clinically significant manner
Menke *et al*[24]	3D OCT1000 (Topcon)	Intrasession, interobserver reproducibility in healthy eyes	The intrasession CV and ICC were 4% (operator 1), 4.2% (operator 2) and 0.90 3D-OCT RNFL thickness measurements in healthy volunteers showed good intra- and interobserver reproducibility
Shin *et al*[25]	RTVue OCT (Optovue)	Reproducibility of two different scan modes, NHM4 and RNFL 3.45	The CV and ICC for mean RNFL thickness were 2.31% and 0.96 in NHM4 mode, 2.03 and 0.95 in RNFL 3.45 modes
			Both NHM4 and RNFL3.45 modes showed excellent measurement reproducibilities

CV, coefficient of variance; HD, high definition; ICC, intraclass correlation coefficient; NHM, nerve head map; TD, time domain.

Table 2

Spectral-domain (SD) optical coherence tomography (OCT) retinal nerve fibre layer (RNFL) thickness measurement diagnostic capabilities

Authors	SD-OCT device (company)	Study design	Main findings
Leung *et al*[18]	Cirrus OCT (Carl Zeiss Meditec)	Comparison with TD-OCT (Stratus)	The AUC was 0.962 for SD- and 0.956 for TD-OCT
			No significant difference was detected between the TD- and SD-OCT
Park *et al*[31]	Cirrus OCT (Carl Zeiss Meditec)	Comparison with TD-OCT (Stratus)	The AUC was 0.962 for SD- and 0.956 for TD-OCT
			SD-OCT showed a better glaucoma discrimination capability than TD-OCT in the early stages of glaucoma
Moreno-Montañés *et al*[32]	Cirrus OCT (Carl Zeiss Meditec)	Comparison with TD-OCT (Stratus)	The AUC was 0.837 for SD- and 0.829 for TD-OCT
			The sensitivity and specificity, and AUCs were similar between TD and SD-OCT
Cho *et al*[33]	SD-SLO/OCT (OTI)	Comparison with TD-OCT (Stratus)	The AUC was 0.969 for SD- and 0.959 for TD-OCT
Li *et al*[34]	RTVue OCT (Optovue)	RNFL and ONH parameters	The AUC for RNFL thickness was 0.816, and for the cup–disc vertical ratio 0.782
Sehi *et al*[35]	RTVue OCT (Optovue)	Comparison with TD-OCT (Stratus)	The AUC was 0.88 for SD- and 0.87 for TD-OCT
			No significant difference was detected between the TD- and SD-OCT
Leung *et al*[36]	Spectralis OCT (Heidelberg Engineering)	Comparison with HRT (Heidelberg Engineering)	SD-OCT RNFL measurement attained a higher sensitivity (AUC; 0.978) than HRT optic disc measurement (0.905)
Jeoung *et al*[37]	Cirrus OCT (Carl Zeiss Meditec)	Comparison with TD-OCT (Stratus)	No significant differences between the AUCs for SD- (0.728) and TD-OCT (0.760) in discriminating preperimetric glaucoma
Sung *et al*[29]	Cirrus OCT (Carl Zeiss Meditec)	Comparison with TD-OCT (Stratus)	SD-OCT demonstrated a higher sensitivity (63.6%) than TD-OCT (40.0%) in normative classification of mean RNFL thickness
Chang *et al*[30]	Cirrus OCT (Carl Zeiss Meditec)	Comparison with TD-OCT (Stratus)	The sensitivity and specificity of various RNFL parameters using the Cirrus OCT for glaucoma with early to moderate visual field defects are excellent and are equivalent to Stratus OCT
Vizzeri *et al*[28]	Cirrus OCT (Carl Zeiss Meditec) Spectralis OCT (Heidelberg Engineering), RTVue OCT (Optovue)	Detection of localised RNFL defect	All three SD-OCTs were able to detect localized glaucomatous structural damage seen in stereophotographs

AUC, area under the receiver operating characteristic curve; HRT, Heidelberg retinal tomograph; ONH, optic nerve head; TD, time domain.