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Analysis of optical coherence tomography angiography measurements following retinal detachment surgery

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Abstract

To analyze the optical coherence tomography angiography (OCTA) measurements in patients who underwent pars plana vitrectomy (PPV) due to rhegmatogenous retinal detachment (RRD). The study was conducted retrospectively in a single-centered eye clinic. Fifteen patients were enrolled in the study. The PPV group (or Study group) included 15 eyes performed PPV±phacoemulsification and the control eyes included 15 fellow eyes without any vitreoretinal surgical procedures. Postoperative 6-month OCTA measurements of the study and control eyes were compared for statistical analysis. The PPV group was also assessed in terms of Pseudophakic PPV and Phakic PPV subgroups. The average age of the patients was 57.72±6.32 years. Mean superficial retinal vessel density (VD, %) measurement of the superior hemifield in the PPV group showed a significantly lower result when compared to the control eyes (48.3±2.91 vs 50.11±2.59, p=0.031). Whereas no significant differences were noted in any segments of deep retinal VD measurements between the PPV and control eyes. We did not also observe any significant differences in any segments of both superficial and deep retinal VD measurements between the Pseudophakic PPV and Phakic PPV subgroups of the study group. Our study results concluded that PPV can lead to a partially decreased superficial retinal vessel density measurement in OCTA images, but phacoemulsification may not affect retinal vessel density measurements.

Keywords: Pars plana vitrectomy, vessel density, optical coherence tomography angiography

Introduction

Pars plana vitrectomy (PPV) combined with silicone or gas tamponade is an efficient method for the treatment of rhegmatogenous retinal detachment (RRD) [1]. However, despite excellent anatomical results, incomplete visual recovery, color visual defects or permanent metamorphosis have been reported [2]. In the absence of abnormalities such as retinal fold and distortions in optical coherence tomography (OCT), patients may still suffer from impaired visual function from other abnormalities that can not be detected by OCT [3].

OCT has become a common tool for the assessment of retinal diseases as a noninvasive method to have high-resolution imaging of the retina and choroid. Several studies using OCT reported that various morphologies and complications of retinal re-attachment were associated with a worse visual acuity, persistent subretinal fluid, a cystoid macular edema, segment/outer segment disruption, and the formation of epiretinal macular membranes [4, 5]. In PPV surgical intervention, recent studies postulated the association of the possible effect of retinal shift on visual acuity [6].

OCT was updated to OCT angiography (OCTA) with additional software to evaluate retinal and choroidal microvascular alteration [7]. OCTA provides clinicians to capture non-invasive, rapid, high-resolution 3-D images and repeatable quantitative information from the retinal and choroidal microvasculature [8]. OCTA runs with the principle of time-related differences in erythrocyte reflective to serve flow maps of retinal microcirculation with segmentation skills [9]. OCTA has proven to be a useful tool for evaluating changes in the retinal microvasculature after vitreoretinal surgeries.

Vessel density (VD) measurements in OCTA may be a good indicator for the alterations in retinal vasculature following vitreoretinal surgeries including PPV. This study aimed to evaluate changes in VD measurements in eyes that underwent PPV±phacoemulsification due to RRD.

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Materials and Methods

The current retrospectively designed study was conducted at an eye clinic from March 2019 to November 2020. The Institutional Review Board of Samsun Trainig ad Research Hospital approved the present study (GOKA/2021/4/9). Informed consent was obtained from all patients prior to the treatment. The study was carried out according to the principles of the Declaration of Helsinki.

Patients

A total of 15 patients were enrolled in this study. Eyes underwent PPV±phacoemulsification procedures due to macula-off RRD served as the PPV (or study) group, and the fellow eyes without any retinal detachment surgical procedures served as the control group. The study group was divided into two subgroups: while pseudophakic eyes with RRD had only PPV surgeries (Pseudophakic PPV subgroup), phakic eyes with RRD had combined PPV±phacoemulsification surgeries (Phakic PPV subgroup). The patients had a detailed ophthalmic examination including best-corrected visual acuity (BCVA, in decimal), intraocular pressure (IOP, Goldmann applanation tonometry, mmHg), anterior and posterior segment examination, and OCTA measurements. Postoperative 6-month parameters were compared between the groups. Exclusion criteria were pediatric age, macular detachment >10 days, grade C or more proliferative vitreoretinopathy, giant tears, previous maculopathy (e.g., senile macular degeneration, macular hole), recurrent retinal detachment after PPV, and any previous ocular comorbidities which could impair visual acuity (e.g., uveitis, glaucoma, diabetic retinopathy,) except for cataract.

Surgical procedure

Providing sterile conditions, standard three-ported 23G PPV was performed by the same surgeon under local anesthesia. The vitreous base was completely removed following the core vitrectomy. The tear was in the superior quadrant of all patients in the study group. We performed endolaser photocoagulation encircling the break(s) and we applied 360° pan-retinal endolaser photocoagulation. Tamponade with 20% sulfur hexafluoride (SF6) was used. Phacoemulsification was performed prior to the PPV (combined phaco-vitrectomy) in phakic eyes.

OCTA measurement protocol

VD (%) measurements were measured using a swept-source Triton model OCTA (Topcon, Tokyo, Japan) using the nominal OCTA ratio analysis algorithm. Fundus image sections were measured on fovea-centered 6x6 mm^2 areas. The 'fovea' was described as the area without vessels and the 'parafovea' was described as a ring-shaped area with 1 mm inner and 3 mm outer circles from the central fovea. VD measurements were performed in the foveal and parafoveal areas of the superficial and deep retina. Parafoveal VD measurements were analyzed in the superior, temporal, inferior, and nasal segments of the superficial and deep retina. The superficial retinal layer was measured between the inner limiting membrane ± 2.6µm and the inner plexiform layer/inner nuclear layer +15.6µm. The measurements of the deep retinal layer were measured from the inner plexiform layer/inner nuclear layer + 15.6µm to the inner plexiform layer/inner nuclear layer+70.2µm. (Figure 1 and 2).

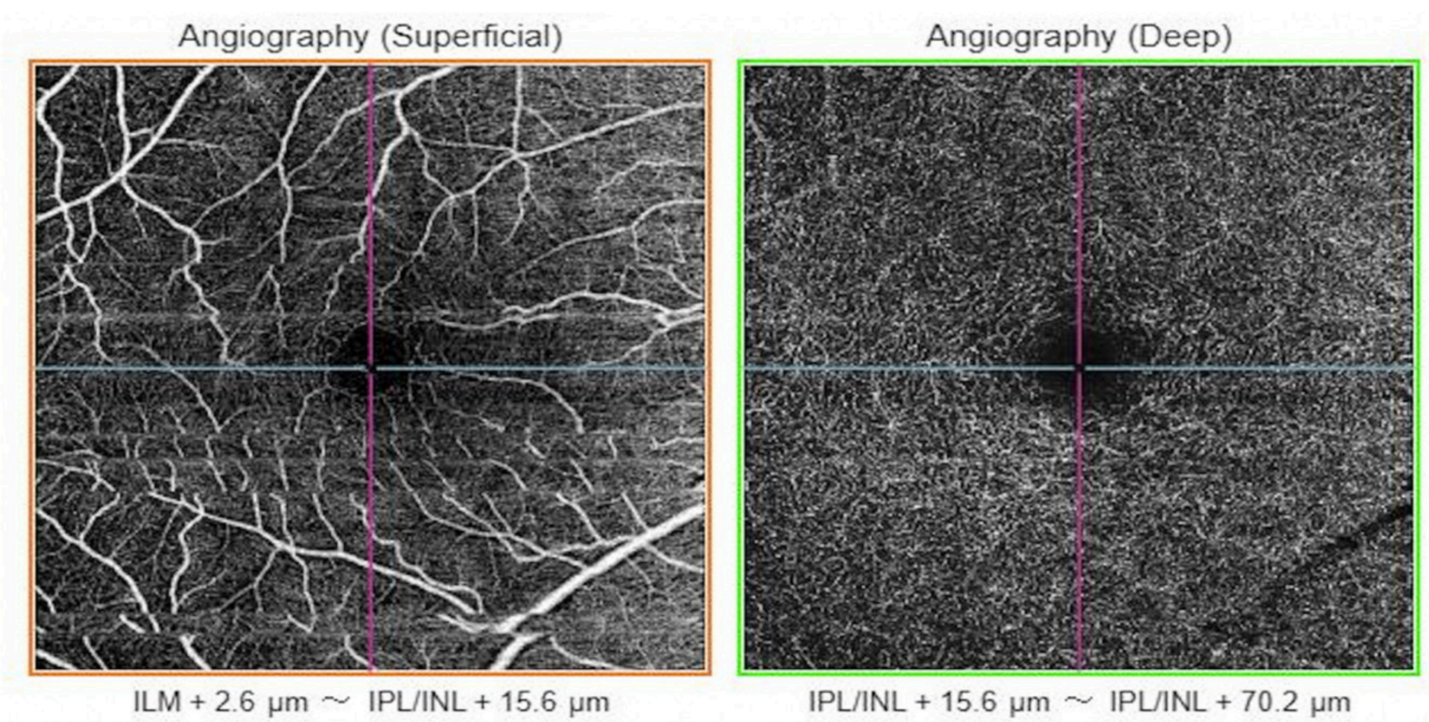

Figure 1. Foveal and parafoveal vessel density measurement in the superficial and deep retinal layers using swept-source optical coherence tomography angiography (retinal layer depths)

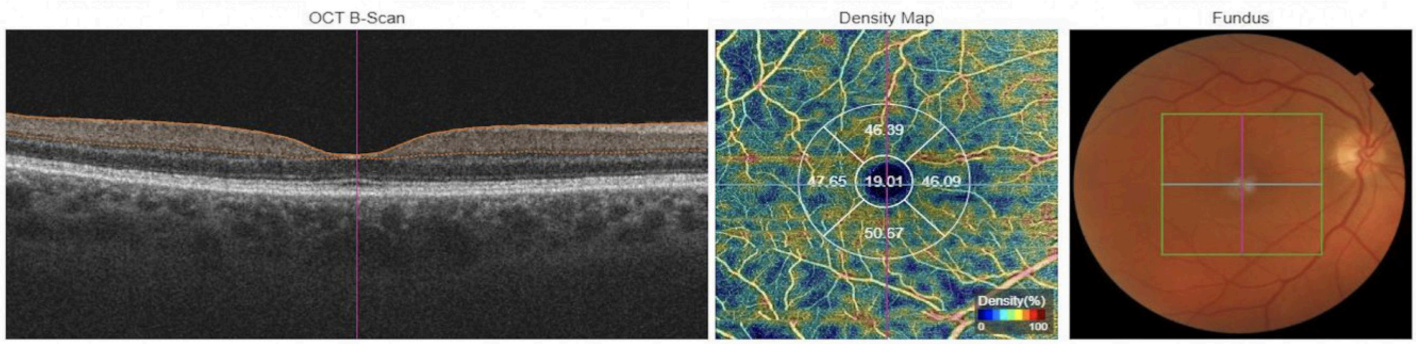

Figure 2. Foveal and parafoveal vessel density measurement in the superficial and deep retinal layers using swept-source optical coherence tomography angiography (OCT B-Scan, Density map, and fundus images)

Statistical analysis

We analyzed the data with SPSS 21.0 software (IBM Corp., Armonk, NY, USA). Constant parameters were demonstrated as the mean±standard deviation. Kolmogorov-Smirnov test was used to detect normal distribution. Statistical analyses were performed by independent samples t-test. The significance level was accepted as p <0.05.

Results

All parameters were assessed in the 6th month of the postoperative period. The average age of 15 patients was 57.72±6.32 years. The mean BCVA of the PPV group was 0.33±0.31, and the mean BCVA of the control eyes was 0.86±0.23 (P=0.01, in decimal). The mean IOP value of the PPV group was 15.72±1.55 mmHg, and the mean IOP of the control eyes was 16.09±2.17 mmHg (P=0.656). The mean signal strength index of OCTA measurements was similar in the PPV and control eyes (6.78/10 versus 6.85/10, P=0.546).

We noted a significantly lower mean value of VD measurement only in the parafoveal superior hemifield of the superficial retinal layer in the PPV group when compared to the control eyes. The comparison of VD measurements between the eyes underwent PPV±phacoemulsification and the fellow eyes are represented in Tables 1 and 2.

Table 1. Comparison of mean vessel density measurements between the superficial retinal layers of the PPV and control groups using SS-OCTA

VD Measurements (%)	PPV Group (n=15)	Control Group (n=15)	P**
Fovea	19.34±6.87	19.79±5.24	0.722
Superior Parafovea	43.80±2.91	50.11±2.59	0.031*
Temporal Parafovea	46.44±2.29	46.33±2.71	0.697
Inferior Parafovea	48.85±3.84	49.69±3.62	0.306
Nasal Parafovea	49.31±2.91	49.27±3.32	0.841

PPV: Pars plana vitrectomy, SS-OCTA: Swept-source optical coherence tomography, VD: Vessel density, **Independent samples t-test was used, *Significant P-value

Table 2. Comparison of mean vessel density measurements between the deep retinal layer of the PPV and control groups using SS-OCTA

VD Measurements (%)	PPV Group (n=15)	Control Group (n=15)	P**
Fovea	19.32±6.67	19.59±5.21	0.727
Superior Parafovea	51.35±2.91	51.11±2.59	0.741
Temporal Parafovea	46.34±2.29	46.13±2.78	0.691
Inferior Parafovea	48.91±3.84	49.71±3.62	0.308
Nasal Parafovea	49.31±2.94	49.28±3.30	0.847

PPV: Pars plana vitrectomy, SS-OCTA: Swept-source optical coherence tomography, VD: Vessel density **Independent samples t-test was used

We also compared VD measurements between the Pseudophakic PPV and the Phakic PPV subgroups of the study group. Six eyes (40%) of the PPV group were phakic, which had combined PPV and phacoemulsification surgeries. The Pseudophakic PPV subgroup (9 patients) had a mean age of 55.40±5.85 years, and the Phakic PPV subgroup (6 patients) had a mean age of 60.17±8.53 years (P=0.104). The mean BCVA of the Pseudophakic PPV subgroup was 0.46±0.38, and the mean BCVA of the Phakic PPV subgroup was 0.40±0.28 (P=0.768, in decimal). The average IOP value of the Pseudophakic PPV subgroup was 15.60±1.94 mmHg, and the mean IOP of the Phakic PPV subgroup was 15.83±1.32 mmHg (P=0.819).

We observed no significant differences in mean VD measurement in any foveal or parafoveal segments of the superficial or deep retina while comparing the Pseudophakic PPV and Phakic PPV subgroups. The comparison of VD measurements between the subgroups of the study group is represented in Tables 3 and 4.

Table 3. Comparison of mean vessel density measurements between the superficial retinal layers of the subgroups of the study group using SS-OCTA

VD Measurements (µm)	Pseudophakic PPV Subgroup (n=9)	Phakic PPV Subgroup (n=6)	P**
Fovea	19.34±6.87	19.79±5.24	0.722
Superior Parafovea	49.98±2.91	50.11±2.59	0.628
Temporal Parafovea	46.56±2.29	46.47±2.71	0.683
Inferior Parafovea	49.45±3.74	49.19±3.62	0.321
Nasal Parafovea	49.711±2.74	49.52±3.32	0.838

SS-OCTA: Swept-source optical coherence tomography, VD: Vessel density, PPV: Pars plana vitrectomy, **Independent samples t-test was used

Table 4. Comparison of mean vessel density measurements between the deep retinal layers of the subgroups of the study group using SS-OCTA

VD Measurements (µm)	Pseudophakic PPV Subgroup (n=9)	Phakic PPV Subgroup (n=6)	P**
Fovea	19.21±6.76	19.38±5.12	0.721
Superior Parafovea	51.75±2.91	51.61±2.59	0.731
Temporal Parafovea	46.43±2.92	46.21±2.87	0.618
Inferior Parafovea	48.91±3.84	49.11±3.62	0.788
Nasal Parafovea	50.11±2.94	50.28±3.43	0.857

SS-OCTA: Swept-source optical coherence tomography, VD: Vessel density, PPV: Pars plana vitrectomy, **Independent samples t-test was used

Discussion

RRD is the disconnection of the neurosensorial retina from the RPE due to fluid leakage through retinal tears and subsequently the accumulation of subretinal fluid under the retina. RRD may result in a remarkable visual acuity reduction unless early detection and treatment [10]. Unfortunately, the postoperative visual gain might remain unsatisfactory even a high anatomical success is achieved [10]. The improvements in OCTA technology have provided the clinicians to assess retinal vasculature modifications non-invasively and understand microvascular reasons for the inadequate postoperative visual gain.

Therefore, in our study, OCTA was used to assess postoperative 6th-month differences in the retinal vasculature between the eyes underwent PPV due to RRD and the fellow normal eyes. We assessed superficial and deep retinal VD measurements for statistical analysis. We found a significant difference for VD measurement of parafoveal superior hemifield in the superficial retinal layer. However, we did not note significant differences in deep retinal VD measurements. We could not accept this insignificancy due to the small number of patients and early measurements of our study, or even due to transient vascular density measurements. We also noted similar results in VD measurements between the subgroups of the PPV group.

There are some theoretical mechanisms of retinal ischemia in RRD patients treated with PPV. RRD itself may alter retinal blood supply and increase the release of inflammatory cytokines, leading to ischemic damage of the neurosensory retina. In retinal detachment, hypoxia can increase the oxygen and metabolic needs supplied by the retinal microcirculation, rather than the choroid [11-13]. Another potential mechanism for retinal blood flow impairment is vasospasm. A significant concentration of endothelin-1 in the subretinal area may result in retinal vasoconstriction with decreased retinal blood flow and thus reduction of VD in the pathological process of retinal detachment [14, 15]. Meanwhile, endothelin-1 can also affect retinal Müller cells increasing their activation of cellular hypertrophy, gliosis, and subretinal fibrosis in both detached and non-detached retinal areas [16-18].

PPV has an important impact on the microcirculation and oxygenation of the retina. Following the vitrectomy, a less viscous medium substitutes the vitreous gel, which facilitates the transmission of cytokines, oxygen and other metabolic molecules [19]. The arrival of oxygen to ischemic regions of the retina and increased clearance of vascular endothelial growth factor (VEGF) and cytokines result in the decrease of neovascularization and edema [19]. Oxygen can change the size of micro-vasculature by affecting the hydrostatic pressure of retinal microcirculation [20]. Thus, PPV may affect postoperative retinal vessel diameter and action through oxygenation regulation [20].

Previous studies reported a decreased retinal blood flow in fluorescein angiographic images of patients recovered from retinal detachment, which was thought to be due to a rise in peripheral resistance [21]. Another study documented a decreased blood flow of macular microcirculation in scanning laser Doppler flowmetry even if RRD spared the macula: The decrease was recovered at month 1 following vitrectomy and the authors postulated that the decrease was due to the extent of the RRD [22]. Besides, color-Doppler ultrasound imaging demonstrated that increased preoperative RRD duration caused a worse central retinal artery hemodynamic outcome [23]. The therapeutic effect of vitrectomy on the microcirculation of the perifoveal retina has also been documented in patients who had branch retinal vein occlusion [24]. However, these reports based on retinal microvasculature did not evaluate the micro-circulation in other retinal layers. The strength of OCTA is the capability to individually analyze different retinal plexuses that can be distinctly affected by pathological conditions. In contrast to our results, a study reported a reduced capillary plexus density of the deep parafoveal retina in OCTA measurements of RRD patients without macular involvement [12].

The deep retinal layer is mostly affected by slower chronic pathologic processes such as diabetic retinopathy, rather than RRD. In the present study, we evaluated retinal micro-vascular density measurements in recently diagnosed patients with early PPV intervention, and we performed OCTA measurements in a relatively early postoperative period (6th month). So, we can claim that our study enrollment criteria might relatively clarify these OCTA results associated with various actions of different retinal layers. We can also hypothesize that the superficial retina might be the first layer indicating a decreased vessel density in a recent onset RRD, which may be due to greater arteriola and smooth muscle density in the superficial retinal layer resulting in stronger and faster contraction when compared to deep retinal layer. Our study has some limitations including the retrospective design, small population, and short follow-up duration. Regarding these limitations, prospective works with a large population and long follow-up duration are needed to investigate the effect of PPV on VD measurements.

In conclusion, OCTA is a method that can noninvasively and rapidly analyze retinal vessel density in patients recovered from retinal detachment. In macula-off patients, superficial retinal vessel density measured by OCTA seemed to be decreased versus the fellow eye. The hypothesis of hypoxia and vasoconstriction might be suggested for the explanation of this result.

Conflict of interests
The authors declare that they have no competing interests.

Financial Disclosure
All authors declare no financial support.

Ethical approval
The Institutional Review Board of Samsun Trainig ad Research Hospital approved the present study (GOKA/2021/4/9).

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