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Intrasession repeatability of 6×6 mm swept-source OCT angiography macular vessel density measurements in high myopia: a prospective methodological study

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Research Article

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Abstract

Background

Quantitative OCT angiography (OCTA) requires well-defined measurement error for longitudinal interpretation, particularly in high myopia. We evaluated intrasession repeatability of automated 6×6 mm swept-source OCTA macular vessel-density measurements in highly myopic eyes.

Methods

Repeated lens-off macular scans were obtained with the DRI OCT Triton 3D Plus using OCTARA. Thirteen participants contributed 23 anatomical eyes and 32 paired comparisons. Superficial and deep capillary plexus (SCP/DCP) vessel density was analyzed centrally and in four parafoveal sectors. Repeatability was assessed with two-way random-effects, single-measure, absolute-agreement ICC [ICC(A,1)], within-subject SD (Sw), coefficient of variation (CV), repeatability coefficient (RC), Bland-Altman limits of agreement, participant-cluster bootstrap confidence intervals, and a one-pair-per-eye sensitivity analysis.

Results

Central reliability was excellent (SCP ICC 0.926, 95% CI 0.643–0.957; DCP ICC 0.934, 0.832–0.961). Sectoral ICCs were lower (0.399–0.691), whereas sectoral CVs remained 2.24%–3.35% and RCs 3.08–4.89 percentage points. Absolute mean bias was ≤ 0.57 percentage points in all regions. Sensitivity analysis preserved excellent central reliability. Eight lens-on pairs were analyzed only exploratorily.

Conclusions

Central 6×6 mm Triton OCTA vessel-density measurements were highly repeatable in high myopia, but parafoveal ICCs were more heterogeneous despite modest absolute error. Region-specific repeatability and standardized acquisition conditions should be considered when interpreting small longitudinal changes.

Background

OCTA provides non-invasive, depth-resolved quantification of retinal microvasculature and is increasingly used in myopia research. Because high myopia is associated with altered macular vascular density, small longitudinal differences can be clinically meaningful only if scan-to-scan measurement error is known [1].

Repeatability depends on device, segmentation, scan size, signal strength, fixation, image processing, and ocular biometry [2–6]. Long axial length and larger scan fields may reduce repeatability, while ocular

magnification changes the true retinal area represented by a nominal 6×6 mm scan [2, 3]. Automated Triton OCTARA measurements have shown high global repeatability in non-myopic populations [7], but regional 6×6 mm SCP and DCP precision in highly myopic eyes remains less well characterized. Because ICC reflects relative reliability and is influenced by between-eye heterogeneity, absolute error measures such as Sw, CV, RC, and Bland-Altman limits provide essential complementary information [8–10].

We therefore evaluated intrasession repeatability of automated 6×6 mm Triton OCTA vessel-density measurements in high myopia. The primary analysis focused on repeated lens-off acquisitions, with clustering-aware inference and a non-overlapping-pair sensitivity analysis. Lens-on repeatability was considered exploratory.

Methods

Study design and imaging

This prospective methodological study was conducted at Eskişehir Osmangazi University between 1 March and 1 June 2021. Ethics approval was obtained before enrollment (Non-Interventional Clinical Research Ethics Committee; 2 January 2021, decision no. 30), and all participants provided written informed consent. Adults with cycloplegic spherical myopia ≤ − 6.00 D were eligible. Exclusion criteria included astigmatism ≥ 2.00 D, previous ocular surgery, retinal/choroidal disease unrelated to myopia, glaucoma or other optic neuropathy, significant media opacity, poor fixation, or ocular/systemic disease likely to affect retinal vascular measurements.

Cycloplegia was induced with cyclopentolate hydrochloride 1% twice at 10-minute intervals; autorefraction was obtained 30 minutes later with a NIDEK TONOREF III. OCTA was performed with the swept-source DRI OCT Triton 3D Plus (Topcon, Tokyo, Japan) using OCTARA over a nominal 6×6 mm macular field. Automated SCP and DCP vessel density was recorded for the central, superior, temporal, inferior, and nasal regions. Primary repeatability scans were acquired lens-off using the device's internal refractive compensation.

Repeatability dataset and statistical analysis

After reconciliation with the eye-level acquisition records, the primary lens-off dataset comprised 13 participants, 23 anatomical eyes, and 32 paired comparisons. Eyes with three analyzable acquisitions could contribute predefined A–B, B–C, or C–A pairs; these were not treated as independent eyes. Lens-on repeats were available for only eight pairs from seven participants and were analyzed descriptively.

Relative reliability was quantified using a two-way random-effects, single-measure, absolute-agreement ICC [ICC(A,1)] [9]. Absolute error was summarized by Sw = SD of paired differences/√2, CV = 100×Sw/grand mean, and RC = 1.96×√2×Sw. Bland-Altman analysis reported repeat-minus-initial bias and 95% limits of agreement [10]. Participant-cluster bootstrap resampling (5,000 replicates) accounted

for bilateral eyes and overlapping pairs. A sensitivity analysis retained one non-overlapping pair per anatomical eye (n = 23). Emphasis was placed on reliability estimates and confidence intervals rather than hypothesis testing.

Results

The primary sample included 13 participants (12 women, 1 man), mean age 27.08 ± 5.09 years (18–36). Cycloplegic spherical refraction was − 7.49 ± 1.49 D in 22 eyes (range − 11.00 to − 6.00 D). Axial length was available for seven eyes (26.93 ± 1.02 mm), preventing meaningful axial-length covariate analysis.

Central SCP and DCP measurements showed excellent relative reliability, with ICC(A,1) values of 0.926 and 0.934, respectively. Sectoral ICCs were lower and heterogeneous (0.399–0.691). In contrast, absolute sectoral error was modest: CVs ranged from 2.24% to 3.35% and RCs from 3.08 to 4.89 percentage points. Central CVs were higher because central mean vessel density was lower. Mean bias was small in every region (absolute bias ≤ 0.57 percentage points), and Bland-Altman plots for representative central and sectoral measurements showed no evident systematic disagreement (Fig. 1). The one-pair-per-eye sensitivity analysis preserved excellent central reliability (SCP 0.910; DCP 0.913) and did not alter the overall regional pattern (Table 1).

Table 1
Primary lens-off repeatability, agreement, and sensitivity estimates

Region	ICC(A,1) (95% CI)	Sw	CV, %	RC	Bias (95% LoA)	Sensitivity ICC
SCP central	0.926 (0.643–0.957)	1.25	5.53	3.45	−0.19 (− 3.65, 3.26)	0.910
SCP superior	0.411 (0.099–0.736)	1.53	3.10	4.24	−0.03 (− 4.26, 4.21)	0.436
SCP temporal	0.430 (− 0.005–0.682)	1.26	2.66	3.50	−0.22 (− 3.72, 3.29)	0.547
SCP inferior	0.659 (0.307–0.838)	1.11	2.24	3.08	−0.05 (− 3.13, 3.04)	0.698
SCP nasal	0.399 (0.097–0.654)	1.35	2.96	3.74	−0.57 (− 4.31, 3.17)	0.517
DCP central	0.934 (0.832–0.961)	1.28	6.37	3.54	−0.10 (− 3.64, 3.44)	0.913
DCP superior	0.691 (0.246–0.861)	1.19	2.28	3.28	0.35 (− 2.93, 3.64)	0.724
DCP temporal	0.403 (0.040–0.729)	1.53	3.18	4.23	−0.25 (− 4.48, 3.98)	0.465
DCP inferior	0.411 (0.144–0.576)	1.77	3.35	4.89	0.08 (− 4.82, 4.97)	0.335
DCP nasal	0.649 (0.098–0.863)	1.51	3.08	4.19	−0.49 (− 4.67, 3.70)	0.753

Sw and RC are vessel-density percentage points. CI: participant-cluster bootstrap 95% confidence interval; LoA: limits of agreement. Sensitivity analysis retained one non-overlapping pair per anatomical eye (n = 23).

Exploratory lens-on analysis included eight paired comparisons. Central point estimates were high (SCP ICC 0.963; DCP ICC 0.962), but sectoral estimates were variable; because of the small sample, these findings were considered descriptive and were not used to compare refractive-correction conditions.

Discussion

The main finding is that 6×6 mm Triton OCTA repeatability in high myopia is region dependent. Central SCP and DCP measurements showed excellent single-measure absolute-agreement reliability, whereas most parafoveal sector ICCs were lower. Importantly, absolute error remained modest, with sectoral CVs near 2%–3% and RCs of approximately 3–5 percentage points. This distinction is expected because ICC depends on between-eye variability as well as within-eye error; a restricted biological range can therefore lower ICC despite acceptable scan-to-scan precision [9].

Our central results are consistent with automated Triton OCTARA data from eyes without ocular disease, where global SCP and DCP ICCs exceeded 0.96 [7]. The lower regional ICCs in our high-myopia cohort indicate that excellent central or global reliability should not be generalized to every sector. Prior studies also show that long axial length, larger scan fields, ocular magnification, signal strength, and platform-specific processing can influence OCTA repeatability [2–6]. These factors are especially relevant in high myopia, where a nominal 6 × 6-mm scan does not represent an identical true retinal area across eyes.

The statistical design strengthens interpretation. We used ICC(A,1) because clinical follow-up generally relies on a single future scan, and we paired relative reliability with Sw, CV, RC, and Bland-Altman limits. Participant-cluster bootstrap inference accounted for bilateral eyes and overlapping scan pairs, while the one-pair-per-eye sensitivity analysis preserved excellent central reliability. Thus, the central finding was not dependent on treating correlated pairs as independent.

The study is limited by the modest sample size, incomplete axial-length data, overlapping repeat pairs in some eyes, and use of a single device and scan size. The wide confidence intervals for several sectoral ICCs should therefore be interpreted cautiously. Residual effects of segmentation, fixation, and image quality could not be modeled comprehensively. Lens-on repeatability was based on only eight pairs and should not be interpreted as evidence of superiority or inferiority. For longitudinal imaging, the practical implication is to reproduce the same refractive-correction and acquisition conditions and to judge small changes against region-specific repeatability limits rather than a single global threshold.

Conclusions

Automated 6×6 mm DRI OCT Triton SS-OCTA measurements in highly myopic eyes showed excellent intrasession repeatability centrally but more heterogeneous parafoveal reliability. Absolute error remained modest across sectors. ICC should therefore be interpreted together with absolute error metrics, and standardized acquisition conditions should be maintained when small longitudinal OCTA changes are considered biologically meaningful.

Abbreviations

CV
coefficient of variation
DCP
deep capillary plexus
ICC
intraclass correlation coefficient
OCTA
optical coherence tomography angiography
RC
repeatability coefficient

SCP
superficial capillary plexus
SS-OCTA
swept-source OCTA
Sw
within-subject standard deviation.

Declarations

Ethics approval and consent to participate: Approved by the Eskişehir Osmangazi University Rectorate Non-Interventional Clinical Research Ethics Committee (2 January 2021; decision no. 30). The study followed the Declaration of Helsinki and written informed consent was obtained from all participants.

Consent for publication: Not applicable. Availability of data and materials: De-identified data are available from the corresponding author on reasonable request, subject to ethical and institutional requirements.

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Authors' contributions: MAE performed participant recruitment, primary data recording, data curation and investigation; both authors contributed to study design, methodology, analysis, interpretation, validation, manuscript drafting/revision, and final approval.

Use of generative AI: ChatGPT (OpenAI) was used for language editing, manuscript organization, and reference-formatting support. It was not used to generate or alter study data. The authors reviewed and verified the final content and take full responsibility for the manuscript.

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Figures

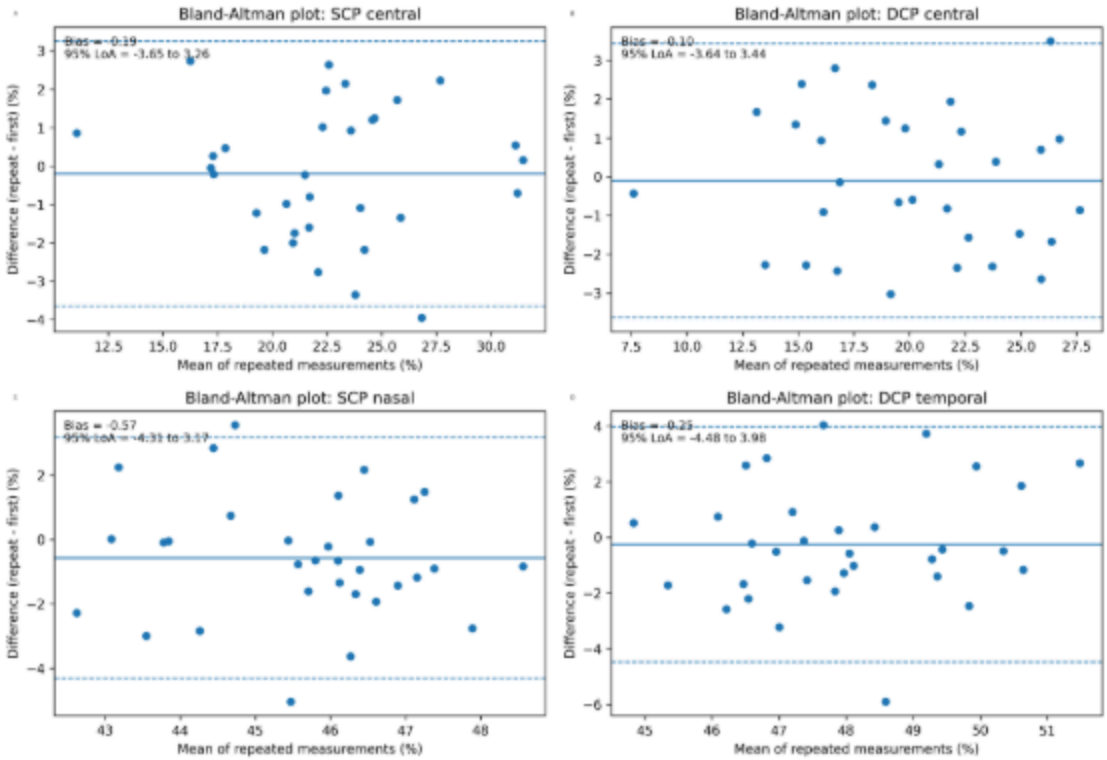


Figure 1

Bland-Altman plots for representative primary lens-off measurements: (A) central SCP, (B) central DCP, (C) nasal SCP, and (D) temporal DCP. Solid lines indicate mean bias and dashed lines the 95% limits of agreement; differences are repeat minus initial measurement.