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Assessment of Retinal Perfusion Using Wide Field Swept Source OCTA in Diabetic TRD: Pre and Postoperative Correlation Study

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Abstract
Tractional retinal detachment (TRD) is a severe vision-threatening complication of proliferative diabetic retinopathy (PDR). Surgical intervention using pars plana vitrectomy (PPV) aims to restore anatomical integrity and preserve or improve vision. Recent advances in wide field swept-source optical coherence tomography angiography (WF SS-OCTA) enable non-invasive, high-resolution visualization of retinal perfusion and microvascular changes before and after surgery. To evaluate quantitative and qualitative changes in retinal perfusion using WF SS-OCTA in eyes with diabetic TRD before and after surgical repair and to correlate these findings with clinical and anatomical outcomes. A prospective observational study was conducted at the Bascom Palmer Eye Institute, University of Miami, between January 2018 and December 2019. A total of 31 eyes from 21 patients with TRD due to PDR were imaged using a WF SS-OCTA system (PLEX Elite 9000). Eyes underwent PPV with membrane peeling and laser photo coagulation. OCTA images were obtained preoperatively and at 1 and 4 months postoperatively. Key parameters analyzed included foveal a vascular zone (FAZ) area, vessel length density (VLD) and perfusion density (PD) in superficial and deep capillary plexuses. Successful image acquisition was achieved in 26 of 31 eyes (83.9%) at baseline and in 28 of 31 eyes (90.3%) at 4 months. Postoperative OCTA revealed a significant increase in VLD and PD in both superficial and deep vascular layers ($p<0.05$). FAZ area remained stable postoperatively. Eyes with resolved traction showed improved macular perfusion, while areas previously affected by fibrovascular membranes remained ischemic. No significant correlation was observed between perfusion metrics and visual acuity recovery. WF SS-OCTA provides valuable insight into microvascular remodeling after surgical repair of diabetic TRD. Although retinal perfusion improves in areas relieved from traction, persistent ischemia in chronically damaged zones limits functional recovery. WF SS-OCTA is a promising tool for longitudinal monitoring of diabetic retinal disease and surgical outcomes.

INTRODUCTION

Proliferative diabetic retinopathy (PDR) is a major sight-threatening complication of diabetes mellitus, characterized by pathological neovascularization and fibrovascular proliferation on the retinal surface[1]. In its advanced stages, the contraction of fibrovascular membranes exerts traction on the retina, leading to tractional retinal detachment (TRD)-a condition that, if left untreated, can result in irreversible visual impairment or blindness. Pars plana vitrectomy (PPV) remains the standard of care for TRD, aiming to remove fibrovascular membranes, relieve traction, reattach the retina and preserve visual function. However, the degree of visual recovery post-surgery is highly variable and often limited by chronic ischemia and microvascular damage that precedes surgical intervention[2]. Conventional imaging modalities such as fluorescein angiography and optical coherence tomography (OCT) have provided critical insights into structural and perfusion abnormalities in diabetic retinopathy. Yet, these methods have inherent limitations-fluorescein angiography is invasive, dye-dependent and may not reliably visualize deeper capillary networks or areas obscured by hemorrhage, while traditional OCT lacks direct vascular imaging capability[3]. In recent years, optical coherence tomography angiography (OCTA) has emerged as a non-invasive, high-resolution imaging technique capable of visualizing the retinal and choroidal vasculature without the need for dye injection. Swept-source OCTA (SS-OCTA), in particular, offers improved penetration and faster scan speeds, enabling deeper tissue imaging and wider field of view[4]. Wide field SS-OCTA (WF SS-OCTA) extends the capability of standard OCTA by allowing visualization of the posterior pole and mid-peripheral retina in a single acquisition. This is especially advantageous in diabetic TRD, where tractional changes and ischemia often extend beyond the macula. By assessing perfusion across both the superficial and deep capillary plexuses, WF SS-OCTA enables comprehensive evaluation of microvascular changes associated with surgical intervention. Quantitative parameters such as vessel length density (VLD), perfusion density (PD) and foveal a vascular zone (FAZ) area offer objective markers of vascular integrity and remodeling[5]. Despite the potential of OCTA in retinal vascular diseases, data on its utility in the setting of surgically treated diabetic TRD remains limited. Postoperative assessment of retinal perfusion changes may provide valuable prognostic insights and help monitor disease progression or recurrence. Moreover, understanding how surgical intervention impacts perfusion may guide future strategies to optimize functional outcomes[6]. This prospective study was conducted at the Bascom Palmer Eye Institute, University of Miami Miller School of Medicine, to evaluate changes in retinal micro vasculature using WF SS-OCTA in eyes with diabetic TRD before and after vitrectomy. The primary objective was to quantify vascular changes in the superficial and deep retinal layers, correlate them with surgical outcomes and assess the feasibility of using OCTA in eyes with complex tractional pathology.

MATERIALS AND METHODS

This prospective observational study was conducted at the Bascom Palmer Eye Institute, University of Miami Miller School of Medicine. The study included 31 eyes from 21 patients diagnosed with diabetic tractional retinal detachment (TRD) due to proliferative diabetic retinopathy (PDR). Patients were recruited and imaged between January 2018 and December 2019. Informed consent was obtained from all participants and the study adhered to the tenets of the Declaration of Helsinki. Patients included in the study were adults with a confirmed diagnosis of PDR and tractional retinal detachment involving the posterior pole or mid-peripheral retina. All eyes had macular or near-macular involvement and surgical repair was indicated based on visual symptoms or progressive retinal traction. Exclusion criteria included coexisting rhegmatogenous retinal detachment, active intraocular inflammation, significant media opacities precluding imaging and history of prior vitrectomy in the study eye. All patients underwent comprehensive pre operative ophthalmic evaluation including best-corrected visual acuity (BCVA), slit-lamp bio microscopy, intraocular pressure measurement, dilated fundus examination and spectral-domain OCT. Wide field SS-OCTA imaging was performed using the PLEX Elite 9000 system (Carl Zeiss Meditec), which uses a 1,060 nm wavelength light source and 100 kHz A-scan rate. A 12×12 mm field-of-view scan centered on the fovea was obtained to assess both macular and extra macular perfusion. Each scan was segmented into superficial and deep capillary plexuses using built-in automated layer segmentation software, with manual corrections when needed.

Quantitative Metrics Analyzed Included:

- Foveal A vascular Zone (FAZ) Area.
- Vessel Length Density (VLD)-defined as the total length of perfused vessels per unit area (mm^{-1}).
- Perfusion Density (PD)-defined as the proportion of area occupied by blood vessels in the region of interest.

Image acquisition was repeated at three time points: preoperatively, 1 month and 4 months postoperatively. Scans with significant motion artifacts, poor signal strength (<6/10), or segmentation errors that could not be corrected were excluded from analysis. Surgical intervention consisted of 23-gauge pars plana vitrectomy (PPV) with dissection of fibrovascular membranes, posterior hyaloid removal,

endo laser photo coagulation and internal tamponade when required. The surgical procedure was performed by experienced vitreoretinal surgeons using a standardized technique. Quantitative OCTA parameters were measured using customized MATLAB-based software. Mean values of FAZ, VLD and PD were compared across time points. Statistical analysis was conducted using paired t-tests and repeated measures ANOVA to evaluate changes between pre-and postoperative measurements. A p-value of <0.05 was considered statistically significant. Additionally, correlations were assessed between OCTA parameters and clinical variables such as visual acuity, extent of detachment and presence of residual traction. Successful image acquisition rates were also reported as a secondary outcome to assess the feasibility of WF SS-OCTA in TRD.

RESULTS AND DISCUSSIONS

A total of 31 eyes from 21 patients with diabetic TRD were enrolled in the study. The mean age was 55.8 years and the majority of patients were male. Successful widefield swept-source OCTA imaging was achieved in most eyes at all follow-up visits. Postoperative improvement in perfusion metrics was noted, particularly in the vessel length density and perfusion density parameters. (Table 1) displays the age distribution of patients. Most participants were in the age group of 51-60 years.

Table 1: Age Distribution of Patients (N=21)

Age Group (years)	Number of Patients	Percentage (%)
41-50	4	19.0
51-60	11	52.4
61-70	6	28.6
Total	21	100.0

(Table 2) shows the gender distribution. Male patients were more commonly affected.

Table 2: Gender Distribution of Patients (N=21)

Gender	Number of Patients	Percentage (%)
Male	15	71.4
Female	6	28.6
Total	21	100.0

(Table 3) presents the number of eyes per patient. Some patients had bilateral involvement.

Table 3: Eye Involvement Pattern (N=31 Eyes)

Involvement Type	Number of Patients	Number of Eyes	Percentage (%)
Unilateral	11	11	52.4
Bilateral	10	20	47.6
Total	21	31	100.0

(Table 4) highlights the rate of successful OCTA image acquisition at each time point.

Table 4: OCTA Image Acquisition Success Rate

Time Point	Successful Scans	Total Eyes	Success Rate (%)
Preoperative	26	31	83.9
1 Month Postop	29	31	93.5
4 Months Postop	28	31	90.3

(Table 5) summarizes changes in foveal avascular zone (FAZ) area over time.

Table 5: Foveal Avascular Zone Area (mm^2)-Superficial Capillary Plexus

Time Point	Mean FAZ Area	Standard Deviation	p-value (vs Pre-op)
Preoperative	0.29	0.07	—
1 Month	0.30	0.08	0.45
4 Months	0.28	0.06	0.31

(Table 6) shows the changes in vessel length density (VLD) in the superficial plexus.

Table 6: Vessel Length Density (mm^{-1})-Superficial Capillary Plexus

Time Point	Mean VLD	Standard Deviation	p-value (vs Pre-op)
Preoperative	13.8	2.4	—
1 Month	15.2	2.2	0.03
4 Months	15.9	1.9	0.01

(Table 7) displays the changes in perfusion density (PD) in the superficial plexus.

Table 7: Perfusion Density (%)-Superficial Capillary Plexus

Time Point	Mean PD	Standard Deviation	p-value (vs Pre-op)
Preoperative	39.6	3.8	—
1 Month	42.1	4.1	0.02
4 Months	43.4	3.6	0.01

(Table 8) shows corresponding improvements in deep plexus vessel density.

Table 8: Vessel Length Density (mm^{-1})-Deep Capillary Plexus

Time Point	Mean VLD	Standard Deviation	p-value (vs Pre-op)
Preoperative	12.5	2.3	—
1 Month	13.4	2.1	0.04
4 Months	14.1	2.0	0.01

(Table 9) shows visual acuity changes across the study period.

Table 9: Mean Best-Corrected Visual Acuity (LogMAR)

Time Point	Mean BCVA	Standard Deviation	p-value (vs Pre-op)
Preoperative	0.94	0.33	—
1 Month	0.76	0.30	0.03
4 Months	0.72	0.27	0.01

(Table 10) outlines observed postoperative changes in ischemic and reperfused zones.

Table 10: Qualitative OCTA Findings at 4 Months

Finding	Number of Eyes	Percentage (%)
Improved perfusion zone	18	64.3
Persistent ischemic zone	10	35.7
Macular traction resolved	26	92.9
Macular traction persistent	2	7.1

Tractional retinal detachment remains a significant complication of proliferative diabetic retinopathy, often resulting from chronic fibrovascular proliferation and contraction. Surgical management through pars plana vitrectomy is essential to relieve traction and restore retinal attachment, but visual and vascular recovery vary based on the extent of preexisting ischemia and macular involvement. In this context, non-invasive imaging tools that objectively evaluate microvascular remodeling are of immense clinical value[7,8]. This study utilized widefield swept-source OCT angiography to quantify perfusion changes before

and after surgical repair in eyes with diabetic TRD. A total of 31 eyes from 21 patients were evaluated and successful imaging was achieved in more than 90 percent of eyes postoperatively. This reinforces the practicality of using widefield SS-OCTA in eyes with complex pathology such as TRD, even in the early postoperative period[9]. The results demonstrated a statistically significant increase in vessel length density and perfusion density in both superficial and deep capillary plexuses at one and four months postoperatively. These findings suggest that release of traction through vitrectomy facilitates revascularization or reperfusion in previously compromised regions. The increase in perfusion metrics was particularly evident in the macular and perimacular zones, areas most likely to be impacted by the resolution of traction and collapse of fibrovascular tissue[10]. The foveal avascular zone area remained stable across all time points, indicating that surgical repair did not significantly alter the size of the FAZ. This is consistent with the understanding that FAZ enlargement in diabetic retinopathy results primarily from capillary dropout, a process less reversible with surgery. Thus, the FAZ may serve as a stable marker of chronic microvascular damage rather than surgical success[11]. Interestingly, while perfusion metrics improved postoperatively, there was only a modest gain in visual acuity. This dissociation between structural perfusion and functional vision highlights the complexity of visual recovery in diabetic TRD. Long-standing ischemia, photo receptor damage and inner retinal thinning may limit visual restoration even after anatomical repair and reperfusion. Similar findings have been reported in previous studies using OCTA and fluorescein angiography, underscoring the need to interpret vascular recovery in conjunction with clinical context[12]. Qualitative evaluation of widefield OCTA images revealed that zones of improved perfusion corresponded to areas previously distorted by fibrovascular traction[13]. In contrast, regions with persistent ischemia often correlated with areas of capillary non-perfusion, suggesting that vascular remodeling is most likely where perfusion potential is preserved. These insights are critical for setting realistic expectations for patients and identifying eyes that may benefit from adjunct therapies[14]. Another important observation was the high success rate of OCTA image acquisition postoperatively. With optimized acquisition protocols and careful segmentation, widefield SS-OCTA proved reliable in evaluating postoperative perfusion, despite previous concerns about media clarity or motion artifacts in vitrectomized eyes[15]. Limitations of this study include its relatively small sample size and short-term follow-up. Longer observation periods would help determine whether the observed perfusion improvements are sustained and whether they correlate with delayed functional gains. Additionally, OCTA cannot assess leakage or choroidal perfusion, and segmentation errors in detached or post-surgical retinas may affect accuracy in some cases. Nonetheless, the findings from this study demonstrate that widefield swept-source OCTA is a valuable tool for monitoring vascular changes following surgery for diabetic TRD. It provides quantitative and qualitative insight into the dynamics of microvascular remodeling and can complement clinical and structural assessments in postoperative care.

CONCLUSION

Wide field swept-source OCT angiography offers a non-invasive, high-resolution method for evaluating retinal microvascular changes in eyes undergoing surgical repair for diabetic tractional retinal detachment. This study demonstrated significant postoperative improvements in vessel length density and perfusion density in both superficial and deep capillary plexuses, particularly in areas previously affected by traction. While anatomical re-attachment and vascular remodeling were evident, functional visual recovery remained variable, likely reflecting chronic ischemic damage. Wide field SS-OCTA is a promising imaging modality for monitoring retinal perfusion dynamics and surgical outcomes in diabetic retinopathy, with potential to guide postoperative management and future therapeutic strategies.

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