Original Article

Longitudinal Study on the Prevalence of Macular Ischemia and Its Association with Visual Acuity After Pars Plana Vitrectomy for Rhegmatogenous Retinal Detachment

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Abstract

Objective: To determine the frequency of macular ischaemia and compare visual acuity in patients with and without macular ischaemia following pars plana vitrectomy for rhegmatogenous retinal detachment(RRD).

Methods: This prospective study included 82 patients aged 18–70 years with primary RRD at the Ophthalmology Department of Alshifa Trust Eye Hospital, Rawalpindi. The exclusion criteria were secondary RRD, prior vitreoretinal surgery, macular disease, low-quality OCTA scans, amblyopia, and/or recurrent retinal detachment. Best-corrected visual acuity (BCVA) and slit-lamp examination were performed. One month postoperatively, macular ischaemia was evaluated using OCTA by measuring the foveal avascular zone (FAZ) and vessel density (VD), alongside postoperative BCVA and macular thickness. Demographic data, OCTA metrics, and visual outcomes were systematically recorded.

Results: Macular ischaemia was observed in 36 participants (43.9%). The median age was 30 years, and 65% were men. The median BCVA improved from 0.51 (IQR 0.28–0.74) before surgery to 0.30 (0.18–0.53) after surgery. The FAZ increased from 0.10 mm² (0.07–0.24) to 0.18 mm² (0.14–0.32), and vessel density decreased from 34.5% to 28.0%, with all changes being statistically significant. In an age-stratified analysis, participants aged 18–35 years showed significant improvement in BCVA and microvascular changes (all $p<0.001$), while those aged 36–70 years had significant changes in FAZ ($p=0.009$) and vessel density ($p=0.03$) but no significant improvement in BCVA ($p=0.10$).

Conclusion: Macular ischaemia is common after PPV for RRD. Although BCVA may improve postoperatively, minor retinal microvascular changes, such as FAZ enlargement and reduced VD, can persist.

Keywords: Macular Ischemia; Tomography, Optical Coherence; Angiography; Retinal Detachment; Vitrectomy

Contributions:
NY AM TA MS - Conception, Design
NY NQ FB - Acquisition, Analysis, Interpretation
NY AM FB MS - Drafting
NQ TA - Critical Review

All authors approved the final version to be published & agreed to be accountable for all aspects of the work.

Conflicts of Interest: None
Financial Support: None to report
Potential Competing Interests: None to report

Institutional Review Board Approval
ERC-36/AST-24
18-09-2024
Al-Shifa Trust Eye Hospital, Rawalpindi

Review began 20/10/2025
Review ended 16/01/2026
Published 31/03/2026

How to cite this article: Younas N, Qureshi N, Manzorr A, Ahmed T, Bukatari F, Shahid M. Longitudinal Study on the Prevalence of Macular Ischemia and Its Association with Visual Acuity After Pars Plana Vitrectomy for Rhegmatogenous Retinal Detachment. JRMC. 2026 Mar. 31;30(1).

https://doi.org/10.37939/jrmc.v30i1.3069

Introduction

RRD occurs when a break in the retina permits the entry of vitreous fluid into the subretinal space, thereby decoupling the neurosensory retina and the retinal pigment epithelium (RPE). It is estimated that it affects approximately 1 out of 10,000 individuals every year.[1] Without surgical intervention, severe visual impairment may result, particularly if the macular region is involved (macula-off RRD). Pars plana vitrectomy (PPV) is a highly effective surgical technique for repairing RRD, achieving anatomical success rates of 80–100%.[2]
Macular complications can occur after PPV for RRD. One study reported that 16.3% of patients developed macular ischaemia after PPV for RRD repair.[3] In approximately 1.1 % cases, macular holes can develop.[4] RRD has also been found to alter retinal vasculature after PPV, as defined by alterations in the foveal avascular zone of both the superficial capillary and deep capillary plexuses.[5] Such macular complications may affect visual outcomes, and not much improvement can be made to the visual outcomes despite successful treatment.[6]
In a noninvasive imaging technique,can be used to detect macular ischaemia, is called OCTA, and allows the measurement of such parameters as vessel density and foveal avascular zone (FAZ) enlargement.[7] Many OCTA results have been reported in macular ischaemia, including loss of vascular density, FAZ expansion, and retinal capillary plexus damage.[8,9] OCTA results, such as widespread capillary non-perfusion and disrupted vasculature, can be helpful in the diagnosis and treatment of macular ischaemia.[10]
The rationale for this study is the incidence and nature of macular ischemia after PPV through the use of OCTA. Through the evaluation of parameters that include the modification of the vascular density and FAZ expansion, the study aims to determine some of the main markers of ischemia, which can be associated with the achievement of a poor visual outcome. The results may enhance patient care practices through bettering the surgical methods, the best selection of patients, and post-operative management of patients to reduce ischemic injuries and promote the post-PPV RRD visual recovery. The study aims to provide a contribution to better clinical practices and outcomes in the treatment of macular ischemia due to an improved understanding of the pathophysiology of these conditions.
The objectives were to determine the frequency of macular ischemia using OCTA in patients who had previously undergone PPV to treat RRD, and also to determine the visual acuity (VA) of patients who had and had not experienced macular ischemia (MI).

Materials And Methods

This longitudinal study was conducted in the Ophthalmology Department of Alshifa Trust Eye Hospital, Rawalpindi, from May 10, 2025, to August 13, 2025. Participants were recruited using a sampling technique of non-probability consecutive sampling.
Using the WHO Sample Size Calculator, the anticipated population proportion was estimated at 16.3% based on a previous study[3]. With an absolute precision of 8% and a 95% confidence interval, the calculated sample size for the study was 82 participants.
We included patients aged 18–70 years who presented with primary rhegmatogenous retinal detachment (RRD) and underwent treatment. Subjects were excluded if they had non-rhegmatogenous retinal detachment or other aetiologies of vitreous haemorrhage or tractional retinal detachment, including proliferative diabetic retinopathy (PDR) or retinal vein occlusion. Patients with a history of previous vitreoretinal surgery or scleral buckling, preexisting macular diseases, including diabetic retinopathy, retinal vein occlusion, or posterior uveitis, or poor-quality optical coherence tomography angiography (OCTA) scans were also excluded. Additionally, patients with a history of amblyopia or repeated retinal detachment surgeries were not included in the study.
The research was conducted in accordance with hospital and research procedures. All participants were informed and provided with clear information on the objectives of the study, methodology, and risks and benefits before providing informed consent to participate. All efforts were made to ensure patient confidentiality during the research process, as required by accepted ethical principles.
Patients who underwent PPV for primary RRD were recruited. Preoperative visual acuity (VA) was measured using a Snellen chart, and a comprehensive slit-lamp examination was performed to evaluate ocular status. Following PPV, patients returned for follow-up one month postoperatively. At this visit, macular ischaemia was assessed using optical coherence tomography angiography (OCTA) with the Optovue device, measuring the foveal avascular zone (FAZ) and vessel density (VD). Postoperative visual acuity was also evaluated with a Snellen chart.
Visual acuity was measured using standardised charts, such as the Snellen chart, to determine the smallest letters or symbols that participants could correctly identify. These results were then converted to the logMAR scale. Macular thickness was assessed to identify changes related to macular ischaemia, which could appear as thinning (central subfield thickness [CST] < 250 µm) or thickening (CST > 300 µm) due to fluid buildup or oedema, with measurements taken one month after surgery. The foveal avascular zone (FAZ) was examined because macular ischaemia often leads to its enlargement, averaging 0.518 mm² in the superficial layer and 0.615 mm² in the deep layer, reflecting severe ischaemic damage and associated visual loss. Vessel density was also recorded, with normal eyes showing a mean macular vessel density of approximately 47.3% in the superficial layer and 55.1% in the deep layer, while eyes affected by macular ischaemia showed a marked reduction compared to these normal values.
R software 4.3.3 was used for data analysis. Qualitative variables, such as sex, macular ischaemia, and categorical visual acuity groups, were calculated as frequencies and percentages. Quantitative variables, including age, foveal avascular zone (FAZ), vessel density (VD), and macular ischaemia, were summarised as means ± standard deviation. Normality was checked using the Shapiro–Wilk test. Due to the lack of normality, the Wilcoxon rank sum test was used to compare preoperative and postoperative visual acuity, as well as changes in FAZ and VD. Age, sex, and macular ischaemia were considered potential effect modifiers through stratification, followed by post-stratification Wilcoxon rank sum tests. A *p-value* < 0.05 was considered statistically significant.

Results

The Shapiro–Wilk test indicated a non-normal data distribution (p <0.001) for age, BCVA, FAZ, and vessel density.
The median age was 30 years (IQR 24–41 years). Mostly the subjects were male (n=53, 64.6%), with females making up just over one-third of the sample (n=29, 35.4%). The majority (n=57, 69.5%) were aged between 18 and 35 years, while the remaining 25 participants (30.5%) were aged between 36 and 70 years. (**Table 1**) Macular Ischemia was present in 36(3.71%). **(Fig 1)**

Table 1: Distribution of demographics of the participants

Characteristic	N = 82
Age in years	30(24, 41)
Gender	
Female	29 (35.37)
Male	53 (64.63)
Age distribution	
18- 35 years	57 (69.51)
36-70 years	25 (30.49)

Table 2 summarises the baseline and postoperative visual and microvascular parameters of the study population (n =82). The median preoperative BCVA was 0.51 (IQR, 0.28–0.74), which improved postoperatively to 0.30 (0.18–0.53). The median preoperative FAZ area was 0.10 mm² (0.07–0.24 mm²), which increased postoperatively to 0.18 mm² (0.14–0.32 mm²). median vessel density decreased from 34.5% (26.0–42.0%) preoperatively to 28.0% (19.0–34.0%) postoperatively.

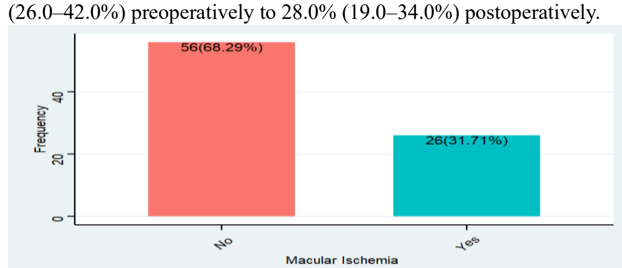

Figure 1: Frequency of Macular Ischemia

Table 2. Baseline and Postoperative Visual and Microvascular Parameters of the Study Population (N = 82)

Characteristic	Median(IQR)
Preoperative best-corrected visual acuity (BCVA)	0.51 (0.28, 0.74)
Postoperative best-corrected visual acuity (BCVA)	0.30 (0.18, 0.53)
Preoperative Foveal avascular zone (FAZ, mm²)	0.10 (0.07, 0.24)
Postoperative Foveal avascular zone (FAZ, mm²)	0.18 (0.14, 0.32)
Postoperative Vessel density (%)	34.50 (26.00, 42)
Postoperative Vessel density (%)	28 (19, 34)

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0.24 mm^2), which increased postoperatively to 0.18 mm^2 (0.14–0.32 mm^2). median vessel density decreased from 34.5% (26.0–42.0%) preoperatively to 28.0% (19.0–34.0%) postoperatively.

Table 3 compares the pre- and postoperative values of BCVA, FAZ, and vessel density in the study population (n=82). BCVA improved significantly postoperatively ($p<0.001$), whereas FAZ area increased and vessel density decreased, both of which were statistically significant ($p<0.001$).

Table 3 compares the pre- and postoperative values of BCVA, FAZ, and vessel density in the study population (n=82). BCVA improved significantly postoperatively ($p<0.001$), whereas FAZ area increased and vessel density decreased, both of which were statistically significant ($p<0.001$).

Table 3. Comparison of Pre- and Post-operative Values of BCVA, FAZ, and Vessel Density (n = 82)

Characteristic	Pre-operative (n = 82)	Post-operative (n = 82)	*p* value
BCVA	0.51 (0.28 , 0.74)	0.30 (0.18 , 0.53)	<0.001
FAZ	0.10 (0.07 , 0.24)	0.18 (0.14 , 0.32)	<0.001
Vessel density	34.50 (26.00, 42.00)	28.00 (19.00, 34.00)	<0.001

Median (Q1 to Q3), Wilcoxon rank sum test

Table 4 presents a comparison of the pre- and postoperative BCVA, FAZ, and vessel density, stratified by age group, sex, and the presence of macular ischaemia. In participants aged 18–35 years, BCVA improved significantly, FAZ increased, and vessel density decreased (all $p<0.001$). Significant changes were present in FAZ and vessel density ($p=0.009$ and $p=0.03$, respectively), whereas the improvement in BCVA was not statistically significant ($p=0.10$) in patients aged 36–70 years. All three parameters changed significantly postoperatively in both generations. BCVA, FAZ, and vessel density all showed significant differences ($p=0.025$) in women, and these changes were also highly significant ($p\leq0.001$) in men.. In patients without macular ischaemia, BCVA and vessel density improved significantly ($p=0.001$ and $p<0.001$), and FAZ increased ($p<0.001$). BCVA and vessel density improved ($p=0.021$ and $p<0.001$), and FAZ increased significantly ($p=0.01$) in cases with macular ischaemia.

Table 4: Comparison of Pre- and Post-operative Values of BCVA, FAZ, and Vessel Density (n = 82) stratified by age group, gender, and macular ischemia

Characteristic	**18- 35 years**			**36- 70 years**		
	Post operative	**Preoperative**	**p-value**[2]	**Post operative**	**Preoperative**	**p-value**
	N = 57	N = 57		N = 25	N = 25	
BCVA	0.39 (0.20, 0.56)	0.60 (0.31, 0.77)	<0.001	0.26 (0.12, 0.40)	0.39 (0.20, 0.61)	0.1
FAZ	0.19 (0.14, 0.31)	0.10 (0.06, 0.24)	<0.001	0.17 (0.15, 0.33)	0.09 (0.07, 0.24)	0.009
Vessel Density	29.0 (23.0, 33.0)	37.00 (30.00, 42.00)	<0.001	24.0 (15.0, 34.0)	31.0 (24.0, 40.0)	0.03
Characteristic	**Female**			**Male**		
	Post operative	**Preoperative**	**p-value**	**Post operative**	**Preoperative**	**p-value**
	N = 29	N = 29		N = 53	N = 53	
BCVA	0.34 (0.18, 0.50)	0.55 (0.28, 0.71)	0.025	0.29 (0.19, 0.53)	0.49 (0.30, 0.74)	0.001
FAZ	0.18 (0.14, 0.33)	0.10 (0.06, 0.25)	0.001	0.18 (0.15, 0.31)	0.10 (0.07, 0.23)	<0.001
Vessel Density	29.00 (22.00, 33.00)	37.00 (30.00, 42.00)	0.003	26.00 (19.00, 34.00)	34.00 (26.00, 42.00)	<0.001
Characteristic	**without Macular Ischemia**			**Macular Ischemia**		
	Post operative	**Preoperative**	**p-value**	**post_opt**	**Preoperative**	**p-value**
	N = 56	N = 56		N = 26	N = 26	
BCVA	0.29 (0.17, 0.55)	0.50 (0.28, 0.76)	0.001	0.32 (0.18, 0.49)	0.53(0.28, 0.7)	0.021
FAZ	0.16 (0.14, 0.19)	0.07 (0.06, 0.10)	<0.001	0.39 (0.33, 0.53)	0.3(0.24, 0.44)	0.01
Vessel Density	31.0 (27.5, 35.0)	39.0 (34.0, 44.0)	<0.001	14.0 (11.0, 20.0)	22(19., 30)	<0.001

Wilcoxon test, median(IQR)

Discussion

The current study determined the frequency of macular ischemia (MI) using Optical Coherence Tomography Angiography (OCTA) in patients who had undergone pars plana vitrectomy (PPV) for rhegmatogenous retinal detachment (RRD). We also assessed the visual acuity (VA) in patients with and without MI following PPV. Macular ischemia was present in 36 (43.9%) of the participants. The median preoperative best-corrected visual acuity (BCVA) was 0.51, which improved significantly to 0.30 after surgery. The foveal avascular zone (FAZ expanded from 0.10 mm^2 to 0.18 mm^2, while vessel density declined from 34.5% to 28.0%, both changes reaching statistical significance. These results indicate that although BCVA improves following surgery, microvascular changes, such as an enlarged FAZ and reduced vessel density, continue to be present.

The findings of our study are consistent with previous research showing significant postoperative changes in FAZ and vessel density. Lee et al. reported microvascular alterations in the nasal parafoveal region after PPV with silicone oil tamponade, with more pronounced effects observed in macula-off RRD cases.[11] Similarly, Tarkova et al,[12] using macular peeling and flap techniques, investigated changes in macular vascular density following PPV for idiopathic macular hole. They reported a significant reduction in the density of the superficial capillary plexus (from 32% to 28%) with a significant increase in the deep capillary plexus density (from 17% to 23%) after one-year follow-up. The intercapillary spaces changed in opposite ways in the two plexuses, showing that the macular microvasculature reorganises after surgery. Our findings support this and show that PPV leads to clear changes in macular microvascular structure, regardless of the type of retinal problem or surgical technique used.

Postoperative improvement in best-corrected visual acuity (BCVA) after PPV for RRD occurs as the retina reattaches and the subretinal fluid is resolved.[13] In RRD, detachment of the neurosensory retina from the retinal pigment epithelium impairs photoreceptor function, thereby reducing vision. PPV relieves vitreous traction, closes retinal breaks, and restores normal photoreceptor alignment, allowing visual function to recover.[14]

Surgery may also be used to treat concurrent conditions, including epiretinal membranes or macular oedema, which also contribute to visual improvement; however, the results depend on macular involvement and the retention time of detachment.[15]
Regarding visual outcomes, our study reported significant improvement in best-corrected visual acuity (BCVA) in patients with and without macular ischaemia after the operation. Sato et al. [16] discovered the same results, having found a BCVA improvement after the repair of macula-off rhegmatogenous retinal detachment with OCTA. However, the fact that microvascular changes persist even when the visual condition improves reflects the complexity of retinal recovery after surgery and points to OCTA as a valuable tool to reveal otherwise unnoticed microvascular changes that cannot be identified by means of confrontation visual acuity (CVA) evaluation alone. A systematic review and meta-analysis of pneumatic retinopexy (PnR) and pars plana vitrectomy (PPV) repair of RRD noted that, although PPV was associated with a better reattachment rate, the visual acuity remained greater in PnR patients. In other words, PnR patients demonstrated higher levels of preoperative and postoperative logMAR scores, and visual acuity improved more in PnR than in PPV patients after retinal detachment repair.[17]
The results should be interpreted with caution, keeping in mind its limitations, such as being a single-center study, having a small sample size, including only young adults, and a predominance of males, which limit generalisability. The study also lacks information on the treatment of macular ischaemia after PPV for RRD.

Conclusions

It can thus be concluded that macular ischaemia was commonly present in patients who received PPV as a treatment for RRD. Despite the significant improvement in BVA following surgery, microvascular changes, such as enlargement of the foveal avascular zone and decrease in the density of retinal vessels, remained. This implies that minor microvascular changes in the retina may persist. Surgeons should optimise surgical techniques to reduce ischaemic injury during PPV. Early detection of macular ischaemia can facilitate the provision of targeted treatments. These may include medications or visual rehabilitation to improve vision. The use of OCTA in routine follow-up can guide patient management and decisions regarding further care.

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