Original Article

Impact of lens opacity and axial length on concomitant screening of maculopathy by swept-source optical coherence tomography-based optical biometer

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Background: Preoperative evaluation of macular disorders is crucial to predict postoperative visual outcomes among patients with cataract. The swept-source optical coherence tomography (SS-OCT) based optical biometer was proved to be useful in screening macular pathology, while the impact of lens opacities and axial lengths on macular disease screening using SS-OCT based optical biometer remained unknown. This study aimed to evaluate the influence of lens opacities and axial lengths on foveal image quality detected by SS-OCT-based optical biometer, as well as sensitivity and specificity for the detection of macular diseases.

Methods: This was a diagnostic accuracy study that retrospectively included patients who underwent preoperative cataract examinations at our hospital between November 2020 and June 2021. All patients underwent SS-OCT based optical biometer and spectral-domain OCT (SD-OCT). The SD-OCT was the golden standard for diagnosing macular diseases. Sensitivity, specificity, and receiver operating characteristic (ROC) were calculated to evaluate the value of foveal SS-OCT scans for the detection of macular disease.

Results: Of the 224 eyes enrolled in the study, 82 eyes were diagnosed with macular disease by SD-OCT. The foveal image was almost indistinguishable due to poor quality when the mean grayscale of the image was less than 40. The posterior subcapsular opacity score and the axial length were significantly correlated with the gray density of the foveal image ($r=-0.70$, $P<0.0001$ and $r=-0.40$, $P<0.0001$). After excluding cases with indistinguishable foveal images (subcapsular opacities score ≥3.5, axial length ≥28.9 mm), the SS-OCT yielded 68% (95% confidence interval, 0.54–0.79) sensitivity and 87% (95% confidence interval, 0.78–0.92) specificity in 136 eyes.

Conclusions: Routine SS-OCT based biometric measurement for the evaluation of macular pathology simultaneously prior to cataract surgery is suggested except for patients with advanced cataract (posterior subcapsular opacities score ≥3.5) and long axial length (≥28.9 mm).

Keywords: Swept-source optical coherence tomography (SS-OCT); cataract; macular diseases

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Introduction

Cataracts remain the leading cause of blindness, and phacoemulsification with intraocular lens implantation is the common treatment of option (1). In recent decades, cataract surgery has made significant developments, which have evolved from sight rehabilitation surgery to refractive surgery. Therefore, a higher expectation of visual outcome is required with cataract surgery.

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Preoperative evaluation of macular disorders is crucial to predict postoperative visual outcomes. However, the preoperative identification of macular pathology could be affected by advanced cataract, high myopia, small pupil, etc. It should be noted that the incidence of cataract or macular diseases increases with age, reaching 70.5% and 25% in patients over 75 years of age, respectively (2,3). In addition, myopia, retinal dystrophy, uveitis, and diabetes can be complicated by cataracts and macular pathology (4). Spectral-domain optical coherence tomography analysis (SD-OCT) was suggested as a routine examination for the evaluation of macular pathology before cataract surgery (5). However, routine preoperative SD-OCT examination before standard cataract surgery may not be possible due to regional economic disparities between different levels of hospitals in China. The cost effectiveness of routine preoperative SD-OCT examination remains to be established (6).

New optical biometer such as the IOL Master 700 (Carl Zeiss Meditec AG, Jena, Germany) with swept-source optical coherence tomography (SS-OCT) based technology, which uses a small central macular scan to evaluate the patient's foveal fixation for quality control. In this case, the SS-OCT based optical biometer not only significantly improved the successful rate of the axial length measurement (7) but also made it possible to measure biometric data and screen macular structure simultaneously. Although the resolution of the foveal image obtained by SS-OCT is limited, 3 studies indicated that such foveal images improved the detection rate of macular disorders before cataract surgery (8-10). Combining SS-OCT based optical biometer and fundus biomicroscopy, the sensitivity rate for detection of macular disease improved from 36% to 63% (10). However, previous studies have excluded the non-interpretable SS-OCT scans without analyzing the reasons (8-10). The impact of lens opacities and axial lengths on macular disease screening using SS-OCT remained unknown.

Here, we attempted to evaluate the influence of lens opacities and axial lengths on foveal image quality detected by SS-OCT based optical biometer during preoperative biometry, as well as the sensitivity and specificity to detect macular diseases. We present the following article in accordance with the STARD reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-22-341/rc).

Methods

Ethics and patients

This study was conducted in accordance with the tenets of the Declaration of Helsinki (as revised in 2013) and was approved by the institutional research ethics committee of Zhongshan Ophthalmic Center, Sun Yat-sen University (No. 2019KYPJ124). The individual consent for this retrospective analysis was waived. This was a diagnostic accuracy study that retrospectively included patients who underwent preoperative cataract examinations at our hospital between November 2020 and June 2021. The sample size was set accordingly (11-13). The study aimed to have more than 50 patients with macular pathologies in order to analysis the diagnostic ability of SS-OCT. In this study, patients who underwent IOL Master 700 (Carl Zeiss Meditec AG, Jena, Germany) and SD-OCT (Spectralis, Heidelberg Engineering, Heidelberg, Germany) were included. Patients with low-quality SD-OCT images were excluded.

Study design

The basic clinical characteristics of the study participants, including age, sex, axial length, and visual acuity, were retrospectively collected from their medical records. A preoperative evaluation was performed on the same day, including visual acuity, slit lamp photograph, IOL Master 700, and SD-OCT. After pupil dilation, a slit lamp photograph was taken. The lens photography was graded according to the Lens Opacities Classification System III (LOCS-III).

Scan analysis

The IOL Master 700 detected a 1 mm × 1 mm central macular image based on an SS-OCT scan. The density of foveal image quality detected by SS-OCT was quantified using ImageJ (version 1.48, National Institutes of Health, Bethesda, MD, USA). The average gray value of the foveal image was measured. These foveal images were analyzed by an ophthalmologist who was blinded to the patient's medical history and SD-OCT results. Foveal images were classified as normal or pathological (definitely normal, probably normal, possibly normal, possibly pathological, probably pathological, or definitely pathological). A specific

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Table 1 Clinical characteristics of study participants

Characteristics	Mean ± SD or n (%)
Age (years)	66.43±11.41
Male	105 (46.9)
Axial length (mm)	25.19±3.22
UDVA before surgery (logMAR)	0.96±0.54
LOCS-III scores	
Nuclear opalescence	3.41±1.06
Cortical opacities	2.32±0.78
Posterior subcapsular opacities	2.74±1.14

SD, standard deviation; UDVA, uncorrected distance visual acuity; LOCS-III, Lens Opacities Classification System III.

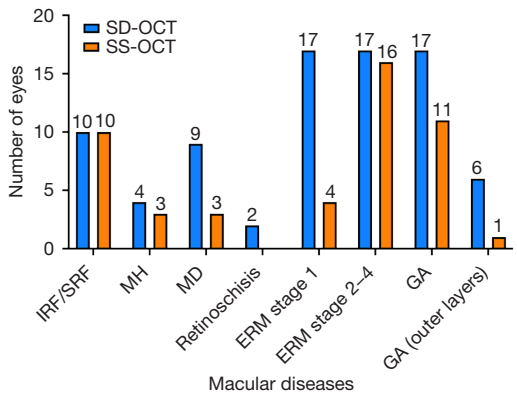

Figure 1 Distribution of macular diseases diagnosed with SD-OCT and SS-OCT. IRF/SRF, intraretinal fluid/subretinal fluid; MH, macular hole; MD, macular drusen; ERM, epiretinal macular membrane; GA, geographic atrophy; SD-OCT, spectral-domain optical coherence tomography; SS-OCT, swept-source optical coherence tomography.

macular pathological diagnosis was not needed due to the low resolution of each retinal layer. Examples of normal and pathological foveal images from an SS-OCT and SD-OCT were provided in Figure S1.

All SD-OCT scans were analyzed by a retina specialist who was blinded to the patient's medical history and the SS-OCT result. The retina specialist documented a specific diagnosis of macular pathology. Furthermore, the epiretinal membrane was graded according to a new OCT-based grading scheme (14). The epiretinal membrane present in the foveal pit and the well-defined retinal layers were defined as stage 1. Epiretinal membrane absence of foveal pit but present with well-defined retinal layers was defined as stage 2. Epiretinal membrane present with ectopic inner foveal layers was defined as stage 3. Epiretinal membrane has altered retinal layers, and ectopic inner foveal layers were defined as stage 4.

Statistical analysis

Statistical analysis was performed with SPSS statistics (version 26.0, Chicago, IL, USA). Visual acuity scores were converted to the logMAR. Descriptive data of the clinical characteristics were presented as mean and standard deviation (SD). Sensitivity, specificity, false positive rate (FPR), false negative rate (FNR), accuracy, positive predictive value (PPV), negative predictive value (NPV), and receiver operating characteristic (ROC) were calculated to evaluate foveal SS-OCT scans to detect macular disease. The ROC curve was created using a web-based calculator made by the Johns Hopkins University School of Medicine (http://www.jrocfit.org/). The fitted area under the ROC curve (AUC) indicates the diagnostic value of the test. Value of 0.5< AUC ≤0.7 indicates low diagnostic value of the test, while 0.7< AUC ≤0.9 indicates medium diagnostic value of the test. And AUC >0.9 indicates high diagnostic value of the test. Values of $P<0.05$ were considered statistically significant.

Results

A total of 224 eyes were enrolled in the study. The clinical characteristics of the study participants are summarized in *Table 1*. There were 105 men with a mean age of 66.43±11.41 years. The mean axial length was 25.19±3.22 mm, and the uncorrected distance visual acuity was 0.96±0.54 logMAR. The average scores of nuclear opalescence, cortical opacities, and posterior subcapsular opacities were 3.41±1.06, 2.32±0.78, and 2.74±1.14, respectively (*Table 1*).

Eighty-two eyes were diagnosed with macular disease using SD-OCT. SS-OCT had a low detection rate for macular drusen, retinoschisis, ERM stage 1, and geographic atrophies (outer layers), and half of the cases were missed (*Figure 1*). The 2 cases of retinoschisis were missed due to poor image quality. SS-OCT had a sensitivity of 59% (95% confidence interval, 0.47–0.71) and a specificity of 91% (95% confidence interval, 0.84–0.95) for the detection of macular pathology (*Table 2*).

The gray densities of the foveal image detected by the

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SS-OCT from 10 to 50 are presented in *Figure 2*. The foveal image was almost indistinguishable due to poor quality when the mean grayscale of the image was less than 40. The posterior subcapsular opacity score and axial length were significantly correlated with the gray density of the foveal image (r=–0.70, P<0.0001 and r=–0.40, P<0.0001) (*Figure 3*). According to linear regression analysis, the grayscale of the foveal image was less than 40 when the subcapsular opacity score was greater than 3.5 and the axial length was greater than 28.9 mm. After excluding these cases (subcapsular opacities score ≥3.5 and axial length ≥28.9 mm), the SS-OCT had a higher sensitivity of 68% with 95% confidence interval range from 0.54–0.79 (*Table 2*). According to the ROC curve, the fitted area under the ROC curve of the second analysis was larger than the first analysis (0.886 *vs.* 0.862), indicating a better detection rate (*Figure 4*).

Table 2 Evaluation the value of foveal SS-OCT scans for screening macular disease

Variable	Analyze 1 (n=224)	Analyze 2* (n=136)
Sensitivity (95% CI)	0.59 (0.47–0.71)	0.68 (0.54–0.79)
Specificity (95% CI)	0.91 (0.84–0.95)	0.87 (0.78–0.92)
Accuracy	0.79	0.79
False positive rate	0.09	0.13
False negative rate	0.21	0.19
Positive predictive value	0.79	0.77
Negative predictive value	0.79	0.81

*, posterior subcapsular opacities <3.5, AL <28.9 mm. SS-OCT, swept-source optical coherence tomography; 95% CI, 95% confidence interval; AL, axial length.

Discussion

The importance of detecting macular diseases before cataract surgery was highlighted, as there are now greater expectations of visual outcomes. However, routine preoperative SD-OCT examination before standard cataract surgery may not be possible due to cost effectiveness and regional economic disparities between hospitals of different levels. The SS-OCT based optical

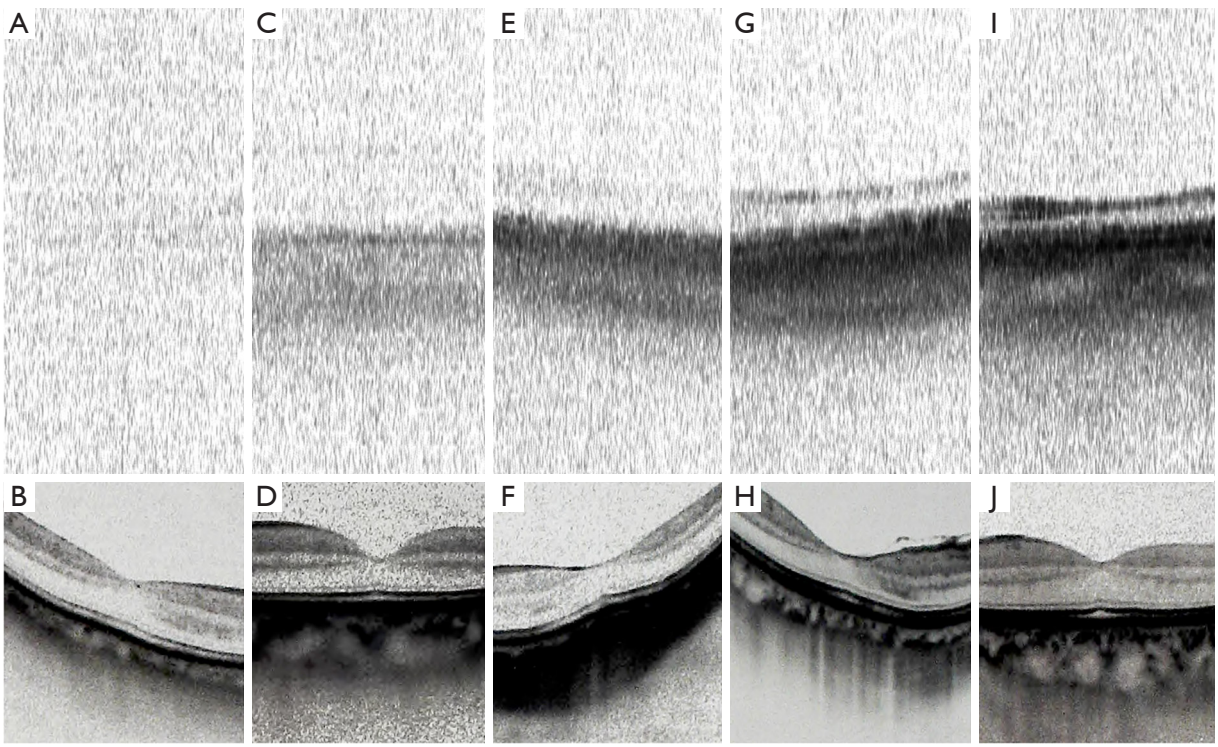

Figure 2 Comparison of the foveal image of SS-OCT with different gray densities and SD-OCT. The average gray density of SS-OCT is 10 (A), 20 (C), 30 (E), 40 (G), and 50 (I), respectively. The images below are the corresponding SD-OCT (B,D,F,H,J). SS-OCT, swept-source optical coherence tomography; SD-OCT, spectral-domain optical coherence tomography.

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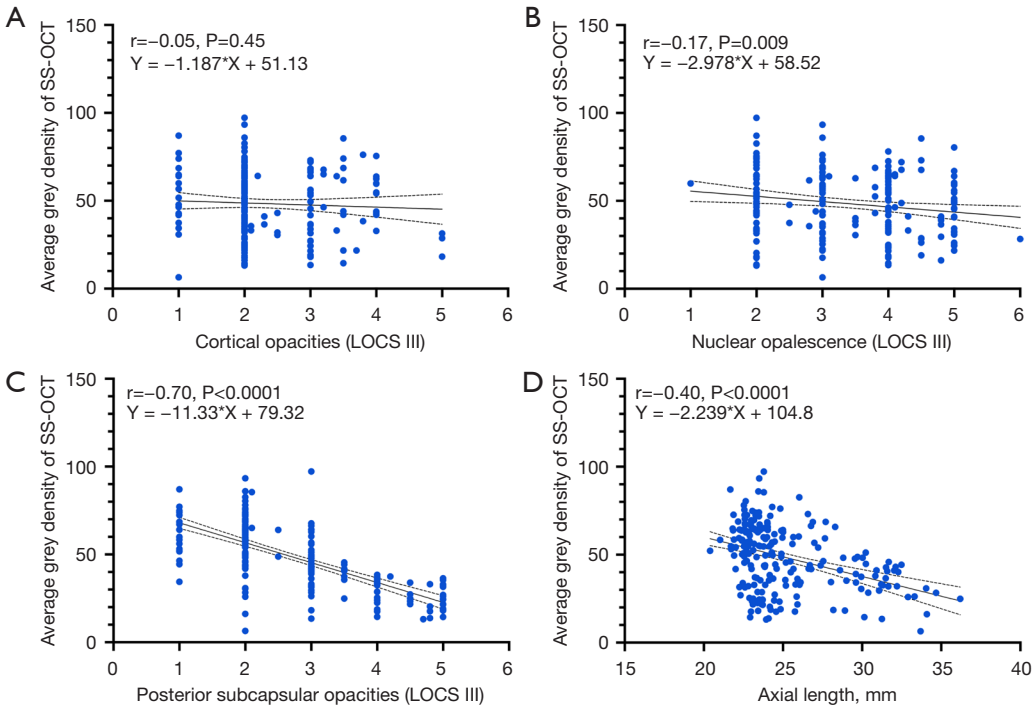

Figure 3 Correlations of LOCS-III scores and axial length with gray density of the foveal image. (A) Cortical opacity scores; (B) nuclear opalescence scores; (C) posterior subcapsular opacity scores; (D) axial length. SS-OCT, swept-source optical coherence tomography; LOCS-III, Lens Opacities Classification System III.

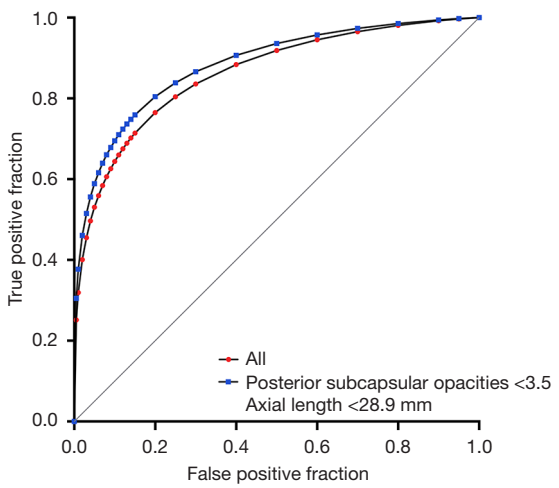

Figure 4 The ROC curve for SS-OCT. The red line was calculated using all eyes enrolled in the study, while the blue line was calculated after excluding cases with a subcapsular opacities score ≥3.5 and axial length ≥28.9 mm. ROC, receiver operating characteristic; SS-OCT, swept-source optical coherence tomography.

biometer allows one to measure biometric data and macular structure simultaneously, and our study indicated that the SS-OCT based optical biometer is a valuable tool for the detection of macular disease before cataract surgery with a sensitivity of 0.68 and a specificity of 0.87. Regarding patients with posterior subcapsular opacity scores greater than 3.5 or AL greater than 28.9 mm, preoperative SD-OCT was recommended, as the density of the foveal image detected by SS-OCT was too low to be recognized.

Bertelmann *et al.* (15) first evaluated the repeatability and precision of the central retinal thickness measured by SS-OCT compared to SD-OCT, which revealed the feasibility of optical biometer with SS-OCT as a macular disease screening method. Two studies had evaluated the value of using SS-OCT for the detection of macular disease, and one study further demonstrated that compared to fundus biomicroscopy, SS-OCT significantly improved the detection of macular disease in cataract patients (10). The sensitivity and specificity rates of SS-OCT were reported

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to range from 63–83% and 72–89%, respectively (5,9,10). Similarly, SS-OCT had a sensitivity of 68% and a specificity of 87% to detect macular pathology in our study. It is worth noting that SS-OCT had a lower sensitivity of 59% and a specificity of 91% when cases with subcapsular opacity score ≥3.5 and axial length ≥28.9 mm were included. These data indicated that the extent and location of lens opacity or ocular axial lengths influence the macular disease detection by SS-OCT based optical biometer.

To date, no research has evaluated the impact of lens opacities and axial lengths on macular disease detection using SS-OCT based optical biometer. By quantifying the grayscale of the foveal image, the posterior subcapsular opacity score and the axial length were found to be significantly correlated with the gray density of the foveal image. The foveal image was almost indistinguishable when the mean grayscale of the image was less than 40 (correlated with the subcapsular opacity score ≥3.5 and axial length ≥28.9 mm). Recent updates of SD-OCT enabled clinicians to obtain qualified macular morphology images of patients with advanced cataracts (posterior subcapsular opacities score ≥3.5) and long axial lengths (≥28.9 mm). It is worth noting that macular pathology, including retinal dystrophy, uveitis, and diabetes, can be complicated with posterior subcapsular cataracts (4,16). High myopia, whose axial length is longer than 30 mm, is often complicated by macular diseases (17). A recent study indicated that adjunctive screening for SD-OCT is cost effective for patients considering implantation of a multifocal intraocular lens, as approximately 20.5% of patients may have macular disease, of which 11% may be neglected without SD-OCT (18). Therefore, SD-OCT is suggested to evaluate macular pathology prior to cataract surgery for patients with advanced cataract (posterior subcapsular opacity score ≥3.5) and long axial length (≥28.9 mm).

Consistent with previous studies, macular pathologies, including intraretinal fluid, subretinal fluid, macular holes, and epiretinal membrane stage 2–4, had a high predictability rate using SS-OCT based optical biometer (5,9,10). The surgical approach could change depending on the detection of these macular pathologies. For macular holes and epiretinal membrane stage 2–4, combined cataract and vitrectomy surgery can be performed instead of cataract surgery alone (19-21). In addition, intravitreal anti-vascular endothelial growth factor injections were suggested to be combined with cataract surgery in patients with diabetic macular edema (22,23).

However, low predictability was observed for macular drusen, retinoschisis, epiretinal membrane stage 1, and geographic atrophies. Macular drusen smaller than 125 μm was found to be difficult to detect using SS-OCT (8). Retinoschisis is a myopic traction maculopathy. Patients with retinoschisis might have a long axial length, leading to poor foveal image quality and a low detection rate (24). Epiretinal membrane stage 1 is difficult to detect with SS-OCT, as the foveal pit and retinal layers remain well defined (14). Regarding geographic atrophies, a severe reduction can be detected in all layer thicknesses of the retina. Mild or outer layer retinal atrophy was often missed due to the low resolution of SS-OCT. It is worth noting that changes in the outer layers [especially the photoreceptor inner segment/outer segment (IS/OS) junction line] of the retina observed in SD-OCT have been shown to be helpful in evaluating whether the cone photoreceptors have degenerated or not, which is closely correlated with postoperative visual function (25). Therefore, SS-OCT cannot replace SD-OCT detection, although SS-OCT provides additional value for detecting macular pathology prior to cataract surgery.

In conclusion, SS-OCT based optical biometer is an effective screening method to detect macular pathology and measure biometric data simultaneously. Routine SS-OCT based biometric measurement for the evaluation of macular pathology simultaneously prior to cataract surgery is suggested except for advanced cataract (posterior subcapsular opacities score ≥3.5) and long axial length (≥28.9 mm). SD-OCT is needed to confirm the macular pathology detected by SS-OCT.

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Footnote

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-22-341/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the institutional research ethics committee of Zhongshan Ophthalmic Center, Sun Yat-sen University (No. 2019KYPJ124) and individual consent for this retrospective analysis was waived.

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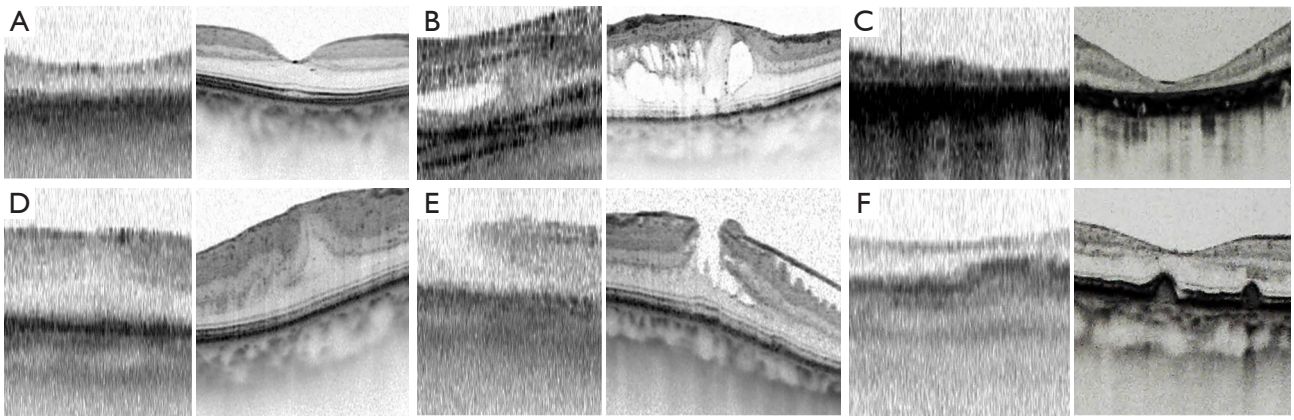

Figure S1 Comparison of the foveal image between SS-OCT (left) and SD-OCT (right). (A) Normal macular; (B) intraretinal fluid; (C) geographic atrophy; (D) epiretinal macular membrane; (E) lamellar macular hole; (F) macular drusen. SS-OCT, swept-source optical coherence tomography; SD-OCT, spectral-domain optical coherence tomography.

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