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Interchangeability and reliability of macular perfusion parameter measurements using optical coherence tomography angiography

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ABSTRACT

Aim The aim of the study was to investigate the interchangeability and reliability of macular perfusion measurements using optical coherence tomography angiography.

Methods A prospective cross-sectional observational study. Healthy adult Chinese subjects were recruited. Macular perfusion parameters were automatically analysed by software included in a spectral-domain optical coherence tomography system. The vessel density (VD) of the whole, parafovea, superior-hemi, inferior-hemi, fovea, temporal, superior, nasal and inferior quadrants as well as the foveal avascular zone (FAZ) and choroidal capillary VD (CCVD) were quantified.

Results A total of 51 eyes in 27 subjects were included (8 men and 19 women, mean age 24±4 years). Significant differences in VD of all quadrants (all $p<0.001$) was detected between the 3×3 mm and 6×6 mm macular scan size. The biggest difference of VD between the two scan size was 5.14±4.03, which was not clinically meaningful. No statistically significant differences were found in FAZ or CCVD between the two different scan sizes. The mean intraclass correlation coefficient (ICC) between two measurements from the inter-rater of 20 eyes was from 0.560 to 0.893 for VD and 0.845 for FAZ. The mean ICC between two measurements from the intrarater of 20 eyes was from 0.497 to 0.870 for VD and 0.780 for FAZ.

Conclusions FAZ and CCVD are interchangeable between the 3×3 mm and 6×6 mm macular scan sizes. The VD differences between the two different scan sizes are not clinically meaningful. The macular perfusion parameters presented good but not perfect reliability, which should be acknowledged in clinical practice.

INTRODUCTION

The ocular vascular system, especially the perfusion of the retina, plays an important role in normal visual function. Dysfunctional regulation of ocular blood flow (eg, in glaucoma or diabetes) can result in irreversible and serious destruction of visual function.[1 2] Different methods have been used to evaluate retinal blood perfusion. Fluorescein angiography (FA) and indocyanine green angiography can qualitatively reveal retinal and choroidal circulation with dye injection, which may take the risk of allergy and could give higher burden on both the patients and the ophthalmologists. Moreover, they cannot provide objective quantitative circulation evaluations.[3 4] Laser Doppler flowmetry and laser speckle flowgraphy can assess retinal blood flow, but the results are too variable to be useful.[5 6] Ultrasound colour Doppler imaging can independently provide haemodynamic measurements of the retinal vasculature, but due to limited resolution, this technique is rarely used to measure retinal microcirculation.

Optical coherence tomography (OCT) has been widely used in clinical and research settings to image and quantify retinal, optic nerve head and choroidal structural pathologies since 1991.[7] Doppler OCT can obtain precise measurements of the total retinal blood flow calculated from the Doppler frequency shift of backscattered light.[8] However, Doppler OCT is not sensitive enough to accurately measure the low velocities of small retinal vessels.[9] Recently, with the development of a new technique known as split-spectrum amplitude-decorrelation angiography (SSADA), retinal vasculature and retinal microcirculation can be clearly and non-invasively evaluated using OCT.[10] Previous papers have demonstrated adequate repeatability and reproducibility with swept source OCT angiography measurements in normal subjects.[11 12] In addition, the evaluation of macular perfusion parameters coming from commercial spectral-domain OCT is applicable in the clinic. Therefore, the purpose of this study was to investigate the interchangeability between 3×3 mm and 6×6 mm scan sizes and reliability of 6×6 mm scan size macular perfusion parameters. To the best of our knowledge, this is the first study to investigate the interchangeability and reliability of macular perfusion using commercial OCT angiography.

Methods

Study population

This study was performed at the First Hospital of Shanxi Medical University (Taiyuan, China). The research protocols were approved by the institutional review boards of the First Hospital of Shanxi Medical University and carried out in accordance with the tenets of the Declaration of Helsinki. Written informed consent was obtained from each subject after they were provided an explanation of the nature of the study.

This study included a total of 51 eyes from 27 normal adult subjects (8 males and 19 females). The inclusion criteria for the subjects included a best-corrected visual acuity of ≥16/20, a refractive error <3 dioptre (D) spheres, normal slit-lamp and

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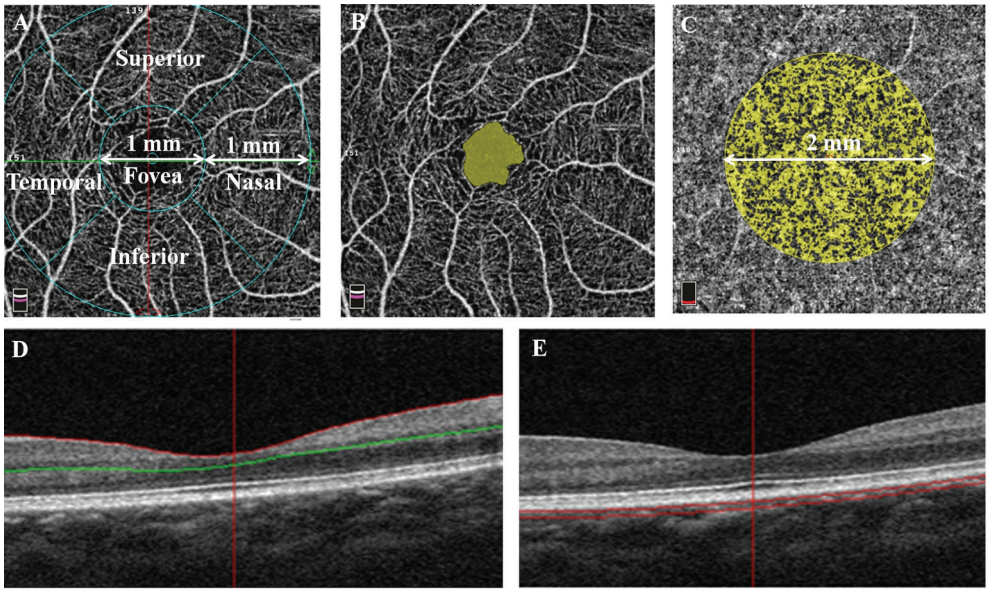

Figure 1 Macular perfusion parameters of a 3x3 mm angiography scan size using optical coherence tomography angiography. (A) The vessel density of five areas of interest, including the fovea (1 mm diameter) and temporal, superior, nasal and inferior quadrants (1 mm annular ring); (B) the foveal avascular zone is automatically delineated by the included software and represented by the colour yellow; (C) the choroidal capillary flow area within a 1 mm radius is represented by the colour yellow; (D) the flow information between the upper red line (inner limiting membrane offset 3 µm) and lower green line (inner plexiform layer offset 31 µm) is defined as the superficial vessel density; (E) the flow information between the upper red line (retinal pigment epithelium reference offset 31 µm) and lower red line (retinal pigment epithelium reference offset 59 µm) is defined as the choroidal capillary vessel density. Note: positive offset values mean the distance moving down from the reference retinal layer.

funduscopy examination results, an intraocular pressure of <21 mm Hg and no history of ocular or systemic corticosteroid use. The exclusion criteria included the presence of all detectable ocular diseases, recent ocular surgery, contact lens wear and use of eye drops.

Data acquisition

OCT angiography scans of the macula were captured by the spectral-domain OCT system RTVue-XR Avanti (V.2015.1.0.90; Optovue, Fremont, California, USA). This OCT system operated at an axial scan speed of 70 KHz using an 840 nm wavelength superluminescent diode with a bandwidth of 45 nm. The 3×3 mm and 6×6 mm 3D OCT angiography scans centred on the fovea were captured for macular perfusion parameter measurements for each eye by the same operator (XGW). Two consecutive B-scans were captured at a fixed position before moving along the slow transverse direction. Two 3D scans, comprising one horizontal priority (x-fast) scans and one vertical priority (y-fast) scans, were obtained in one session. The SSADA algorithm was used to distinguish flowing blood from static tissue, and motion artefacts were corrected with a 3D orthogonal registration algorithm.[13 14] An en face macular angiogram of four default segmentations was created and processed by internal software (V.2015.1.0.90). Only good quality OCT angiograms, as defined by a signal strength index of ≥45, were used for analysis.

Macular perfusion parameters

To evaluate macular perfusion, retinal circulation was automatically segmented along the boundary from the inner limiting membrane to the retinal pigment epithelium and projected into an en face view. The macula was automatically centred at the avascular zone on the OCT angiogram. The superficial macular vessel density (VD) was defined as the average flow signal within the five areas of interest (fovea with 1 mm diameter, temporal, superior, nasal and inferior quadrant) around the foveal centre (figure 1A). The parafovea VD (PFVD) was defined as the average flow signal within the temporal, superior, nasal and inferior quadrants. The whole VD (WVD) was defined as the average flow signal within the five areas of interest. The foveal avascular zone (FAZ), which is the non-flow area on the superficial retinal plexus angiogram, and choroidal capillary flow area of the ring area with a 1 mm radius using the default boundary were automatically calculated using the included software

Table 1 Summary of the vessel parameter measurements and mean differences between the 3 mm and 6 mm scan sizes

	Scan size (n=51)			
	3×3 mm	6×6 mm	3×3 mm–6×6 mm	Pp*
SSI	64±7	61±5	3±4	0.000
WVD (%)	50.17±3.07	47.14±2.99	3.03±3.01	0.000
PFVD (%)	52.46±3.39	48.63±3.31	3.83±3.11	0.000
SHVD (%)	52.68±3.39	49.31±3.44	3.37±2.96	0.000
IHVD (%)	52.24±3.60	47.95±3.47	4.29±3.58	0.000
FVD (%)	28.86±4.82	31.77±4.60	−2.91±2.66	0.000
TVD (%)	52.63±3.29	50.33±4.10	2.30±3.71	0.000
SVD (%)	53.23±3.87	49.07±4.38	4.16±3.29	0.000
NVD (%)	51.22±4.17	47.59±4.18	3.63±3.94	0.000
IVD (%)	52.68±4.03	47.54±4.01	5.14±4.03	0.000
FAZ (mm²)	0.327±0.081	0.332±0.081	−0.004±0.027	0.243
CCVD (%)	59.44±1.45	59.12±1.43	0.33±1.51	0.130

*Paired sample t-test.
CCVD, choroidal capillary vessel density; FAZ, foveal avascular zone; FVD, fovea vessel density; IHVD, inferior hemivessel density; IVD, inferior vessel density; NVD, nasal vessel density; PFVD, parafoveal vessel density; SHVD, superior hemivessel density; SSI, signal strength index; SVD, superior vessel density; TVD, temporal vessel density; WVD, whole vessel density.

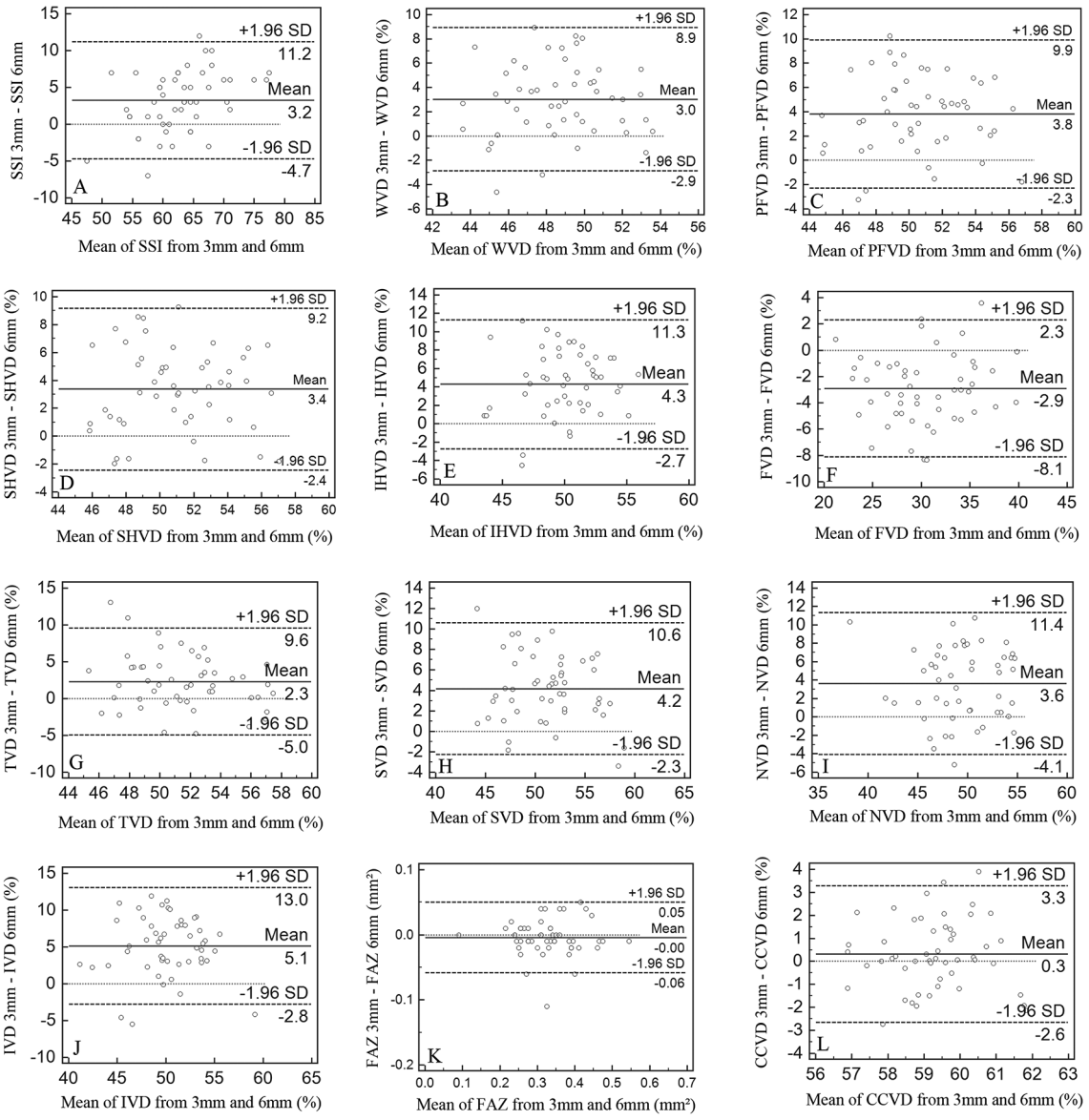

Figure 2 Interscan size differences in the mean SSI and macular perfusion parameters. The interscan size 95% LoA range for the SSI (A), WVD (B), PFVD (C), SHVD (D), IHVD (E), FVD (F), TVD (G), SVD (H), NVD (I), IVD (J), FAZ (K) and CCVD (L) values were 15.9, 11.8%, 12.2%, 11.6%, 14.0%, 10.4%, 14.6%, 12.9%, 15.6%, 15.8%, 0.11 mm2 and 5.9%, respectively. CCVD, choroidal capillary vessel density; FAZ, foveal avascular zone; FVD, fovea vessel density; IHVD, inferior hemivessel density; IVD, inferior vessel density; NVD, nasal vessel density; PFVD, parafoveal vessel density; SHVD, superior hemivessel density; SSI, signal strength index; SVD, superior vessel density; TVD, temporal vessel density; WVD, whole vessel density.

(figure 1B and C). For whole 3×3 mm area, choroidal capillary flow signal analysis of the 3×3 mm scan size centering on the fovea, due to partially absent flow signal of some quadrants, which may underestimate the flow information, we finally chose a default radius of 1 mm circular area for choroidal capillary flow area analysis in this study. Moreover, we divided choroidal capillary flow area by the circular area values with 1 mm radius and modelled it as a percentage as the choroidal capillary VD (CCVD) for final analysis.

Inter-rater and intrarater reliability

The inter-rater reliability of the signal strength index (SSI) and all of the macular perfusion parameters for the 6×6 mm scan were calculated from 20 eyes within a single visit by two operators (with the sequence of XGW and JD). The intrarater reliability of the 6×6 mm scan size macular perfusion parameters was also calculated from the same 20 eyes with two sets of scans obtained on two separate days approximately the same time as the first visit by the same operator (XGW).

Statistics

Statistical analyses were performed with commercial software (SPSS V,13.0). To compare the macular perfusion parameters of the 3×3 mm and 6×6 mm scan sizes, paired two-tailed t-tests were performed. The intraclass correlation coefficients (ICCs) and coefficient of variation (CV) were calculated to assess the inter-rater and intrarater reliability of the macular perfusion parameter measurements (ICC values over 0.80 indicate an almost perfect agreement between every two repeated measurements and ICC values lower than 0.40 indicate a poor to fair agreement between repeated measurements). Moreover, the agreement between the two scan size and inter-rater/intrarater agreement was evaluated using the Bland-Altman analysis. The inter-rater and intrarater differences were plotted against their

Table 2 Macular perfusion parameters of different measurements

	Measurements, mean±SD (n=20)		
	Measurement 1	Measurement 2	Measurement 3
SSI	61±4	61±4	61±3
WVD (%)	47.16±3.80	46.77±3.80	47.29±2.57
PFVD (%)	48.08±4.70	47.59±3.51	48.02±3.05
SHVD (%)	48.32±4.64	48.08±3.74	48.33±3.09
IHVD (%)	47.81±5.01	47.11±3.66	47.72±3.37
FVD (%)	31.95±4.57	32.25±5.25	32.39±4.62
TVD (%)	48.98±5.82	49.34±4.04	49.27±4.21
SVD (%)	48.41±4.51	47.94±4.12	48.05±3.19
NVD (%)	47.02±5.85	46.28±4.89	46.87±4.16
IVD (%)	47.90±4.76	46.83±3.83	47.90±3.75
FAZ (mm^2)	0.341±0.100	0.327±0.073	0.327±0.076
CCVD (%)	59.53±1.10	59.06±1.52	59.31±1.21

Note: Measurements 1 and 2 indicate the 2 measurements performed by the observer XGW over two sessions; measurement 3 comprises the third measurement performed by observer JD

CCVD, choroidal capillary vessel density; FAZ, foveal avascular zone; FVD, fovea vessel density; IHVD, inferior hemivessel density; IVD, inferior vessel density; NVD, nasal vessel density; PFVD, parafoveal vessel density; SHVD, superior hemivessel density; SSI, signal strength index; SVD, superior vessel density; TVD, temporal vessel density; WVD, whole vessel density.

means, and the 95% limits of agreement (LoA) were determined using this method. The significance level for all of the tests was set at 5%.

RESULTS

A total of 27 normal Chinese subjects (54 eyes) were studied. For all subjects, three eyes were excluded due to low signal strength (two eyes) and inaccurate segmentation (one eye). Therefore, 27 normal subjects (51 eyes) were included in the final analysis. There were 8 men (14 eyes) and 19 women (37 eyes) included. The mean age was 24±4 years (range, 20–43 years). The mean SSI and macular perfusion parameters of the 3×3 mm and 6×6 mm scan sizes are summarised in table 1. A statistically significant difference in SSI between the two scan sizes was detected ($p<0.001$). Significant differences existed between the 3×3 mm and 6×6 mm scan size macular perfusion parameters, with the exception of the FAZ and CCVD ($p=0.243$; $p=0.130$).

The interscan size 95% LoA range for the SSI (A), WVD (B), PFVD (C), superior hemivessel density (SHVD; D), inferior hemivessel density (IHVD; E), FVD (F), temporal vessel density (TVD; G), superior vessel density (SVD; H), nasal vessel density (NVD; I), inferior vessel density (IVD; J), FAZ (K) and CCVD (L) values were 15.9, 11.8%, 12.2%, 11.6%, 14.0%, 10.4%, 14.6%, 12.9%, 15.6%, 15.8%, 0.11 mm^2 and 5.9%, respectively (figure 2).

The mean macular perfusion parameters of 20 eyes, as measured by two operators during two sessions, are presented in table 2. The mean ICC values between the two measurements from the inter-rater of 20 eyes was from 0.560 to 0.893 for VD and 0.845 for FAZ. Correspondingly, the inter-rater coefficient of variation (CV) was from 0.012 to 0.065 for VD, 0.111 for FAZ. The mean ICC values between the two measurements from the intrarater of 20 eyes was from 0.497 to 0.870 for VD and 0.780 for FAZ. Correspondingly, the intrarater CV was from 0.015 to 0.075 for VD, 0.125 for FAZ. (table 3).

The inter-rater 95% LoA range for the SSI (A), WVD (B), PFVD (C), SHVD (D), IHVD (E),FVD (F), TVD (G), SVD (H), NVD (I), IVD (J), FAZ (K), and CCVD (L) values of the 6×6 mm scan size were 11.6, 9.5%, 14.1%, 12.8%, 16.2%, 8.3%, 18%, 11.3%, 16.5%, 15.8%, 0.2 mm^2, and 3.9%, respectively (figure 3). The intrarater 95% LoA range for the SSI (A), WVD (B), PFVD (C), SHVD (D), IHVD (E),FVD (F), TVD (G), SVD (H), NVD (I), IVD (J), FAZ (K), and CCVD (L) values of the 6×6 mm scan size were 16.3, 8.8%, 14.9%, 13.9%, 16.8%, 10.0%, 16.1%, 14.0%, 19.7%, 16.9%, 0.23 mm^2, and 4.6%, respectively (figure 4).

Table 3 Inter-rater and intrarater reliability analysis of the macular perfusion parameters.

	Intraclass correlation coefficient	95% CI		Coefficient of variation
		Lower bound	Upper bound	
SSI 1–2	0.641	0.296	0.839	0.044
SSI 1–3	0.732	0.438	0.885	0.031
WVD 1–2	0.789	0.546	0.910	0.033
WVD 1–3	0.718	0.414	0.878	0.035
PFVD 1–2	0.589	0.218	0.813	0.055
PFVD 1–3	0.589	0.210	0.814	0.051
SHVD 1–2	0.655	0.319	0.847	0.051
SHVD 1–3	0.657	0.313	0.849	0.047
IHVD 1–2	0.530	0.134	0.782	0.063
IHVD 1–3	0.532	0.129	0.784	0.059
FVD 1–2	0.870	0.705	0.946	0.055
FVD 1–3	0.893	0.749	0.956	0.046
TVD 1–2	0.675	0.349	0.856	0.058
TVD 1–3	0.590	0.211	0.815	0.065
SVD 1–2	0.667	0.338	0.853	0.052
SVD 1–3	0.727	0.430	0.882	0.042
NVD 1–2	0.579	0.203	0.808	0.075
NVD 1–3	0.658	0.314	0.849	0.062
IVD 1–2	0.497	0.090	0.764	0.065
IVD 1–3	0.560	0.168	0.799	0.058
FAZ 1–2	0.780	0.530	0.906	0.125
FAZ 1–3	0.845	0.650	0.936	0.111
CCVD 1–2	0.578	0.201	0.807	0.015
CCVD 1–3	0.632	0.275	0.836	0.012

Note: Numbers 1 and 2 indicate the 2 measurements performed by the observer XGW over two sessions; measurement 3 indicates the third measurement performed by the observer JD

CCVD, choroidal capillary vessel density; FAZ, foveal avascular zone; FVD, fovea vessel density; IHVD, inferior hemivessel density; IVD, inferior vessel density; NVD, nasal vessel density; PFVD, parafoveal vessel density; SHVD, superior hemivessel density; SSI, signal strength index; SVD, superior vessel density; TVD, temporal vessel density; WVD, whole vessel density.

DISCUSSION

The normal circulatory system in retinal tissues plays an important role in mediating metabolic needs, including providing nourishment and oxygen, controlling immune responses, among others.[15] Retinal vasculature is generally regulated and affected by angioactive factors and local or systemic factors.[16–18] An abnormal vascular system can result from all of the above-mentioned factors, which can exceed certain normal ranges. An abnormal vascular system and damaged retinal structure may cause functional abnormalities in the retina and lead to severe visual impairment.[19] Therefore, research into normal retinal perfusion is essential for the early monitoring and diagnosing of macular vascular disease. As a non-invasive retinal circulation evaluation technique, OCT angiography is essential

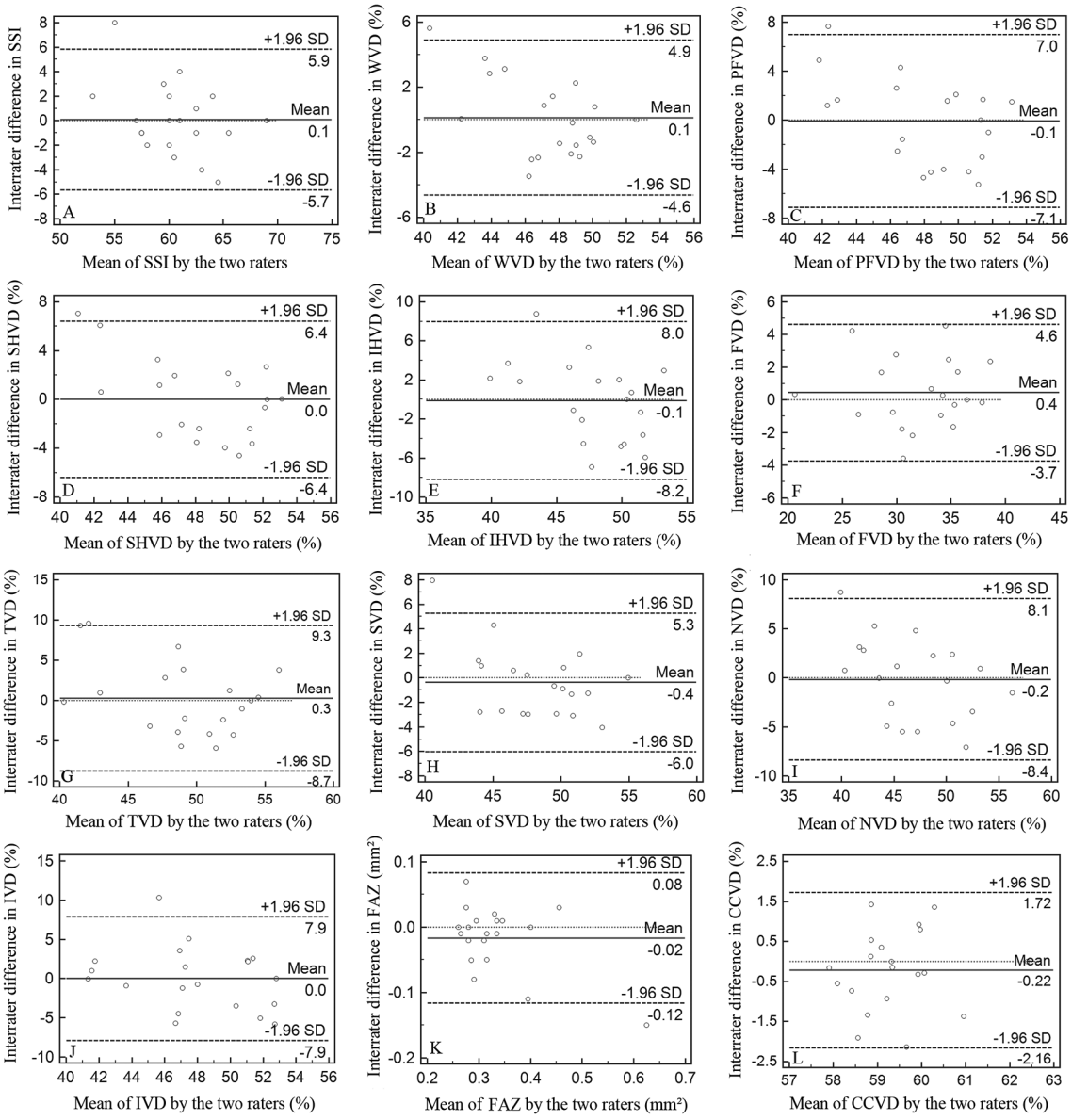

Figure 3 Inter-rater differences in the mean SSI and macular perfusion parameters. The inter-rater 95% LoA range for the SSI (A), WVD (B), PFVD (C), SHVD (D), IHVD (E), FVD (F), TVD (G), SVD (H), NVD (I), IVD (J), FAZ (K), and CCVD (L) values of the 6x6 mm scan size were 11.6, 9.5%, 14.1%, 12.8%, 16.2%, 8.3%, 18%, 11.3%, 16.5%, 15.8%, 0.2 mm^2, and 3.9%, respectively. CCVD, choroidal capillary vessel density; FAZ, foveal avascular zone; FVD, fovea vessel density; IHVD, inferior hemivessel density; IVD, inferior vessel density; NVD, nasal vessel density; PFVD, parafoveal vessel density; SHVD, superior hemivessel density; SSI, signal strength index; SVD, superior vessel density; TVD, temporal vessel density; WVD, whole vessel density.

for community-based retinal care. Moreover, this study helps to fine-tune OCT angiography parameters to guide clinical care.

We compared macular perfusion parameters, including macular VD and FAZ, in normal Chinese subjects with different scan sizes and evaluated the reliability of these parameters using a commercial OCT angiography system. The results demonstrated that the macular FAZ and CCVD were interchangeable between the 3×3 mm and 6×6 mm OCT angiography scan sizes. The biggest difference of VD between the two scan sizes was about 5.14%, which was not clinically meaningful based on previous research about diabetic retinopathy.[20] Due to the imperfect overlap between the 3×3 mm scan size and the corresponding size VD analysis, we finally used the 6×6 mm scan size to investigate the reliability of the macular perfusion parameters. The reliability of the 6×6 mm scan size taken by one or more operators on two different visits should exhibit low intra-rater and inter-rater variation to yield reliable data. Our results demonstrated relatively good reliability for the assessment of macular perfusion parameters.

The central avascular region, defined as the macular FAZ in this study, is thought to maximise the optical quality of the fovea pit by decreasing light scattering. Previous studies using different imaging methods demonstrated a similar FAZ as our research in normal subjects, which was approximately 0.33 mm.[2 21 22] However, our mean FAZ value is smaller than that of the Yu *et al*[23] study using the same OCT system for normal Chinese subjects, which was approximately 0.474 mm^2. The differences in participant ages may account for this difference because the mean age of participants in the Yu *et al* study was 36±11 years old, which is older than the mean patient age in this study. The authors also

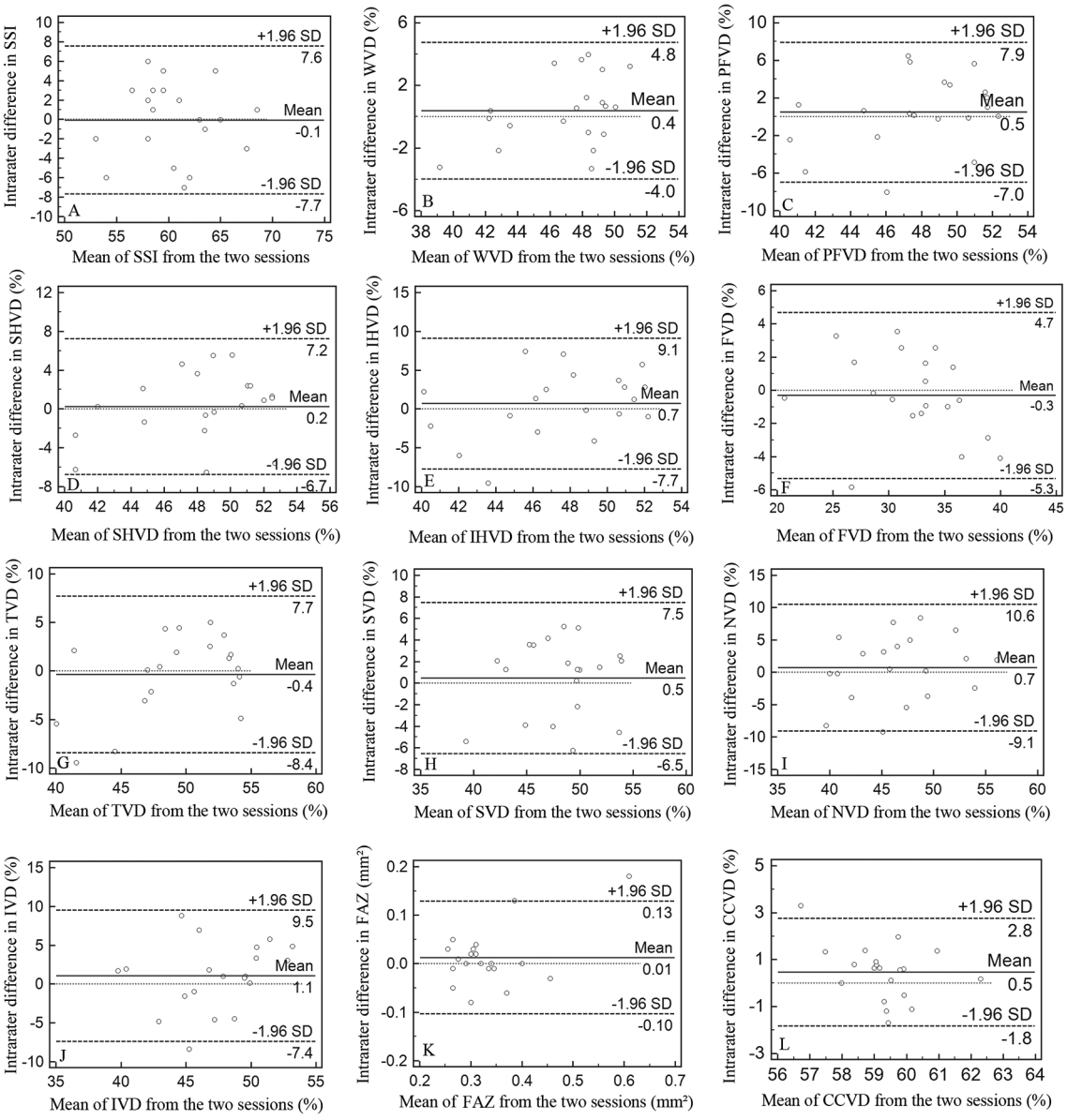

Figure 4 Intrarater differences in mean SSI and macular perfusion parameters. The intrarater 95% LoA range for the SSI (A), WVD (B), PFVD (C), SHVD (D), IHVD (E), FVD (F), TVD (G), SVD (H), NVD (I), IV D (J), NFA (K), and CCVD (L) values of the 6x6 mm scan size were 16.3, 8.8%, 14.9%, 13.9%, 16.8%, 10.0%, 16.1%, 14.0%, 19.7%, 16.9%, 0.23 mm^2, and 4.6%, respectively. CCVD, choroidal capillary vessel density; FAZ, foveal avascular zone; FVD, fovea vessel density; IHVD, inferior hemivessel density; IVD, inferior vessel density; NVD, nasal vessel density; PFVD, parafoveal vessel density; SHVD, superior hemivessel density; SSI, signal strength index; SVD, superior vessel density; TVD ,= temporal vessel density; WVD, whole vessel density.

demonstrated that age was positively correlated with the FAZ. The FAZ was interchangeable between the 3×3 mm and 6×6 mm scan sizes and demonstrated almost perfect inter-rater and intrarater reliability. This indicates that FAZ could be used as an important indicator for the presence of macular vascular disease, which can damage the foveal avascular zone.

The VD values, but not CCVD, were significantly different between the 3×3 mm and 6×6 mm scan sizes, and all of the VD values in the 3×3 mm scan were higher than the values in the 6×6 mm scan, with the exception of FVD. We speculate that this was mainly b (1) the incomplete overlap of the scan area and analysis area due to the fluctuation of the patient's fixation during the examination (figure 5A); (2) increased flow intensity and a more detailed microvasculature in the 3×3 mm scan compared with the 6×6 mm scan size due to sampling. Each pixel on the en face image of a 3×3 mm scan covers ~10×10 μm, which covers ~20×20 μm if the A-scan and B-scan numbers remain the same for a 6×6 mm scan (figure 5B) and (3) different heart rates and blood pressures during image capture, which may potentially influence retinal blood perfusion. However, the mechanisms behind higher FVD values in the 6×6 mm scan versus the 3×3 mm scan should be explored in future studies. The ICC for inter-rater VD analysis was from 0.560 to 0.893, which is slightly higher than 0.497 to 0.870 for the intrarater ICC (figure 6). All of the VD ICC and CV values were acceptable but lower than those reported in previous studies using swept source OCT or the same OCT system.[11 12 23] This may be attributed to different sample sizes and different VD subregions used for reliability analysis.

According to the ideal segmentation of the outer retina from the outer plexiform layer to Bruch's membrane, there should be no flow information in this range.[24] On the contrary, flow

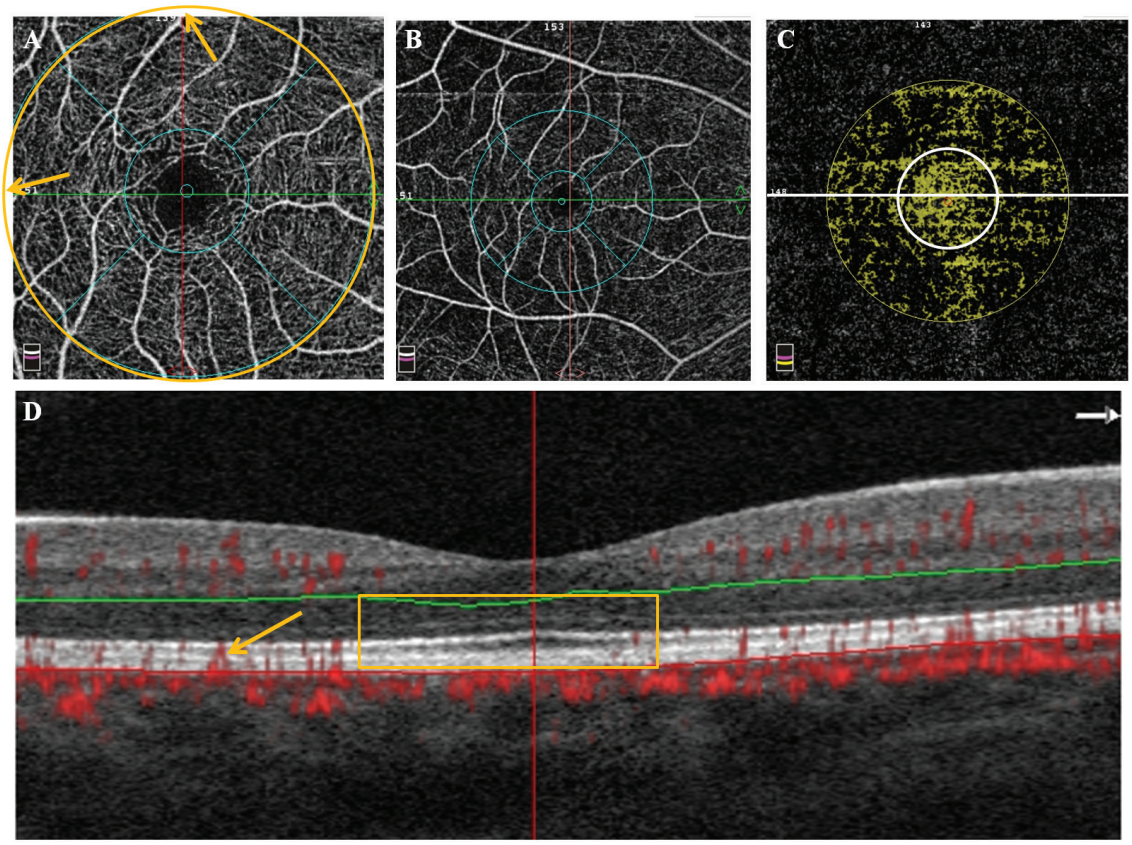

Figure 5 Optical coherence tomography (OCT) angiograms and structural OCT imaging of a normal Chinese subject. (A) Absent flow information of the superior and temporal quadrants (yellow arrows) due to the incomplete overlap of the 3×3 mm scan size; (B) relatively less detailed flow information in every quadrant of the 6×6 mm scan size compared with the 3×3 mm scan size; (C) outer retinal flow area (from upper - inner plexiform layer offset 69 µm to lower – retinal pigment epithelium reference offset 31 µm), revealing flow information that should not exist in normal eyes, especially within the white circle; (D) a horizontal cross-sectional macular structural OCT image with flow information (red colour) corresponding to the location of the white line in C. The scattered flow information on the retinal pigment epithelium (yellow arrow) is from strong projection artefacts. Moreover, the rectangle area no-flow information is inconsistent with the high-flow information within the white ring in C.

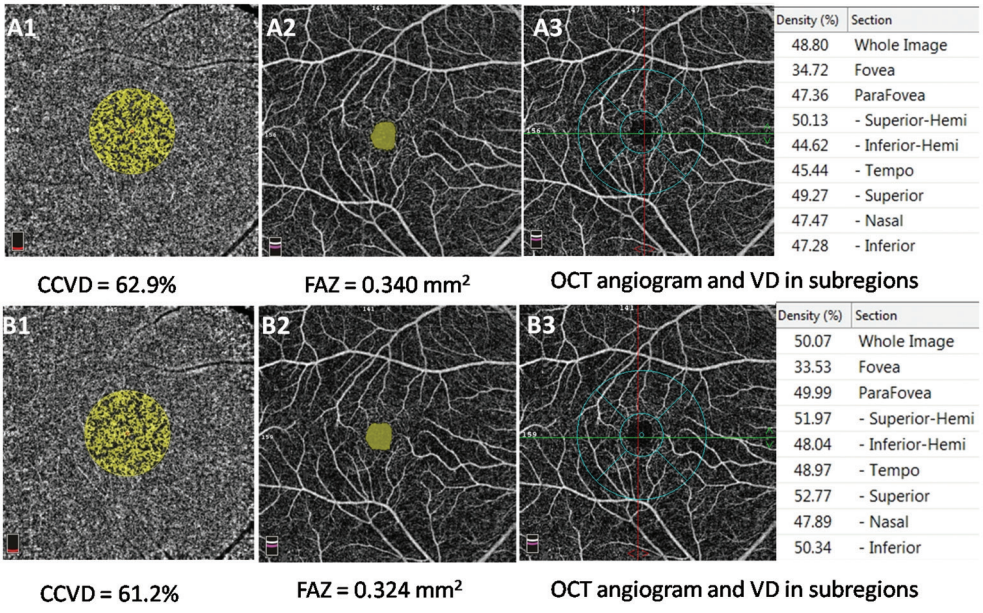

Figure 6 Macular perfusion parameters of a 6x6 mm scan size and corresponding values for a normal Chinese subject, such as choroidal capillary vessel density (CCVD: A1, B1), foveal avascular zone (FAZ: A2, B2), optical coherence tomography (OCT) angiograms and vessel density in subregions (VD: A3, B3), captured by XGW (A1–3) and JD (B1–3) in the same session.

information was found in the default segmentation in the outer retina (figure 5C). This inconformity may be mainly attributed to projection artefacts.[25] Moreover, identification and quantification of choroidal neovascularisation in the outer retina were usually manually identified or using customised imaging processing techniques.[26 27] Therefore, we did not analyse the outer retina flow information of normal eyes in this study.

No significant difference was found between the two different scan sizes for CCVD in this study. We can, therefore, use both scan sizes to image and quantify certain areas of choroidal capillaries. Moreover, the ICC values for inter-rater and intrarater CCVD were 0.632 and 0.578, respectively. The acceptable, but not perfect, reliability may also be associated with some angioactive factors and local or systemic factors.[12 16–18]

There are a few limitations of this study. First, in some subjects, both eyes of the same subject were included, which may compromise the potential intrapatient correlation in the final statistical analysis. Second, previous research has demonstrated that subjects with different ethnic backgrounds have different retinal structures.[28] This cross-sectional study included a limited number of cases and involved only Chinese subjects and therefore cannot be directly generalised to different ethnic backgrounds. Therefore, more larger multiracial studies are needed to draw definitive conclusions for clinical care guidelines. Third, retinal perfusion analysis of SSADA depends on different scan patterns, different SSIs, the analysed and segmentation algorithm and the threshold value to detect vessels. Therefore, care must be taken to interpret the results even from the same system. Finally, gender inequality and only young patients enrolled were also potential limitations of this study. Despite these limitations, this prospective study to investigate the reliability and interchangeability of macular perfusion provides useful information for clinical practice.

In conclusion, macular FAZ and CCVD are interchangeable between the 3×3 mm and 6×6 mm macular scan sizes. The VD differences between the two different scan sizes are not clinically meaningful. The macular perfusion parameters presented good, but not perfect, reliability, which should be acknowledged in clinical practice.

Contributors XGW: conception, design, data acquisition, analysis, drafting, critical revision. JD: conception design, data acquisition, drafting, critical revision. YDJ, QW, SHZ, YLJ, DH: conception, analysis, critical revision. All authors: final approval of the manuscript.

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Competing interests OHSU, YJ and DH have a significant financial interest in Optovue. DH also has a financial interest in Carl Zeiss Meditec. These potential conflicts of interest have been reviewed and managed by OHSU.

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Interchangeability and reliability of macular perfusion parameter measurements using optical coherence tomography angiography

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