• Clinical Research •

Comparative study between swept-source and spectral-domain OCTA for imaging of choroidal neovascularization in age-related macular degeneration

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Abstract

● **AIM:** To compare the differences of choroidal neovascularization (CNV) measurements between swept-source and spectral-domain optical coherence tomography angiography (SS-OCTA and SD-OCTA) in neovascular age-related macular degeneration (nAMD) and the imaging reliability of the two devices.

● **METHODS:** Prospective comparative study. SS-OCTA and SD-OCTA were used to scan the same eye with the modes of 3×3 and 6×6 mm^2 centered on the neovascularization. Only qualified images were chosen and the border of CNV was manually delineated by two graders independently. The area of CNV (ACNV), vascular perfusion density (PD), and vessel length density (VLD) within the delineation were calculated using Image J. The differences of CNV measurements between the two OCTA devices were compared using Bland-Altman analysis. The agreement between the two graders on the measurements of each device was compared using the intraclass correlation coefficient (ICC).

● **RESULTS:** A total of 18 patients (22 eyes) with nAMD were included. The measurements of ACNV, PD, and VLD were 7.247±4.586 and 4.901±3.741 mm^2, 43.202±9.636 and 34.904±10.489, 6.339±1.228 and 5.908±1.741 mm^{-1} for SS-OCTA and SD-OCTA, respectively. The differences between the two devices were 2.346±3.030 mm^2 (Z=-3.782, P<0.0001), 8.298±14.160 (Z=-2.419, P=0.016), and 0.431±2.114 mm^{-1} (Z=-0.828, P=0.408) for ACNV, PD and VLD, respectively. The ICC between two graders were 0.893 (P<0.001), 0.902 (P<0.001), 0.885 (P<0.001) for ACNV, PD, VLD in SS-OCTA, and 0.971 (P<0.001), 0.976 (P<0.001), 0.973 (P<0.001) in SD-OCTA, respectively.

● **CONCLUSION:** Both OCTA devices have high imaging reliability. Compared with SD-OCTA, SS-OCTA has a larger ACNV measurements, but doesn't show better resolution of internal vessels of CNV and well signal strength.

● **KEYWORDS:** neovascular age-related macular degeneration; swept-source; spectral-domain; optical coherence tomography angiography

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INTRODUCTION

Age-related macular degeneration (AMD) is the leading cause of irreversible blindness in people over the age of 50. Neovascular age-related macular degeneration (nAMD) is an important subtype of advanced AMD characterized by the formation and development of choroidal neovascularization (CNV). This often leads to severe irreversible visual impairment without intervention[1-3]. At present, the diagnosis of CNV still relies on fundus fluorescein angiography (FFA) and indocyanine green angiography (ICGA). However, both FFA and ICGA are invasive methods that require intravenous dye and 10-30min to complete the imaging process, additionally, the dye may carry the risk of serious allergic reactions. Compared with FFA and ICGA, one of the advantages of optical coherence tomography angiography (OCTA) is that it can quantitatively observe the changes of retinal and choroidal microvasculature[4]. Therefore, for

progressive diseases such as AMD, regular monitoring of the retinal and choroidal vasculatures are required[5].

Although it has only been 10y since OCTA was commercially launched in 2014, numerous studies have demonstrated the application of OCTA in various eye diseases, such as CNV, AMD, diabetic retinopathy (DR), retinal vascular occlusions, retinal vasculitis[6]. In recent years, OCTA has largely emerged as an alternative imaging method for retinal and choroidal vasculatures[7]. It has been reported that OCTA has a high diagnostic value for active CNV, and its diagnostic accuracy is independent of device type and algorithm. In some studies, OCTA has even shown greater specificity than fluorescence angiography[8-9]. OCTA is a rapid, non-invasive, dye-free, and high-resolution diagnostic test, that provides qualitative and quantitative information about retinal and choroid circulation. OCTA images retinal vasculature by calculating changes in signal strength and/or phase characteristics, caused by red blood cells movement during two consecutive OCT scans at the same location[10-12]. At present, OCTA can be divided into two categories: spectral-domain OCTA (SD-OCTA) and swept-source OCTA (SS-OCTA). SD-OCTA has a working wavelength of 840 nm, the scanning speed is 68 000-70 000 times/s, and the scanning depth is 1.8-2.2 mm. Due to the back-scattering of the retinal pigment epithelium (RPE)-Bruch membrane complex, the imaging of the structures under the RPE is blurred, and the sensitivity gradually decreases with the increase in depth. On the other hand, SS-OCTA has a working wavelength of 1050 nm and a scanning speed of 100 000-200 000 times/s. Due to its longer wavelength, it can penetrate deeper tissues (2.6-3.0 mm) and is not easily affected by the transparency of refractive media. Moreover, SS-OCTA has higher sensitivity and lower signal-to-noise ratio in deep tissues. Therefore, SS-OCTA can better overcome the imaging barrier formed by RPE pigments[10], which makes SS-OCTA superior to SD-OCTA in obtaining the structural and blood flow information of deep choroid tissues[13-16].

There have been studies comparing the differences between the two OCTA devices in measuring the area of CNV (ACNV), but the SS-OCTA used was mostly Zeiss PLEX Elite 9000 (scanning speed of 100 000 times/s)[12,17-19] or the SS-OCTA which was only used for scientific research (scanning speed of 400 000 times/s)[20-21]. There has been no report on the comparison between SS-OCTA (scanning speed of 200 000 times/s), which has been used in clinical practice, and the current mainstream SD-OCTA.

In this regard, this study will compare the differences in the measurement results of nAMD-related CNV between SS-OCTA and SD-OCTA, and the reliability of the imaging of the two devices.

SUBJECTS AND METHODS

Ethical Approval This comparative study prospectively enrolled patients with nAMD from April 2021 to June 2021 at the First Affiliated Hospital of Xi'an Jiaotong University. All participants gave written informed consent. The study was approved by the Institutional Ethical Review Board of First Affiliated Hospital of Xi'an Jiaotong University and conducted in accordance with the Tenets of the Declaration of Helsinki.

Inclusion and Exclusion Criteria for Participants The inclusion criteria were as follows: 1) No other eye diseases except nAMD; 2) Participants were informed and agreed to participate in the study. The exclusion criteria included: 1) Unable to cooperate with the examination due to the bad fixed vision; 2) Poor quality of OCTA images due to the opacity of the refractive medium.

Ophthalmic Examination All subjects received a comprehensive ophthalmic examination. OCTA images were obtained by SD-OCTA (Cirrus 5000 HD-OCT, Dublin, Germany) and SS-OCTA (VG200D, SVision Imaging, Ltd., Luoyang, China), respectively. OCTA images in 3×3 and 6×6 mm^2 scanning modes were obtained with the neovascularization as the center. Each eye was scanned 2-3 times with two OCTA devices, and images with clear neovascular lesions, no scanning line of sight, and signal strength (SS) ≥6 were taken for analysis.

Images Processing and Analysis OCTA images in 6×6 mm^2 scanning mode were selected for processing and calculation with Image J (2.1.0/1.53C). The specific processes were as follows: 1) Match the images of the two devices (Figure 1A and 1B), so that the spatial positions of the images of the blood vessels in the same eye on different devices were completely consistent, and the average pixel values were consistent; 2) Since the outer retinal and choroidal capillary (ORCC) layer of SS-OCTA cannot automatically remove the projection artifacts of superficial large blood vessels, we first automatically segmented larger blood vessels based on the superficial vascular network of SS-OCTA as described in detail previously[22], and then cut the large blood vessels from the ORCC layer (Figure 1C). The ORCC layer of SD-OCTA has its own de-projection artifact processing (Figure 1D); 3) All the selected images were independently read by two graders, and the range of CNV were marked in the ORCC layer images after the above preprocessing (Figure 2A-2D); 4) Denoising and binarization were performed on the images (Figure 2E-2H), and then skeletonization was performed on this basis (Figure 2I-2L); 5) Calculation: ACNV (mm^2); perfusion density (PD), defined as the ratio of blood flow signal coverage area to demarcated area (based on vascular binarization diagram, %); vessel length density (VLD), defined as the ratio

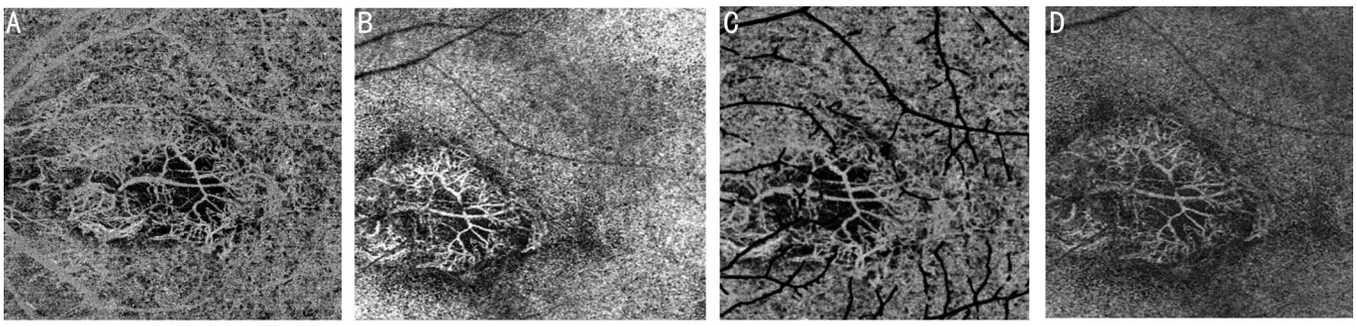

Figure 1 Optical coherence tomography angiography images A-B: Original images obtained by SS-OCTA (A) and SD-OCTA (B); C-D: Uniformity processing of images obtained by SS-OCTA (C) and SD-OCTA (D). SS-OCTA: Swept-source optical coherence tomography angiography; SD-OCTA: Spectral-domain optical coherence tomography angiography.

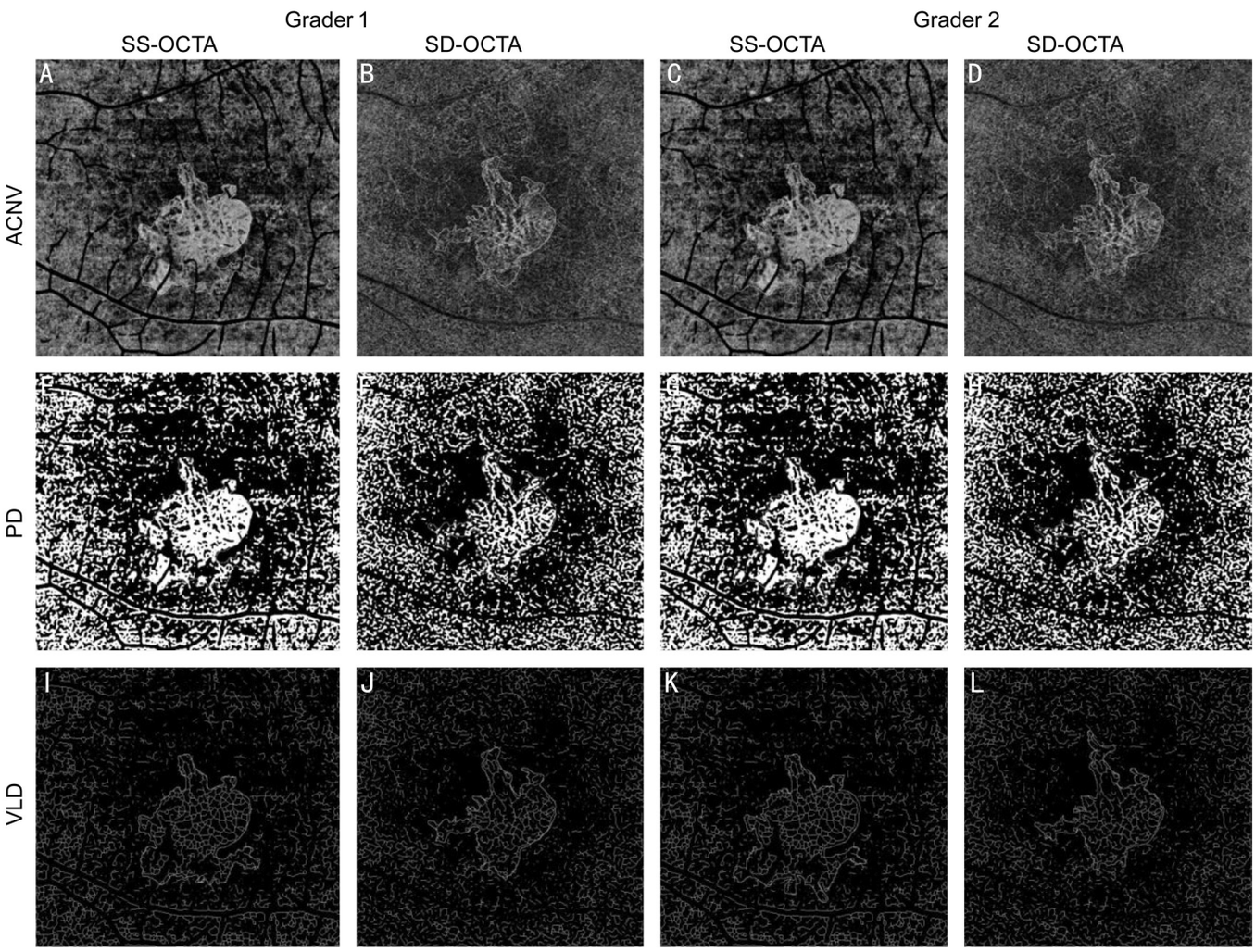

Figure 2 Choroidal neovascularization marker images from grader 1 and grader 2 A-D: Images of ACNV; E-H: Images of PD; I-L: Images of VLD. SS-OCTA: Swept-source optical coherence tomography angiography; SD-OCTA: Spectral-domain optical coherence tomography angiography; CNV: Choroidal neovascularization; ACNV: Area of choroid neovascularization; PD: Perfusion density; VLD: Vessel length density.

of vessel signal length to calibration area (based on vascular skeletonization diagram, mm^{-1}).

Statistical Analysis Data was statistically analyzed using GraPhPad Prism9 (GraphPad Software, La Jolla, CA, USA) and SPSS23.0 (IBM, SPSS statistics, version 23; Inc, Armonk, NY, USA). All values were expressed as mean±standard deviation. Normality of data was checked using Shapiro-Wilk test. The difference of CNV measured between the two OCTA devices was compared by paired *t*-test, non-parametric test and Bland-Altman analysis. The consistency of the two graders was compared using intraclass correlation coefficient (ICC), bidirectional mixed effect model, and 95% confidence interval (CI) of absolute consistency. ICC ranges from 0 to 1. It is generally believed that ICC<0.4 indicates poor consistency, and ICC>0.75 indicates high consistency. Statistical difference was considered significant at $P<0.05$.

Table 1 Reproducibility of CNV measurements between two graders

Parameters	ACNV		PD		VLD	
	SS-OCTA[a]	SD-OCTA[a]	SS-OCTA[a]	SD-OCTA[a]	SS-OCTA[a]	SD-OCTA[a]
ICC	0.893	0.971	0.902	0.976	0.885	0.973
95%CI	0.764-0.954	0.932-0.988	0.782-0.958	0.944-0.990	0.748-0.950	0.938-0.989
P_{ICC}	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

SS-OCTA: Swept-source optical coherence tomography angiography; SD-OCTA: Spectral-domain optical coherence tomography angiography; CNV: Choroidal neovascularization; ACNV: Area of choroid neovascularization; PD: Perfusion density; VLD: Vessel length density; ICC: Intraclass correlation coefficient; CI: Confidence interval. [a]Non-normal distribution, Wilcoxon signed rank test (*Z* value) was used for comparison.

RESULTS

Demographics of Participants A total of 26 nAMD patients (33 eyes) were collected, 11 eyes were excluded due to the SS of <6 and significant artifacts on the OCTA images. A total of 18 nAMD patients (22 eyes) included for the analysis. There were 13 males and 5 females with an average age of 67.22±10.77y.

OCTA Images Signal Strength Analysis In mode 3×3 mm^2, the mean signal strength of SS-OCTA and SD-OCTA were 8.318±1.041 and 9.045±1.090, respectively, and the difference between the two devices was 0.727±1.316 (*Z*=-2.312, *P*=0.021). In mode 6×6 mm^2, the mean SS of SS-OCTA and SD-OCTA were 8.409±1.182 and 9.091±1.019, respectively, and the difference between the two devices was 0.682±1.427 (*Z*=-2.040, *P*=0.041), as shown in Figure 3.

Reproducibility of Choroidal Neovascularization Measurements Between Two Graders In mode 6×6 mm^2 of SS-OCTA, the difference between grader 1 and grader 2 were 0.473±2.177 mm^2 (*Z*=-0.487, *P*=0.626), 0.769±4.405 (*Z*=-0.974, *P*=0.330), and 0.129±0.606 mm^{-1} (*Z*=-1.088, *P*=0.277), for ACVN, PD and VLD, respectively. And in mode 6×6 mm^2 of SD-OCTA, the difference between grader 1 and grader 2, were 0.094±0.925 mm^2 (*Z*=-0.295, *P*=0.768), 0.330±2.333 (*Z*=-0.747, *P*=0.455), 0.080±0.406 mm^{-1} (*Z*=-0.991, *P*=0.322), for ACVN, PD, VLD, respectively (Figure 4). ICC between graders were 0.893 (95%CI, 0.764-0.954), 0.902 (95%CI, 0.782-0.958), and 0.885 (95%CI, 0.748-0.950), for ACNV, PD, and VLD in SS-OCTA, respectively. On the other hand, in SD-OCTA, the ICC between graders were 0.971 (95%CI, 0.932-0.988), 0.976 (95%CI, 0.944-0.990), and 0.973 (95%CI, 0.938-0.989), for ACNV, PD, and VLD, respectively (Table 1).

Comparison of Choroidal Neovascularization Measurements Between SS-OCTA and SD-OCTA In mode 6×6 mm^2, the mean ACNV, PD, VLD (averaging values from the two graders) were 7.247±4.586 and 4.901±3.741 mm^2, 43.202±9.636 and 34.904±10.489, 6.339±1.228 and 5.908±1.741 mm^{-1}, for SS-OCTA and SD-OCTA, respectively. And the differences between SS-OCTA and SD-OCTA were 2.346±3.030 mm^2 (*Z*=-3.782, *P*<0.0001), 8.298±14.160 (*Z*=-2.419, *P*=0.016), 0.431±2.114 mm^{-1} (*Z*=-0.828, *P*=0.408), for ACVN, PD, VLD, respectively (Table 2). Figure 5 illustrated the differences between SS-OCTA and SD-OCTA in ACNV, PD, and VLD by Bland-Altman plots.

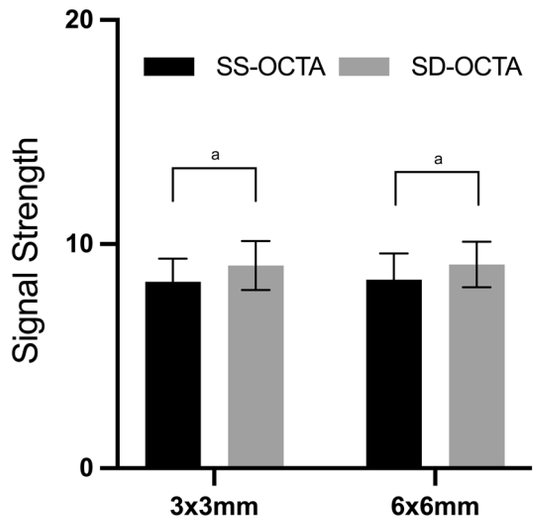

Figure 3 Comparison of images signal strength between SS-OCTA and SD-OCTA SS-OCTA: Swept-source optical coherence tomography angiography; SD-OCTA: Spectral-domain optical coherence tomography angiography. [a]*P*<0.05.

Table 2 Comparison of CNV measurements between SS-OCTA and SD-OCTA mean±SD

Parameters	ACNV (mm^2)[a]	PD (%)[a]	VLD (mm^{-1})[a]
SS-OCTA	7.247±4.586	43.202±9.636	6.339±1.228
SD-OCTA	4.901±3.741	34.904±10.489	5.908±1.741
Z	-3.782	-2.419	-0.828
P	<0.0001	0.016	0.408

SS-OCTA: Swept-source optical coherence tomography angiography; SD-OCTA: Spectral-domain optical coherence tomography angiography; CNV: Choroidal neovascularization; ACNV: Area of choroid neovascularization; PD: Perfusion density; VLD: Vessel length density. [a]Non-normal distribution, Wilcoxon signed rank test (*Z* value) was used for comparison.

DISCUSSION

OCTA is a newer, non-invasive technique that rapidly visualizes the retinal and choroidal vasculatures through "motion contrast", which helps to understand the microvascular changes that occur in retinal and choroidal vasculatures[23-24]. Since the introduction of the first commercial OCTA in 2014, OCTA has rapidly demonstrated its superiority in the clinical management

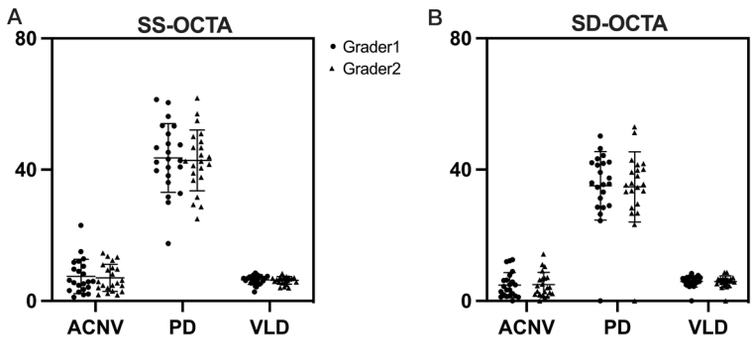

Figure 4 Comparison of CNV measurements between two graders in SS-OCTA and SD-OCTA A: The scatter plot displayed the difference of CNV measurements between two graders in SS-OCTA; B: The scatter plot displayed the difference of CNV measurements between two graders in SD-OCTA. SS-OCTA: Swept-source optical coherence tomography angiography; SD-OCTA: Spectral-domain optical coherence tomography angiography; CNV: Choroidal neovascularization; ACNV: Area of choroid neovascularization; PD: Perfusion density; VLD: Vessel length density.

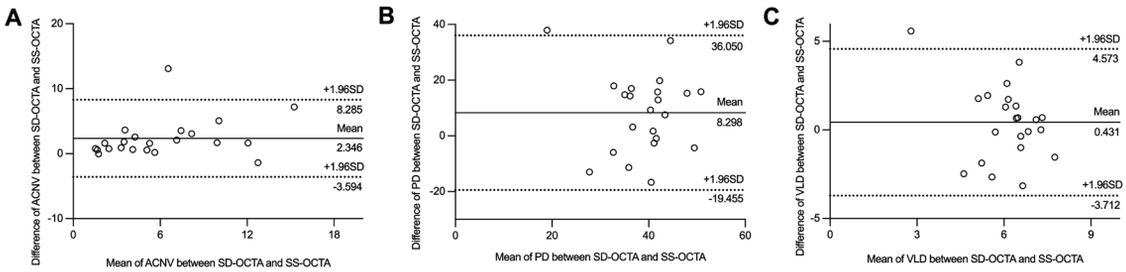

Figure 5 Bland-Altman plots shown the differences between SS-OCTA and SD-OCTA in ACNV, PD, and VLD A: Bland-Altman plots of ACNV; B: Bland-Altman plots of PD; C: Bland-Altman plots of VLD. SS-OCTA: Swept-source optical coherence tomography angiography; SD-OCTA: Spectral-domain optical coherence tomography angiography; ACNV: Area of choroid neovascularization; PD: Perfusion density; VLD: Vessel length density.

of multiple chorioretinal diseases, including AMD, DR, myopic degeneration, and different types of CNV[10,25]. Some studies have shown that OCTA will be able to locate the site of feeder vessels derived from the choroid or breaking through the Bruch membrane, and provide quantitative assessment of vascular density, vascular connectivity, which may provide new insights into the pathogenesis of CNV[26]. Compared with traditional two-dimensional angiography, OCTA can perform three-dimensional imaging of the retinal and choroidal vasculatures and provide corresponding data, which makes the location of lesions more precise. At present, OCTA has become the most commonly used retreatment imaging method for patients with nAMD, with a diagnostic sensitivity of 85% for active nAMD[13,23].

In recent years, some studies had compared the measurement difference of CNV secondary to nAMD in SS-OCTA and SD-OCTA, and the results were as follows. Several studies[12,20-21] showed that SS-OCTA could measure larger and more accurate ACNV than SD-OCTA. Miller *et al*[18] further compared the difference of ACNV measurements between SS-OCTA and SD-OCTA in 3×3 mm and 6×6 mm modes, and the results showed that the difference of ACNV measurements between the two OCTA devices were more pronounced in 6×6 mm model. Cicinelli *et al*[17] compared the differences of ACNV measurements among SS-OCTA, SD-OCTA and ICGA, they found that the ACNV measurements measured by both OCTA devices were smaller than ICGA, however, SS-OCTA showed better CNV than SD-OCTA. Zhang *et al*[19] used their self-developed automatic algorithm to quantify the ACNV and compared it with the manual measurement. They found that the ACNV measured by the automatic algorithm was consistent with the manual measurement, and the automatic and manual measurement values of ACNV by SS-OCTA were both greater than those measured by SD-OCTA. There were two main types of SS-OCTA used in the above studies. One was the SS-OCTA with a scanning speed of 100 000 scans per second by Zeiss and the other SS-OCTA with a scanning speed of 400 000 scans per second, which was only used for scientific research and independently developed by the laboratory. There were no reports on SS-OCTA and related studies with a scanning speed of 200 000 times per second, which has started to enter the clinic. Therefore, our study compared the differences of CNV measurements between the SS-OCTA, which has a scanning speed of 200 000 times/s, and the current mainstream SD-OCTA in 6×6 mm scanning mode.

We first analyzed the reliability of SS-OCTA and SD-OCTA for CNV measurements. Therefore, we compared the consistency of CNV measurements in the same OCTA

between two graders. The higher the consistency, the better the reliability of CNV measurements. In our results, the ICC of ACNV, PD, and VLD between the two graders in SS-OCTA and SD-OCTA were all greater than 0.75 (all P<0.001). This result indicated that both OCTA devices used in this study had relatively high reliability in imaging of CNV, and the CNV measurements of the two graders had high consistency. On this basis, we further compared the differences in CNV measurements of the two OCTA devices in 6×6 mm scanning mode. The difference of ACNV between SS-OCTA and SD-OCTA was 2.346±3.030 mm^2 (P<0.0001), which indicated that SS-OCTA could measure larger ACNV compared with SD-OCTA. This was also consistent with the results of previous studies. Furthermore, we compared the differences of the two OCTA devices on the internal blood vessels of CNV, and the differences of PD and VLD between SS-OCTA and SD-OCTA were 8.298±14.160 (P=0.014) and 0.431±2.114 mm^{-1} (P=0.425), respectively. Our results showed that SS-OCTA measured a larger proportion of ACNV, however it did not segment a larger number of vessels. This indicated that SS-OCTA was not significantly superior to SD-OCTA in terms of resolution of internal vessels of CNV. It was also found in this study that the signal strength of SD-OCTA was significantly higher than that of SS-OCTA (P<0.05) in both 3×3 and 6×6 mm scanning modes for the same eye, which to compensated for the deficiencies in scanning depth and scanning speed of SD-OCTA. This may also explain that although SD-OCTA measured less of ACVN and PD than SS-OCTA, there was no significant difference in VLD.

With the continuous improvement of OCTA image quality, the detection rate of neovascularization has gradually increased in recent years. It has been pointed out in the literature that the detection rate of neovascularization in SD-OCTA was between 32% and 87%, and that in SS-OCTA was between 75% and 94%[27]. At present, SS-OCTA with 200 000 times per second has been used in clinical practice, and will gradually become the mainstream of clinical application in the future. With the further improvement of SS-OCTA technology, the high-frequency SS-OCTA of 400 000 times per second will not be limited to the laboratory, which will help us obtain more detailed quantitative data of retinal and choroidal vasculatures in the clinic.

This study also has some limitations, mainly due to the small sample size. At this time, this study was the first to compare the difference of CNV measurements between SS-OCTA with scanning speed of 200 000 times per second and mainstream SD-OCTA, it was only an exploratory study, and further studies with larger sample size were needed for verification. In addition, we did not compare the SS-OCTA (VG200D, SVision Imaging, Ltd., China) with the mainstream SS-OCTA. Therefore, our next study will compare the difference in CNV measurements between this SS-OCTA and the mainstream SS-OCTA.

In conclusion, our study found that SS-OCTA could detect more ACNV than SD-OCTA, but did not show better resolution of internal vessels of CNV and well signal strength.

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REFERENCES

1 Gheorghe A, Mahdi L, Musat O. Age-related macular degeneration. *Rom J Ophthalmol* 2015;59(2):74-77.

2 Roh M, Miller JW, Jeng-Miller KW, Wang JC, Laíns I, Silverman RF, Loewenstein JI, Husain D, Vavvas DG, Miller JB. Subthreshold exudative choroidal neovascularization associated with age-related macular degeneration identified by optical coherence tomography angiography. *J Vitreoretin Dis* 2020;4(5):377-385.

3 Vira J, Marchese A, Singh RB, Agarwal A. Swept-source optical coherence tomography imaging of the retinochoroid and beyond. *Expert Rev Med Devices* 2020;17(5):413-426.

4 Ahn SM, Choi M, Yun C, Kim SW, Oh J. Changes on optical coherence tomography angiography and fluorescein angiography in eyes with neovascular age-related macular degeneration. *Int J Ophthalmol* 2022;15(11):1837-1844.

5 Chen CX, Liu ML, Cao K, Yusufu M, Wang JD. Diagnostic value of optical coherence tomography angiography for choroidal neovascularization in age-related macular degeneration: a systematic review and meta-analysis. *Ophthalmic Res* 2021;64(5):704-712.

6 Koutsiaris AG, Batis V, Liakopoulou G, Tachmitzi SV, Detorakis ET, Tsironi EE. Optical coherence tomography angiography (OCTA) of the eye: a review on basic principles, advantages, disadvantages and device specifications. *Clin Hemorheol Microcirc* 2023;83(3):247-271.

7 Ahmed D, Stattin M, Graf A, Forster J, Glittenberg C, Krebs I, Ansari-Shahrezaei S. Detection of treatment-naive choroidal neovascularization in age-related macular degeneration by swept source optical coherence tomography angiography. *Retina* 2018;38(11):2143-2149.

8 Kalra G, Zarranz-Ventura J, Chahal R, Bernal-Morales C, Lupidi M, Chhablani J. Optical coherence tomography (OCT) angiolytics: a review of OCT angiography quantitative biomarkers. *Surv Ophthalmol* 2022;67(4):1118-1134.

9 Wang M, Gao S, Zhang Y, Zhang M. Sensitivity and specificity of optical coherence tomography angiography in the diagnosis of active

choroidal neovascularization: a systematic review and meta-analysis. *Graefes Arch Clin Exp Ophthalmol* 2021;259(12):3529-3536.

10 Laíns I, Wang JC, Cui Y, Katz R, Vingopoulos F, Staurenghi G, Vavvas DG, Miller JW, Miller JB. Retinal applications of swept source optical coherence tomography (OCT) and optical coherence tomography angiography (OCTA). *Prog Retin Eye Res* 2021;84:100951.

11 Lavinsky F, Lavinsky D. Novel perspectives on swept-source optical coherence tomography. *Int J Retina Vitreous* 2016;2:25.

12 Mastropasqua R, Evangelista F, Amodei F, D'Aloisio R, Pinto F, Doronzo E, Viggiano P, Porreca A, di Nicola M, Parravano M, Toto L. Optical coherence tomography angiography in macular neovascularization: a comparison between different OCTA devices. *Transl Vis Sci Technol* 2020;9(11):6.

13 Schneider EW, Fowler SC. Optical coherence tomography angiography in the management of age-related macular degeneration. *Curr Opin Ophthalmol* 2018;29(3):217-225.

14 Su GL, Baughman DM, Zhang Q, Rezaei K, Lee AY, Lee CS. Comparison of retina specialist preferences regarding spectral-domain and swept-source optical coherence tomography angiography. *Clin Ophthalmol* 2017;11:889-895.

15 Wang F, Zhang Q, Deegan AJ, Chang J, Wang RK. Comparing imaging capabilities of spectral domain and swept source optical coherence tomography angiography in healthy subjects and central serous retinopathy. *Eye Vis (Lond)* 2018;5:19.

16 Wong CW, Yanagi Y, Lee WK, Ogura Y, Yeo I, Wong TY, Cheung CMG. Age-related macular degeneration and polypoidal choroidal vasculopathy in Asians. *Prog Retin Eye Res* 2016;53:107-139.

17 Cicinelli MV, Cavalleri M, Consorte AC, Rabiolo A, Sacconi R, Bandello F, Querques G. Swept-source and spectral domain optical coherence tomography angiography versus dye angiography in the measurement of type 1 neovascularization. *Retina* 2020;40(3):499-506.

18 Miller AR, Roisman L, Zhang Q, *et al*. Comparison between spectral-domain and swept-source optical coherence tomography angiographic imaging of choroidal neovascularization. *Invest Ophthalmol Vis Sci* 2017;58(3):1499-1505.

19 Zhang Q, Chen CL, Chu Z, Zheng F, Miller A, Roisman L, Rafael de Oliveira Dias J, Yehoshua Z, Schaal KB, Feuer W, Gregori G, Kubach S, An L, Stetson PF, Durbin MK, Rosenfeld PJ, Wang RK. Automated quantitation of choroidal neovascularization: a comparison study between spectral-domain and swept-source OCT angiograms. *Invest Ophthalmol Vis Sci* 2017;58(3):1506-1513.

20 Novais EA, Adhi M, Moult EM, Louzada RN, Cole ED, Husvogt L, Lee B, Dang S, Regatieri CV, Witkin AJ, Baumal CR, Hornegger J, Jayaraman V, Fujimoto JG, Duker JS, Waheed NK. Choroidal neovascularization analyzed on ultrahigh-speed swept-source optical coherence tomography angiography compared to spectral-domain optical coherence tomography angiography. *Am J Ophthalmol* 2016;164:80-88.

21 Told R, Ginner L, Hecht A, Sacu S, Leitgeb R, Pollreisz A, Schmidt-Erfurth U. Comparative study between a spectral domain and a high-speed single-beam swept source OCTA system for identifying choroidal neovascularization in AMD. *Sci Rep* 2016;6:38132.

22 Lei J, Pei C, Wen C, Abdelfattah NS. Repeatability and reproducibility of quantification of superficial peri-papillary capillaries by four different optical coherence tomography angiography devices. *Sci Rep* 2018;8(1):17866.

23 Hobbs SD, Pierce K. Wet Age-related macular degeneration (Wet AMD). In: *StatPearls.* edn. Treasure Island (FL): StatPearls Publishing LLC. 2021.

24 Thomas CJ, Mirza RG, Gill MK. Age-related macular degeneration. *Med Clin North Am* 2021;105(3):473-491.

25 Yao XC, Alam MN, Le D, Toslak D. Quantitative optical coherence tomography angiography: a review. *Exp Biol Med(Maywood)* 2020;245(4):301-312.

26 Yuan MZ, Chen LL, Yang JY, Luo MY, Chen YX. Comparison of OCT and OCTA manifestations among untreated PCV, neovascular AMD, and CSC in Chinese population. *Int J Ophthalmol* 2020; 13(1):93-103.

27 Haas AM, Ahmed D, Stattin M, Graf A, Krepler K, Ansari-Shahrezaei S. Comparison of macular neovascularization lesion size by the use of spectral-domain optical coherence tomography angiography and swept-source optical coherence tomography angiography versus indocyanine green angiography. *Acta Ophthalmol* 2021;99(2): e260-e266.