A Critical Analysis of Postoperative Outcomes in Rhegmatogenous Retinal Detachment Associated with Giant Tears: A Consecutive, Multicenter Study

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Research Article

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Abstract

Background: Currently there remains controversy in the surgical management of rhegmatogenous retinal detachment (RRD) due to giant retinal tears (GRTs), a potentially blinding condition. To clarify which surgical technique is better depending on the origin and magnitude of the giant tear this study aimed to analyze the anatomical and functional outcomes. To analyze trans- and postoperative surgical complications, we used long-term final postoperative structural, optical coherence tomography (OCT) and correlated the results with the final postoperative best-corrected visual acuity (BCVA) in three different groups of eyes.

Methods: Seventy-six consecutive eyes of 66 patients from three participant institutions were recruited and classified according to the degree of GRT-associated RRD extension as follows: group 1, 42 eyes with GRT-associated RRD extension < 180°; group 2, 23 eyes with GRT-associated RRD extension = 180°–270°; and group 3, 11 eyes with GRT-associated RRD extension > 270°. Structural and functional outcomes were compared across groups.

Results: Of the 76 eyes analyzed, 63 were phakic, and 13 were pseudophakic. The mean age of the patients was 43.0 ±13.0 years (range, 19–76 years); 36 females, and 40 males. The mean preoperative time for GRT surgery was 1.8 weeks, the mean preoperative and postoperative BCVA was 1.87 logMAR and 0.35 logMAR, respectively ($p<0.05$), and the mean postoperative follow-up was 28.1 months. Five patients (6.57%) had bilateral GRT-associated RRD, 61 patients (80.26%) had a monocular condition, and 21 eyes (27.63%) had a BCVA ≥20/40. Proliferative vitreoretinopathy resulted in multiple surgeries in 31.57% of the eyes. Postoperative OCT yielded abnormal retinal thickness in all groups, ellipsoid band disruptions, and external limiting line discontinuities in all groups, predominantly in macula-off GRTs requiring multiple surgeries.

Conclusions: Multiple structural alterations in spectral-domain OCT biomarkers were observed. Eyes that developed secondary epiretinal membrane (ERM) proliferation showed significantly improved BCVA after proliferation, and the internal limiting membrane was removed. This study presents the severe consequences of macular structure and function. The structural findings correlated with the BCVA allow us to conclude severe consequences of the macular structure and that, despite a fully reattached retina without ERM proliferation, GRTs-associated RRD has a guarded functional prognosis.

Background

Multiple surgical trans- and postoperative complications might be present in the already difficult surgical management of rhegmatogenous retinal detachment (RRD) associated with giant retinal tears (GRTs). Retinal detachment associated with GRTs is defined as a tractional event that is commonly acute and complicated by the vitreoretinal interface, in which pathological contraction phenomena of the vitreous and in the bed of a normal or predisposed retina causes a full-thickness circumferential retinal tear of >90° associated with vitreous detachment.[1–2] GRTs tend to form radial extensions that quickly cause detachment of the retina or the macula, depend on their location, thereby worsening the prognosis of visual recovery. These GRTs are often accompanied by complications such as vitreous hemorrhage and subretinal hemorrhage that can reach the submacular space, worsening the anatomical and functional prognoses with retinal pigment epithelium (RPE) cell dispersion in a gravity-dependent fashion with a rapid occurrence of proliferative vitreoretinopathy (PVR), and acute alterations in intraocular pressure due to uveal dysfunctions with a pro-cytokine inflammatory cascade from the blood-retinal barrier.

Currently, the calculated incidence ranges from 0.05% to 0.09% per 100,000 people per year, a condition that predominantly occurs in men with an incidence of 72%[1–6]; they represent 1.5% of the total RRDs, with an average age at diagnosis of 42 years and with a described bilateral not necessarily simultaneous presentation of 12.8%.[1,2,3,7]

Pathogenesis has involved pathological vitreous traction on the peripheral retina, especially the posterior edge of the vitreous base, often associated with condensation of the peripheral vitreous and liquefaction of the central vitreous. This is accompanied by anomalous or pathological contraction of the vitreous with collapse due to acute or subacute detachment of the posterior vitreous hyaloid face. Generally, the condensed posterior hyaloid face of the vitreous remains attached to only the anterior edge of the tear, making the liquefied vitreous quickly detach from the neurosensorial retina, which may fold over on itself. Hence, the posterior flap of the GRT is freely mobile and may fold over posteriorly.[2]

The retina can tear acutely in variable magnitudes depending on the substrate and conditions of each eye, or it can break subacutely and result in tears that gradually progress in a zipper fashion.[8] In some cases, the GRT associated with vitreoretinal traction may be caused by the coalition of multiple horseshoe tears that form posterior to the posterior border of the vitreous base during syneresis or collapse and synchytic phenomena due to acute pathological contraction of the vitreous, all of the above leads with certain local or systemic risk factors along with idiopathic or secondary conditions to the circumferential rupture of the retina greater than one peripheral quadrant (>90° retina rupture).[2,9,10] GRTs can be caused by different conditions; approximately 54% of GRTs are idiopathic, 25% are myopia-associated, 14% are associated with hereditary conditions with defects in type 2 collagen synthesis, such as Marfan's, Stickler–Wagner, and Ehrler Danlos syndromes, and 12.3% result from close-eye blunt trauma.[1,2,10–12]

GRTs are associated with certain local conditions of the eye (ocular risk factors) such as blunt trauma to the eyeball, high myopia, aphakia, pseudophakia, and generally genetic systemic alterations (systemic risk factors) such as young age and diseases that phenotypically manifest with collagen vascular disorders.[1,2,10–12]

The rate of anatomic success after the first procedure has been reported to be between 80% and 90%, while the final reattachment rate is 94%–100%.[13–15] However, this condition poses great challenges in its management due to its high risk of intra- and postoperative complications due to many technical difficulties involved, and the high rate of recurrent RRD due to the appearance of PVR reaches an incidence between 40% and 50%.[16]

Because of the limited published information related to long-term structural and functional results, this study mainly used visual acuity to assess changes in visual function after surgery. However, central retinal sensitivity is important for the quality of vision. Thus, this study aimed to describe the long-term postoperative structural and multimodal functional findings of GRT-associated RRD. This study intended to consecutively determine the postoperative comparative incidence of PVR and epiretinal membrane (ERM) proliferation over the macula, according to the extent of the tear and to the anatomical preoperative state of the macula, statistically analyze other trans- and postoperative surgical complications, provide long-term final postoperative structural, optical coherence tomography (OCT) findings, and correlate these results with the final postoperative best-corrected visual acuity (BCVA) in different surgical management methods for GRT-associated RRD.

Methods

The present study adhered to the tenets of the Declaration of Helsinki. All required approval was acquired from the three institutions enrolled (no reference number were provided for the present study). Written informed consent was obtained from all 30 patients, in accordance with institutional guidelines.

The clinical charts of 218 consecutive patients diagnosed with GRT-associated RRD who were surgically managed between January 2010 and January 2021 were analyzed. Only eyes with the retina applied and functional vision on the patients' last postoperative evaluations, regardless of the number of surgical procedures needed, were included. Thus, 76 selected eyes of 66 patients were included and classified according to the circumferential size of the GRT. Of the 76 eyes, 42 eyes had RRD associated with circumferential retinal tears <180° (group 1), 23 eyes had RRD associated with circumferential retinal tears between 180 °and 270° (group 2), and 11 eyes had RRD associated with circumferential GRTs >270° (group 3). Each eye of these groups was statistically analyzed to demonstrate the major anatomic clinical features of macula-off retinal detachment at the time of the first surgical procedure, the presence of an SB at the end of follow-up, the type of tamponade used, the rates and types of major transoperative and postoperative complications, and the number of additional vitreoretinal surgical procedures needed. Figure 1a-l shows different types of giant retinal tears.

The study was also designed to comparatively analyze the anatomical and structural outcomes of primary vitrectomy techniques without a supplemental buckle in eyes with a giant circumferential retinal tear >180° (more than two retinal quadrants) and vitrectomy techniques with a supplemental SB in eyes with a giant circumferential retinal tear of <180°. The postoperative redetachment rate and the incidence of postoperative ERM proliferation were defined in the three surgical groups. Only eyes in which the retina was successfully reattached for a minimum of 6 months of follow-up after the last vitreoretinal surgical procedure were included in the general dataset.

Moreover, only patients with GRT-associated RRD without consideration of etiology and with the retina fully attached without the presence of intraocular silicon in the last follow-up visit were included; thus, 43 patients (65.15%) with GRTs of idiopathic etiology and 23 patients (34.84%) who were considered to have GRTs associated with high myopia, connective tissue alterations (Marfan–Stickler syndrome), and severe closed-eye contusion trauma were included.

Only the charts of patients aged ≥18 years who fulfilled the inclusion criteria of a GRT-associated RRD, evidence of PVR grade B or less, retina attached at the last follow-up examination visit, postoperative BCVA in the functional range (20/800 or better), absence of intraocular silicone oil in the last follow-up visit, at least 6 months of follow-up, and a well-serial documented structural and functional assessment of the macula during follow-up were included.

The exclusion criteria were as follows: prior complicated vitreoretinal surgery or intravitreal injections, GRT-associated RRD due to penetrating or perforating open-eye injury, GRT-associated RRD combined with macular hole retinal detachment due to myopic traction maculopathy, postoperative BCVA of 20/800 or worse, presence of intraocular silicone oil at the last follow-up evaluation visit, severe grade C posterior PVR or anterior PVR with evidence of recurrent and complicated RRD at the last follow-up visit, and history of active glaucoma. The additional exclusion criteria were impossibility to follow-up, loss of follow-up, surgery in a non-designated institution, presence of severe complications such as endophthalmitis, recurrent, complicated severe PVR RRD at the last follow-up visit evaluation, and refractory corneal opacity development during follow-up.

The following postoperative structural assessments of the eyes were statistically analyzed in the three groups: long-term postoperative structural spectral-domain (SD)-OCT findings including central subfoveal thickness (CSFT), foveal contour profile, central subfoveal ellipsoid band status, central subfoveal external limiting membrane (ELM) line appearance, en-face imaging or cross-sectional SD-OCT B scan analysis for the presence of dissociated optic nerve fiber layer (DONFL) defects, and the presence of ERM proliferation over the macula. Postoperative functional evaluations were performed with the final BCVA in logMAR units.

Results

Examinations

The 76 eyes of 66 patients underwent a general ophthalmic evaluation and preoperative examinations, including BCVA assessment, biomicroscopy slit-lamp examination, fundus examination by a panfundoscopic contact lens, and indirect ophthalmoscopy. Cross-sectional images of the macular region were acquired along the horizontal plane through the foveal center using the Spectralis OCT (Heidelberg Engineering, Heidelberg, Germany) or in some cases by using SD-OCT (RTVue-XR platform SD-OCT, Optovue Inc., Fremont, CA, USA), the axial lengths were measured using partial coherence laser interferometry (Zeiss IOL Master 700; Carl Zeiss Meditec AG, Oberkochen, Germany). The presence of RTassociated RRD was confirmed by indirect ophthalmoscopy and B-scan ultrasonography (A and B Ultrasound Unit, Quantel Medical, Du Bois Loli, Auvergne, France). A postoperative microstructural evaluation was performed using SD-OCT Spectralis OCT), SD-OCT RTVue-XR platform SD-OCT), and a swept-source (SS)-OCT device (Topcon Medical Systems, Inc., Oakland, NJ, USA). All OCT images were analyzed by three experienced retina specialists (co-authors) from the three participating institutions.

Surgical technique

A standard 23- or 25-gauge 3-port pars plana vitrectomy (Alcon Constellation Vision System, Alcon Labs, Fort Worth, TX, USA) was performed in all eyes under local anesthesia and sedation by one of the authors (MAQR). The vitrectomy was performed using a contact wide-angle viewing precorneal lens system (ROLS reinverted system Volk Medilex, Miami, FL, USA), the Wide Angle Viewing System (WAVS) with the resight non-contact lens (Carl Zeiss Meditec AG, Jena Germany), or recently in the last four cases the Zeiss ARTEVO 800 digital ophthalmic 3-D head-up microscope with the resight non-contact lens system, which was implemented as a hybrid mode (coaxial and 3-d HD 4K monitor), and integrated transoperative OCT allowed retinal structural intraoperative imaging analysis and real-time detection of ERM proliferation, enabling a more precise membrane dissection and stripping. In addition to central vitrectomy, our standard technique includes the use of diluted triamcinolone acetonide adjuvant (Kenalog 40 mg/mL; Bristol-Myers Squibb, New York, NY, USA) to identify and better visualize the vitreous face, vitreous base, and its posterior border, and safely perform an integral removal of the cortical face from the surface of the retina using a silicone-tipped cannula with active suction prior to perfluorocarbon liquid (PFCL) infusion and reattachment of the retina. The vitreous was carefully and precisely removed mainly from the anterior border of the GRT. The absolute release of the posterior retinal flap was checked, and showed that it tended to bend on itself, as was in many surgical cases. Then, the anterior retinal flap was trimmed in most cases to avoid anterior PVR and the release of vascular endothelial growth factor from this ischemic retina. The retina was reattached by a PFCL-assisted technique to effectively perform hydropneumatic retinal manipulation and assisted subretinal fluid (SRF) endodrainage; in all the cases, we performed meticulous drying of the subretinal space and RPE along the edges of the GRT, and in some cases, a direct perfluorocarbon-silicon oil exchange was performed to avoid posterior retinal slippage.

Phacoemulsification with in-the-bag intraocular lens implantation techniques was uneventfully performed in all phakic eyes. Subsequently, the vitreous base was shaved 360°, assisted with scleral depression or recently by doing self-scleral depression assisted with a single 27-gauge (disposable Eckard TwinLight Chandelier; Dutch Ophthalmic Research Center International, DORC International, Zuidland Netherlands), that was inserted into the trocar, and the non-contact WAVS with the resight lens was carefully applied in regions where the retina was detached and not broken or attached. This assisted scleral depression allowed the complete removal of the vitreous traction from the GRT and careful shaving and debulking of the vitreous base using mostly closed port duty cycle with high speed and low vacuum levels to perform a safer shaving of peripheral vitreous mainly over areas of the detached retina without producing iatrogenic retinal tears. Our young patients generally showed vitreous that was attached or only partially detached, and removing the core vitreous was relatively straightforward. However, separation of the posterior hyaloid and other areas of adherent vitreous in the periphery with a very mobile retina was technically intricate, especially when concurrent lattice degeneration was present. Injection of a PFCL is used to flatten and unfold to manipulate and immobilize the posterior retina. Once the retina was reattached without an SB, performing meticulous peripheral vitrectomy and ensuring a complete vitreous release with trimming of the anterior giant retinal flap, after all other retinal tears were identified and laser-treated along with the retinal lateral posterior extension tears (horns tears), were crucial. Additional benefits of the vitrectomy technique in these eyes were the removal of all vitreous opacities, attending to opacified lens capsules, and addressing the cases where significant macular ERM proliferation pre- or transoperatively was confirmed. Once the retina was completely attached and before the SB placement, for the ERM proliferation/removal, a transoperative surgical macular staining was performed using 0.15 mL of a 0.25 mg/mL (0.025%) diluted isomolar solution (pH 7.4) of Brilliant Blue G dye (BBG), to selectively stain and remove the internal limiting membrane (ILM) en-bloc with the ERM. For the ILM–ERM en bloc removal technique, a 23- or 25-gauge diamond-dusted membrane scraper and 25-gauge 0.44 ILM forceps (Grieshaber Revolution DSP ILM forceps; Alcon Labs, Fort Worth, TX, USA) and a 23- or 25-gauge Finesse ILM flex loop microinstrument (Grieshaber; Alcon Labs) to facilitate the removal of ERM and ILM from arcade to arcade. In cases where the removal was performed in two steps (double staining technique), trypan blue 0.15% ophthalmic solution (Membrane Blue; Dutch Ophthalmic, Exeter, NH, USA) was instilled under air to remove the ERM proliferations after washing the dye; in the second step, the ILM was stained with the aforementioned BBG dye and removed (two-step or double staining technique removal).

We performed SRF endodrainage very slowly by implementing a first-step fluid-to-fluid exchange over the edge of the GRT to avoid posterior retinal slippery and to remove viscous proteinaceous SRF, to reduce the extent of SRF and minimize the chance of trapped SRF before proceeding to an air-fluid exchange and continuing with SRF drainage. Once the retina was completely free of vitreous traction and completely reattached, 360° continuous argon laser endophotocoagulation in three to four rows, mainly at the peripheral edge of the circumferential retinal giant tear and lateral posterior radial extensions (horns tears) of the giant lesion, was thoroughly performed. To completely dry out the subretinal space, a second air-fluid exchange was performed, and as the last surgical step, a non-expandable bubble containing 15% perfluoropropane (C_3F_8) gas mixture or lighter than water silicon oil was used as a long-acting tamponade at the end of the procedure in all cases. Figure 2 shows surgical approaches (images a–l).

As part of the standardized selected technique of the author, and once the retina is fully reattached only with vitrectomy techniques and laser retinopexy to avoid posterior retinal slippage or radial folds in all eyes, a methodical, standardized, classical complementary low-lying SB surgical procedure was performed in the eyes with GRTs < 180° (by one of the authors, MAQR) consistent with traditional 504, 503, 360° round Lincoff episcleral sponges (Storz model E-5395-4) and oval foam silicon sponges (506 style S 1981-5 or 501 style S 1981-4) with the new designed profile (Labtician Ophthalmics, Inc., Oakville, Ontario, Canada) around the equator according with the axial length of the eye, or standard 240 circling silicon band (style 240/S-2987 by DORC) and 41 circling silicon band (style 41/S-2970 by DORC) in some cases, the SB was fixed with polyester 5-0 MERSILENE® Polyester Sutures, double-armed 3/8 circle spatulated needle suture (ETHICON, Johnson & Johnson, Brunswick, NJ, USA).

Statistical methodology

A two-tailed Student's t-test was used to assess the normality of the distribution of continuous variables, and eyes were divided into three groups according to tear magnitude: group 1, tear <180°; group 2, tear 180–270°; and group 3, tear >270°. Variables were expressed as frequencies for discrete factors and mean values for continuous factors. Statistical comparisons were performed using the two-tailed chi-square test for categorical variables, and a two-tailed Student's t-test for continuous variables was appropriate. Significance was set at p-value <0.05. A two-tailed paired samples t-test was conducted to examine whether the mean difference in preoperative BCVA in logMAR units and final postoperative BCVA in logMAR units was significantly different from zero. Repeated measures analysis of variance (ANOVA) was applied to see the before-and-after differences among the tear magnitude groups associated with other study factors. A linear regression analysis was conducted to assess whether CSFT in microns, DONFL defects, ELM line, tear magnitude, and ellipsoid band status (inner segment/outer segment band-IS/OS zone) significantly predicted final postoperative BCVA in logMAR units. A multivariate binary logistic regression analysis was performed to evaluate possible factors important for lower final postoperative BCVA in logMAR units. The Kaplan–Meier method was used to evaluate the general survival for final postoperative BCVA logMAR units between the divided eye groups. All statistical analyses were performed using SPSS 27 (IBM Corp., Armonk, NY, USA). The size of the effect observed in Student's t-test was also determined. Cohen's *d* was calculated as 1.87, resulting in a large effect size according to the 1988 Cohen conventions.[17] Cohen's *d* gives a biased estimate of the population effect size, especially when the samples are <20.[18] Therefore, Cohen's *d* is referred to as the uncorrected effect size. The corrected value is Hedges' *g,* which for our study was 1.65, indicating a relatively large effect size.

We determined that the power of the Mann–Whitney U tests and the Kruskal–Wallis tests that we used were very good (power = 86.5% and power = 99.0%) for the given sample size (n = 76) and for a medium effect size (Cohen's d = 0.5).

The Shapiro–Wilk normality test results showed that most numerical data followed a normal distribution (p<0.05); hence, the nonparametric Mann–Whitney U test was used to investigate the associations of the preoperative BCVA and postoperative BCVA in terms of the differences in medians of these variables.

Statistical results

The patients' general and demographic data are presented in Table 1. Among the 76 eyes analyzed, the general prevalence of preoperative primary ERM proliferation was 4.78% (11 eyes), but only eight eyes (10.52%) with attached retina underwent ERM-ILM surgery; however, this prevalence was not statistically considered due to the heterogeneity of criteria used to define preoperative primary or postoperative secondary ERM proliferation and because the GRT associated RRD eyes are in high risk of developing surgical complication with additional surgical procedures.

Throughout the postoperative follow-up, additional surgical procedures were performed in nine (11.84%) eyes in which significant and symptomatic macular folds were detected due to posterior retinal slippage, vitrectomy review by retained PFCLs in five eyes (6.57%) and reoperation for a macular hole that was not detected in the first surgical time in one eye (1.31%) as aforementioned (Figure 3). According to our statistical results there was no significant difference in postoperative ERM proliferation incidence by tear magnitude.

Structural results (SD-OCT patterns)

To describe the structural postoperative SD-OCT findings (Table 1), we used the terminology proposed by the International Nomenclature for Optical Coherence Tomography Panel report,[20] which were correlated with the functional findings. The statistical program yielded the following SD-OCT abnormalities in the macula-off GRT-associated RRD group: ellipsoid band disruption was observed in 57.9%, CSFT abnormalities in 74.7%, and ELM line alterations in 42.1% of the eyes. In the macula-on GRT-associated RRD group, ellipsoid band disruption was observed in 41.3%, CSFT abnormalities in 62.3%, and ELM line alterations in 51.9% of eyes (Figure 4a-j, Figure 5a-l). The differences between these categorical variables were not considered significant ($p>0.05\%$).

Table 1

Comparison between tear magnitude groups to measure the associations from the other study variables

	Sample	Tear <180°	Tear 180-270°	Tear>270°	p-value	N
	N=76	*N=44*	*N=21*	*N=11*		
Age	43.0 (13.0)	44.1 (12.8)	40.0 (11.3)	44.7 (16.8)	0.453	76
Sex:					0.239	76
Female	36 (47.4%)	24 (54.5%)	9 (42.9%)	3 (27.3%)		
Male	40 (52.6%)	20 (45.5%)	12 (57.1%)	8 (72.7%)		
Eye:					0.986	76
Right	41 (53.9%)	24 (54.5%)	11 (52.4%)	6 (54.5%)		
Left	35 (46.1%)	20 (45.5%)	10 (47.6%)	5 (45.5%)		
Preop lens status:					0.426	76
Pseudophakic	13 (17.1%)	8 (18.2%)	2 (9.52%)	3 (27.3%)		
Phakic	63 (82.9%)	36 (81.8%)	19 (90.5%)	8 (72.7%)		
Etiology:					<0.001	76
Idiopathic	42 (55.3%)	30 (68.2%)	11 (52.4%)	1 (9.09%)		
Myopia	15 (19.7%)	7 (15.9%)	7 (33.3%)	1 (9.09%)		
Blunt trauma	5 (6.58%)	3 (6.82%)	2 (9.52%)	0 (0.00%)		
Marfan	5 (6.58%)	0 (0.00%)	0 (0.00%)	5 (45.5%)		
Stickler	5 (6.58%)	1 (2.27%)	1 (4.76%)	3 (27.3%)		
Marchesani	4 (5.26%)	3 (6.82%)	0 (0.00%)	1 (9.09%)		
Macula at surgery:					0.219	76
Macula-on	15 (19.7%)	7 (15.9%)	7 (33.3%)	1 (9.09%)		

	Sample	Tear <180°	Tear 180-270°	Tear>270°	p-value	N
	N=76	*N=44*	*N=21*	*N=11*		
Macula-off	61 (80.3%)	37 (84.1%)	14 (66.7%)	10 (90.9%)		
preop logMAR	1.07 (0.61)	1.13 (0.57)	0.82 (0.53)	1.30 (0.77)	0.063	76
Months of follow-up	41.1 (29.1)	38.0 (27.0)	51.2 (35.3)	33.9 (20.2)	0.157	76
Final postop logMAR	0.56 (0.26)	0.55 (0.27)	0.68 (0.24)	0.35 (0.15)	0.002	76
Recurrent RRD	18 (23.7%)	8 (18.2%)	8 (38.1%)	2 (18.2%)	0.253	76
Recurrence cause:					0.363	76
No	58 (76.3%)	36 (81.8%)	13 (61.9%)	9 (81.8%)		
PVR	12 (15.8%)	4 (9.09%)	6 (28.6%)	2 (18.2%)		
PVR+choroidals	5 (6.58%)	3 (6.82%)	2 (9.52%)	0 (0.00%)		
Undetected macular hole	1 (1.32%)	1 (2.27%)	0 (0.00%)	0 (0.00%)		
Tamponade type:					0.020	76
C_3F_8	53 (69.7%)	36 (81.8%)	12 (33.3%)	5 (9.09%)		
Silicon	23 (30.3%)	8 (18.2%)	9 (42.9%)	6 (54.5%)		
Additional surgery:					0.300	76
No	56 (73.7%)	35 (79.5%)	12 (57.1%)	9 (81.8%)		
Silicon removal	2 (2.63%)	1 (2.27%)	1 (4.76%)	0 (0.00%)		
Vitrectomy revision	18 (23.7%)	8 (18.2%)	8 (38.1%)	2 (18.2%)		
Postop ERMs	18 (23.7%)	12 (27.3%)	4 (19.0%)	2 (18.2%)	0.745	76

	Sample	Tear <180°	Tear 180-270°	Tear>270°	p-value	N
	N=76	*N=44*	*N=21*	*N=11*		
ERM surgery:					0.899	76
ERM removal	8 (10.5%)	6 (13.6%)	1 (4.76%)	1 (9.09%)		
No	58 (76.3%)	32 (72.7%)	17 (81.0%)	9 (81.8%)		
Vitrectomy revision + ERM removal	10 (13.2%)	6 (13.6%)	3 (14.3%)	1 (9.09%)		
Other complications:					0.451	76
Macular fold	9 (11.8%)	5 (11.4%)	4 (19.0%)	0 (0.00%)		
No	61 (80.3%)	36 (81.8%)	16 (76.2%)	9 (81.8%)		
Retained PFCL	5 (6.58%)	2 (4.55%)	1 (4.76%)	2 (18.2%)		
Undetected macular hole	1 (1.32%)	1 (2.27%)	0 (0.00%)	0 (0.00%)		
CSFT microns	209 (28.2)	210 (27.6)	199 (24.3)	228 (29.4)	0.019	76
Foveal contour:					0.067	76
Normal	23 (30.3%)	14 (31.8%)	3 (14.3%)	6 (54.5%)		
Abnormal	53 (69.7%)	30 (68.2%)	18 (85.7%)	5 (45.5%)		
Ellipsoid band:(IS/OS)					0.845	76
Normal	48 (63.2%)	28 (63.6%)	14 (66.7%)	6 (54.5%)		
Disrupted	28 (36.8%)	16 (36.4%)	7 (33.3%)	5 (45.5%)		
DONFL defects:					0.296	76
Absent	53 (69.7%)	30 (68.2%)	17 (81.0%)	6 (54.5%)		
Present	23 (30.3%)	14 (31.8%)	4 (19.0%)	5 (45.5%)		
ELM line:					0.635	76

	Sample	Tear <180°	Tear 180-270°	Tear>270°	p-value	N
	N=76	*N=44*	*N=21*	*N=11*		
Normal	47 (61.8%)	25 (56.8%)	14 (66.7%)	8 (72.7%)		
Disrupted	29 (38.2%)	19 (43.2%)	7 (33.3%)	3 (27.3%)		

C_3F_8, perfluoropropane; CSFT, central subfoveal thickness; DONFL, dissociated optic nerve fiber layer; ELM, external limiting membrane; ERM, epiretinal membrane; IS/OS, internal segment/external segment; PFCL, perfluorocarbon liquid; Postop, postoperative; Preop, preoperative; PVR, proliferative vitreoretinopathy; RRD, rhegmatogenous retinal detachment

Functional results

The mean preoperative BCVA was 1.87±0.15 logMAR vs the mean postoperative BCVA of 0.35±0.21 in logMAR units with a p value < 0.05 (p = 0.01) (Table 1).

The Spearman's rank correlation coefficient test showed a moderate negative correlation (rho = −0.53, p < 0.01) of the postoperative BCVA (logMAR) with the CSFT in microns **(**Figure 6).

A chi-square test of independence was conducted to examine whether tear magnitude and etiology were independent. The results of the chi-square were significant based on an alpha value and p < .001, suggesting a relationship between tear magnitude and etiology. An ANOVA was conducted to determine whether there were significant differences in the final postoperative BCVA logMAR units by tear magnitude.

There were significant differences in final postoperative BCVA in logMAR units among the levels of tear magnitude (Table 1). The eta squared was 0.16, indicating tear magnitude explained approximately 16% of the variance in final postoperative BCVA. Regarding the main effect of tear magnitude, the mean final postoperative BCVA for tear magnitude was significantly larger than for tear >270º (p =.048). For the main effect of tear magnitude, the mean of final postoperative BCVA for tear 180-270º was significantly larger than for tear>270º (p = .001). No other significant effects were found. However, paired *t*-tests were calculated between each pair of measurements to further examine the differences among the variables. Tukey pairwise comparisons (post hoc) were conducted for all significant effects, based on an alpha of 0.05.

The chi-square test results showed a significant relationship between tear magnitude and tamponade type based on an alpha value of 0.05, $\chi2(2) = 7.69$, p = 0.21.

A linear regression analysis was conducted to assess whether CSFT, DONFL defects, ELM line, tear magnitude, and ellipsoid band status (IS/OS) significantly predicted final postoperative BCVA in logMAR units. The Shapiro–Wilk test determined that results were not significant based on an alpha value of 0.05, $W = 0.97$, $p = .091$[20]. This result suggests the possibility that the residuals of the model were produced by a normal distribution, indicating that the assumption of normality was met.

Multicollinearity

High Variance inflation factors (VIFs) indicate increased effects of multicollinearity in the model. VIFs > 5 are cause for concern, whereas VIFs of 10 should be considered the maximum upper limit.[22] VIFs for all predictors in the regression model were < 10. Table 2 presents the VIFs for each predictor in the model.

Table 2

Variance inflation factors for CSFT in microns, DONFL defects, ELM line, TEAR MAGNITUDE, and ELLIPSOID band

Variable	VIF
CSFT in microns	1.23
DONFL defects	1.29
ELM line	1.51
Tear magnitude	1.23
Ellipsoid band (IS/OS zone)	1.47

CSFT, central subfoveal thickness; DONFL, dissociated optic nerve fiber layer; ELM, external limiting membrane; IS/OS, internal segment/external segment; VIF, variance inflation factors

The results of the linear regression model were significant ($p < .001$) indicating that approximately 37% of the variance in final postoperative BCVA in logMAR units were explained by CSFT in microns, DONFL defects, ELM line, tear magnitude, and ellipsoid band status (IS/OS zone). CSFT significantly predicted the final postoperative BCVA ($p < .001$). This indicated that, on average, a one-unit increase of CSFT in microns decreased the value of final postoperative BCVA in logMAR by 0.00 units. The category of DONFL defects did not significantly predict the final postoperative BCVA ($p = .898$). Based on this sample, this suggests that moving from the absent to presence of DONFL defects did not have a significant effect on the mean final postoperative BCVA. The disrupted category of the ELM line did not significantly predict final postoperative BCVA ($p = .476$). Moreover, this suggests that moving from the normal to disrupted category of ELM did not have a significant effect on the mean final postoperative BCVA. The tear 180–270° category of tear magnitude did not significantly predict final postoperative BCVA ($p = .120$), suggesting that moving from the tear 270° category of tear magnitude did not significantly predict final postoperative BCVA ($p = .157$) or have a significant effect on the mean final postoperative BCVA (Figure 7). The disrupted category of ellipsoid band did not significantly predict the final postoperative BCVA ($p = .658$), suggesting that moving from the normal to disrupted category of ellipsoid band status (EZ) did not have a significant effect on the mean final postoperative BCVA. Table 3 summarizes the results of regression model.

Table 3

Regression model parameter estimates to measure the association of the OCT biomarkers.

Variable	*B*	*SE*	90% CI	β	*t*	*p*
(Intercept)	1.46	0.21	[1.11, 1.81]	0.00	6.96	< .001
CSFT in microns	−0.00	0.00	[−0.01, −0.00]	−0.48	−4.55	< .001
DONFL (present)	0.01	0.06	[−0.10, 0.11]	0.01	0.13	.898
ELM line (disrupted)	0.05	0.06	[−0.06, 0.15]	0.08	0.72	.476
Tear magnitude (tear 180–270°)	0.09	0.06	[−0.01, 0.19]	0.16	1.57	.120
Tear magnitude (tear>270°)	−0.11	0.08	[−0.24, 0.02]	−0.15	−1.43	.157
Ellipsoid band (disrupted)	0.03	0.06	[−0.08, 0.13]	0.05	0.44	.658

Note: Results: $F(6,69) = 6.77$, $p < .001$, $R^2 = 0.37$

CSFT, central subfoveal thickness; DONFL, dissociated optic nerve fiber layer; CI, confidence interval; ELM, external limiting membrane; OCT, optical coherence tomography; SE, standard error

The results of the two-tailed paired samples *t*-test was significant based on an alpha value of 0.05, ($p < .001$), indicating that the null hypothesis could be rejected. Thus, the difference in the mean preoperative BCVA in logMAR units and the mean of final postoperative BCVA in logMAR units was significantly different from zero. The mean preoperative logMAR was significantly higher than the mean final postoperative BCVA in logMAR units. The results are presented in Table 4. A bar plot of the means is presented in Figure 8.

Table 4

Two-tailed paired samples t-test for the difference between preoperative logMAR and final postoperative logMAR

PREOP logMAR		FINAL POSTOP logMAR				
M	*SD*	*M*	*SD*	*t*	*p*	*d*
1.07	0.61	0.56	0.26	6.88	<0.001	0.79

Note: N = 76. Degrees of freedom for t-statistic = 75. d represents Cohen's d.

M, mean; POSTOP, postoperative; PREOP, preoperative; SD, standard deviation

To further understand the significant differences between preoperative BCVA and final postoperative BCVA, a repeated measures analysis of covariance (ANCOVA) with one within-subjects factor was conducted to determine whether significant differences existed between preoperative BCVA and final postoperative BCVA after controlling for tear magnitude and tamponade type. Table 5 shows the most significant factors that controlled the differences between preoperative BCVA and final postoperative BCVA.

Table 5

Repeated measures ANCOVA results for the difference between preoperative logMAR and final postoperative logMAR

Source	*df*	*SS*	*MS*	*F*	*p*	$\eta_p 2$
Between-subjects						
Tear magnitude	2	0.50	0.25	1.17	.317	0.03
Tamponade type	2	1.73	0.86	4.01	.022	0.10
Residuals	71	15.29	0.22			
Within-subjects						
Within factor	1	6.88	6.88	39.19	<.001	0.36
Tear magnitude: within.factor	2	3.04	1.52	8.66	<.001	0.20
Tamponade type: within.factor	2	0.60	0.30	1.71	.188	0.05
Residuals	71	12.46	0.18			

ANCOVA, analysis of covariance; postop, postoperative; preop, preoperative; SS, sum of squares; MS, mean square

The results were examined based on an alpha of 0.05. Tear magnitude was not significantly related to preoperative BCVA and final postoperative BCVA ($p = .317$). Tamponade type was significantly related to preoperative BCVA and final postoperative BCVA ($p = .022$). The main effect for the within-subjects factor was significant ($p < .001$), indicating significant differences between the values of preoperative BCVA and final postoperative BCVA after controlling for tear magnitude and tamponade type. The interaction effect between the within-subjects factor and tear magnitude was significant, ($p < .001$), indicating that the relationship between preoperative BCVA and final postoperative BCVA differed significantly between the levels of tear magnitude (Figure 9). The interaction effect between the within-subjects factor and tamponade type was not significant ($p = .188$), indicating that the relationship between preoperative BCVA and final postoperative BCVA was similar between the levels of tamponade type. Table 5 presents the ANCOVA results.

A binary logistic regression analysis was conducted to examine whether months of follow-up, tear magnitude, CSFT in microns, status of the macula at surgery, recurrent RRD, foveal contour appearance, ellipsoid zone (EZ), DONFL defects, and ELM line had a significant effect on the odds of observing the 20/300 or worse category of postoperative BCVA. The reference category for final BCVA was between 20/50 to 20/200.

The model was evaluated based on an alpha of 0.05 (Table 6). The overall model was significant ($p < .001$), suggesting that months of follow-up, tear magnitude, CSFT in microns, status of the macula at surgery, recurrent RRD, postoperative foveal contour appearance, EZ status, DONFL defects, and ELM line appearance had a significant effect on the odds of observing the 20/300 or worse category of postoperative BCVA. McFadden's R-squared was calculated to examine the model fit, where values > .2 are indicative of models with excellent fit.[22] The McFadden R-squared value calculated for this model was 0.49. The regression coefficient for months of follow-up was significant ($p = .020$), indicating that for a one-unit increase in months of follow-up, the odds of observing the 20/300 or worse category of postoperative BCVA increased by approximately 4%. Additionally, the regression coefficient for macula-off at surgery was significant ($p = .04$), indicating that for a one-unit increase in macula-off at surgery, the odds of observing the 20/300 or worse category of postoperative BCVA increased by approximately 638%. However, the regression coefficient for foveal contour appearance was significant ($p < .001$), indicating that for a one-unit increase in foveal contour abnormality, the odds of observing the 20/300 or worst category of postoperative BCVA also increased.

Table 6

Multivariate logistic regression results

Model coefficients – logMAR post

						95% Confidence interval	
Predictor	**Estimate**	**SE**	**Z**	**p**	**Odds ratio**	**Lower**	**Upper**
Intercept	−1.5319	3.9450	−0.388	0.698	0.216	9.48e−5	492.81
Months of follow-up	0.0421	0.0184	2.294	0.022	1.043	1.0062	1.08
Tear magnitude:							
Tear 180–270°–tear <180°	0.7277	0.8821	0.825	0.409	2.070	0.3675	11.66
Tear>270°–tear <180°	−1.0039	1.2716	−0.789	0.430	0.366	0.0303	4.43
CSFT in microns	−0.0232	0.0157	−1.476	0.140	0.977	0.9474	1.01
Macula at surgery:							
Off–macula-on	1.9408	0.9464	2.051	0.040	6.964	1.0896	44.51
Foveal contour:							
Abnormal–normal	4.3954	1.2975	3.387	< .001	81.074	6.3741	1031.19
Ellipsoid band:							
Disrupted–normal	0.4868	0.9474	0.514	0.607	1.627	0.2541	10.42
DONFL defects:							
Present–absent	−0.3840	1.0001	−0.384	0.701	0.681	0.0959	4.84
ELM line:							
Disrupted–normal	−0.4387	0.9702	−0.452	0.651	0.645	0.0963	4.32

Note. Estimates represent the log odds of "logMAR post = 20/300 or worse" vs. "logMAR post = between 20/50 and 20/200"

CSFT, central subfoveal thickness; DONFL, dissociated optic nerve fiber layer; ELM, external limiting membrane; SE,standard error

A Cox proportional hazards model was used to determine whether tear magnitude had a significant effect on the hazard of final postoperative BCVA categories. The 20/300 or worse category of final postoperative BCVA was used to indicate survival, while the 20/50 to 20/200 group category was used to represent a hazard event. The model's results were significant (p = .006), indicating that tear magnitude adequately predicted the hazard of the final postoperative BCVA (Table 7).

The coefficient for the tear 180–270° group category of tear magnitude was significant (p = .027), indicating that at any particular time, an observation in the tear 180–270° category had a hazard that is 0.33 times as large as the tear 270° was not significant (p = .151), indicating that being in the tear >270° category of tear magnitude did not have a significant effect on the hazard of final postoperative BCVA (Table 7).

Table 7

Cox proportional hazards regression coefficients for tear magnitude

Variable	*B*	*SE*	95% CI	*z*	*p*	*HR*
Tear magnitude (tear 180–270°)	−1.10	0.50	[−2.07, −0.12]	−2.21	.027	0.33
Tear magnitude (tear >270°)	0.57	0.40	[−0.21, 1.35]	1.43	.151	1.77

CI, confidence interval; HR, hazard ratio; SE, standard error

A calculation of survival probability according to the tear magnitude was performed and the results are shown in risk tables 7 and 8.

Kaplan–Meier survival plots

A Kaplan –Meier survival probability plot was included for tear magnitude. Each plot represents the survival probabilities of the different groups over time (Figure 10).

Table 8

Risk table for tear magnitude = tear 180–270°

Quantile	Time	No. at risk	Survival probability	Std. error
0%	6.000	21	1.000	0.000
25%	24.000	17	0.895	0.079
50%	38.000	11	0.763	0.139
75%	77.000	6	0.763	0.139
100%	118.000	1	0.610	0.264

No. number; Std., standard

Table 9

Risk table for tear magnitude = tear >270°

Quantile	Time	No. at risk	Survival probability	Std. error
0%	11.000	11	0.909	0.095
25%	15.000	9	0.727	0.185
50%	28.000	7	0.519	0.302
75%	39.000	4	0.312	0.474
100%	77.000	1	0.000	Inf

No. number; Std., standard

Additionally, we used generalized linear models (GLM) to further investigate potential associations of the postoperative BCVA with the other variables. The selected by “step” generalized additional model for the postoperative BCVA revealed that the postoperative BCVA was significantly associated with the number of follow up months ($p < 0.01$), the CSFT ($p < 0.01$), and the “Normal foveal contour” ($p < 0.01$), when adjusting for cofounders with multivariable analyses (Table 10).

Table 10

The “best” generalized linear model results of the postoperative BCVA in logMAR units.

	Estimate	Std. Error	t value	p value	significance
(Intercept)	1.35736	0.1802913	7.529	**1.45E−10**	***
Male sex	−0.065232	0.0440148	−1.482	0.14288	
Macula-on at surgery	−0.0822018	0.0561708	−1.463	0.14789	
Follow-up in months	0.0021417	0.0007667	2.793	**0.00675**	**
Recurrent RRD	0.0846707	0.0526205	1.609	0.11216	
CSFT in microns	−0.0037141	0.000813	−4.569	**2.09E−05**	***
Normal foveal contour	−0.2649488	0.049419	−5.361	**1.04E−06**	***

The significant variables are in bold writing and marked with *.

BCVA, best-corrected visual acuity; CSFT, central subfoveal thickness; E, error; RRD, rhegmatogenous retinal detachment; Std., standard

Discussion

Our results showed that there was no difference in the degrees of tear magnitude between the patients' age or sex, however there was an influence of the cause that led to GRTs-associated RRD. Most cases of tears <180º and 180º to 270º were spontaneous, while most cases of tears >270º were related to Marfan or Stickler-Wagner Syndrome. It is important to know that, in addition to disease-related causes, the idiopathic etiology is of concern and correct and early diagnosis of ruptures are essential. Findings on the benefit of adding an encircling SB to vitrectomy for GRTs-associated RRD are controversial. Studies which favor buckling argue that GRTs occur in patients with an abnormal vitreous base and that supporting this region decreases the tractional forces and could result in reopening the break or extension into the uninvolved retina.[23,24] In eyes undergoing vitreous surgery for GRTs-associated RRD, the value of adding a scleral buckle remains controversial because its placement before reattaching the retina, although capable of facilitating the removal of the anterior vitreous, favors posterior slippage of the retina, which is one reason why we always place the scleral buckle after full transoperative reattachment of the retina. Other authors believe that buckling is an essential part of the surgical approach, as it contributes to relieving the traction at the edges of the GRT and provides support for the rest of the vitreous base, mainly at its posterior border.[25]

Some degree of general agreement among retinal surgeons has led to the idea of using scleral buckling in GRTs < 180°, especially in the absence of total posterior vitreous detachment (PVD) and of folding of the retina on itself; in contrast, some authors argue that GRTs, especially if their extent is >180°, already involve significant release of vitreous traction. Consequently, it is unnecessary to adapt an SB if much of the vitreous traction has already been released if the goal is merely to ensure that the posterior retina is released and free of possible abnormal vitreoretinal adhesions commonly seen in this condition. In these cases, trimming of the devitalized anterior retina is advised to minimize the occurrence of anterior PVR or abnormal neovascularization.

Our surgical technique helped minimize the chance of retinal posterior slippage and reduced the chance of producing a posterior radial retinal fold at the time of fluid-gas exchange, which is known to increase the risk of leakage from tears and increase the recurrence rate for RRD. In complex PVR cases, when we decided to use a higher lying buckle, the goal was to position the posterior edge of the GRT to fall on the plateau of the indentation, to release and avoid pathological contraction of the residual vitreous base over the detached, but not torn, retina and to reduce the possibility of new retinal tears at the level of the remaining attached retina.

Regarding vitreous surgical management in cases associated with trauma or genetic syndromes (Marfan syndrome, Stickler–Jansen syndrome, vitreous base avulsion, etc.), PVD was less commonly present, and many abnormal vitreoretinal adhesions were found. Consequently, thorough, full dissection of the vitreous base is advised, with the aid of scleral depression, if available, as was done in our study. In most of our cases, we performed assisted scleral depression or self-scleral depression with a single 27-gauge disposable Eckard TwinLight Chandelier, as previously described.

Our results suggest that the surgical approaches adopted are similar among the three levels of tears studied. Vitrectomy is crucial to reversing the state of the eye and the main factor requiring attention is when to perform the procedure. The procedure performed early prevents future damage to the eye. However, patients with a tear magnitude of 180º-270º had the best probability of survival, while patients with a tear magnitude >270º had the worst survival rate. Thus, the treatment of these patients must be carried out quickly, to avoid irreversible damage.

Lensectomy or clear lens removal is not necessary for the vast majority of cases unless lenticular opacity is an impediment, according to some authors.[26] In most cases, the retinopexy continued anteriorly to the ora serrata to ensure a reduction in vascular endothelial growth factor. There is no scientific evidence to support the addition of a 360° endolaser in the absence of lattice degeneration[24]; accordingly, we do not regularly apply such endolaser, even for GRTs with extents <180°, instead we prefer to support the residual vitreous base with a low-lying buckle, as previously mentioned. Fluid-air exchange is arguably the most critical step in the surgical repair of GRT-associated RRDs, and an improper technique can result in retinal slippage or radial retinal folds. Meticulous, slow aqueous removal with an extrusion cannula at the air-PFCL interface and at the edge of the tear is essential. Our study showed a very low incidence of macular retinal folds due to posterior slippage in eyes with GRTs extending <180°, which was higher (but not significantly so) in GRTs extending >180°. Some surgeons believe that the use of moderate- to high-lying buckles is associated with an increased risk of retinal slippage during the air-fluid exchange, while others believe that buckling is an essential part of surgical management, as it helps relieve traction at the edges of the GRT and provides support for the rest of the vitreous base.[20] Therefore, we recommend the application of low-lying buckles mainly in GRT-associated RRDs extending <180° without complete PVD.

In relation to the type of tamponade, we avoided the use of short-acting gas (sulfur hexafluoride) because there is evidence that suggests it leads to higher rates of redetachment.[26] However, we showed that the tamponade type was different between groups, C_3F_8 was used more in eyes with tears <180º. Additionally, we observed that that the results of the chi-square test based on alpha value suggested that tear magnitude and tamponade type were related to one another.

Many factors contribute to the choice of tamponade agents. In this study, we only used 15% nonexpanding, long-acting C_3F_8 gas or, for very rare cases of poor compliance with postoperative positioning in eyes with primarily inferior GRTs, lighter than water silicone oil. In contrast, Kunikata et al.[33] used silicone oil as a tamponade in 34 of 41 eyes (83%) of its GRT-associated RRD.

In this study, we found a bilateral GRT incidence of 6.57%. Patients who experience spontaneous GRT-associated RRD are at a high risk of developing GRT in the fellow eye. High-risk fellow eyes include those with high myopia, Wagner or Stickler syndrome, and progressively increasing areas of white-without-pressure (WWOP) with a sharp posterior margin and increased vitreous base condensation.[27] Although neither the annual nor cumulative risk after 3, 5, or 7 years of GRT-associated RRD in the fellow eye has been precisely defined, there is substantial potential visual morbidity associated with GRT-associated

RRD, and many authors have discussed the use of lasers and even surgical prophylaxis in the fellow eye.[24,28]

The need for prophylaxis remains controversial, and some authors advocate for retinopexy for any peripheral retinal breaks or lattice degeneration in the fellow eye in the context of progressive WWOP. Patients with a syndromic connective tissue predisposition and certain local ocular, high-risk peripheral retinal lesions such as WWOP or vitreous conditions such as abnormal condensation of the vitreous base are especially at high risk and are deserving of close monitoring or even discussion of the role of a highly debated, thorough, prophylactic buckle.[29] Some authors advocate prophylactic, 360° cryotherapy posterior to the ora serrata in the fellow eye of persons with Stickler syndrome,[29] while others have suggested prophylactic buckling along with cryopexy.[30] Prophylactic 360° laser photocoagulation can also be considered, especially in eyes with multiple risk factors.

Causes of RRD recurrence include anterior PVR and persistent or new epiretinal traction at the corners of the tear, missed or new tears in different locations from the GRT, the presence of undetected macular holes, and, most commonly, the severe posterior PVR.[16] In our study, the incidence of RRD recurrence due to posterior PVR was 32.89% (25 eyes) with evidence of postoperative ERM proliferation over the detached macula; we speculate that this contributed to the creation or activation of new tears through diffuse posterior epiretinal traction. All recurrent RRD eyes underwent buckling procedures, revision vitrectomy, epiretinal and macular membrane stripping, and ILM removal during follow-up. Five (6.57%) of these PVR-complicated eyes showed severe concurrent serous 360° choroidal detachment, which contributed to the severity of the inflammatory process. Seven (9.21%) out of 25 eyes with posterior PVR were found to be associated with different stages of anterior PVR and some intrinsic contraction areas of the detached retina during follow-up; these eyes were managed with radical vitreous base surgery and circumferential retinectomy. Only eyes with a fully attached retina and functional vision at the end of follow-up were included in the statistical analysis, as described previously.

In this report, major postoperative complications other than PVR included symptomatic macular folds associated with retinal posterior slippage in 13 eyes (17.10%) and two (2.63%) in the group with GRTs <180° extent, five (6.57%) in the group with GRTs greater than 180°, and six (7.89%) in the group with GRTs greater than 270°, which is consistent with the available literature;[10,31] 10 eyes (13.55%) in the group with GRTs greater than 180° showed either pre- or subretinal residual PFCL that warranted removal. The rate of reattachment following one procedure is 80%–90%, while the final reattachment rate is 94%–100%.[14,32] However, if PVR is present, visual prognosis is poor despite reattachment and anatomical success, as was demonstrated here and in a previous study.[1] In contrast, Kunikata et al.[33] reported that the most common postoperative complications occurred in 16 eyes (39%) including macular ERM proliferation, cystoid macular edema, macular hole, subretinal perfluorocarbon liquid, retinal folds, vitreous hemorrhage, and redetachment.

Some authors[34] have emphasized that in non-complex cases, good anatomic and functional results can be obtained only with vitrectomy techniques. We observed a 79% rate of reattachment after one surgical procedure, which is consistent with the 75% single surgery anatomic success at 3 months and 65% at 2 years (95 confidence interval: 47%, 78%), as reported by Liu et al.[34]

The analysis of the results of a prospective study in the management of different types of retinal detachments concluded that the GRTs-associated RRD retinal detachment is associated with a high-risk complex pathology; eyes that underwent even timely surgery hardly achieved a recovery of vision of 20/40 or better,[35] which must be considered for knowing what to expect, especially if the tear is >180°, and the macula is detached before surgery. The presence or absence of scleral cerclage does not seem to influence the final functional result according to our results, although its absence influenced a higher incidence of postoperative complications such as redetachment and retinal folds. The characteristics of having a retinal detachment associated with a GRT together with a patient aged over 70 years, low intraocular pressure of less than 10 mmHg, retinal detachment with more than four rhegmatogenous lesions, and retinal detachment of more than three quadrants are associated risk factors for poor visual recovery and not achieving 20/25 vision or better in the long-term analysis of the postoperative period.[35] However, a multivariate logistic regression analysis performed to identify the risk factors such as presenting with worse visual acuity, ≥150° giant retina tear, macula-off status, and presence of PVR were associated with postoperative BCVA of >1.0 in logMAR units (all $p < 0.05$). The types of surgery (primary vitrectomy vs. combined SB and vitrectomy techniques), number of breaks, lens extraction, and additional cryotherapy were not associated with functional or anatomical success according to Ting et al.[36] In this study, the postoperative BCVA in logMAR units was significantly associated with the CSFT in microns and the normal foveal contour, when adjusting for cofounders with multivariable analyses.

The preoperative BCVA was higher than the postoperative BCVA; in addition, the postoperative BCVA was negatively correlated with the CSFT, that is, the higher the CSFT, the lower the postoperative BCVA. Even after long-term postoperative B-scan SD-OCT image, foveal count and CSFT were normal. The preoperative logMAR was higher in tear >270º and the final postoperative logMAR was lower in the same group.

We acknowledge that this study has several limitations, mainly its consecutive nature. However, there were several inherent strengths, such as its multicenter and long-term follow-up design; single-surgeon design, all surgical procedures were performed by the same surgeon, which is well known to eliminate the surgeon-bias factor and critical statistical analysis; the relative rarity of GRT-associated RRD allowed us to incorporate a structural evaluation by means of long-term final postoperative SD-OCT findings analysis to be correlated with final postoperative BCVA.

Conclusions

In conclusion, despite the advent of modern vitrectomy techniques and devices, including micro-incisional surgery, PFCL, chandelier illumination, and valved cannulas, GRT-associated RRD remains a potentially blinding condition with limited final functional outcomes. Nevertheless, all these advancements have dramatically improved our anatomical success in the management of GRT-associated RRD. Surgical timing is important in reducing long-term complications, minimizing the complication rate, and improving the reattachment rate, but the long-term functional results continue to be disappointing. Nevertheless, attention needs to be given to the crucial steps of the vitrectomy procedure to ensure anatomical success and improve the final functional outcomes. Today, the use of vitrectomy techniques has expanded greatly, with unprecedented advances in the development of vastly improved vitrectomy platforms, more rigid, small-gauge cutters with improved fluidics, PFCLs, and better instrumentation and the far-reaching availability of WAVS with superior endoilluminators. This study has a multicenter and long-term follow-up design, without a surgeon-bias factor. Due the relative rarity of GRT-associated RRD, this study is important because it incorporated structural evaluation by means of long-term final postoperative SD-OCT findings analysis correlated with final postoperative BCVAs. The most important lessons learned in this study concerning the management of GRT-associated RRD include the benefits of thorough vitrectomy with trimming of the anterior flap of the retina and vitreous base, endolaser photocoagulation of the posterior edge of the GRT along with its radial extension, identification of all distant breaks and removal of all anterior fluid by drying the edges of the break thoroughly to prevent slippage with selective long-acting tamponade according to the conditions of the eye and the patient.

Abbreviations

C_3F_8, perfluoropropane; BBG, Brilliant Blue G; BCVA, best-corrected visual acuity; CSFT, central subfoveal thickness; DONFL, dissociated optic nerve fiber layer; ELM, external limiting membrane; ERM, epiretinal membrane; GRT, giant retinal tear; ILM, internal limiting membrane; IS/OS, internal segment/external segment; OCT, optical coherence tomography; PFCL, perfluorocarbon liquid; PVD, posterior vitreous detachment; PVR, proliferative vitreoretinopathy; RD, retinal detachment; RPE, retinal pigment epithelium; RRD, rhegmatogenous retinal detachment; SB, scleral buckle SD, spectral domain; SS, swept source; SRF, subretinal fluid; VIF, Variance inflation factors; WAVS, wide-angle viewing systems. WWOP, white without pressure

Declarations

Ethics approval and consent to participate

This retrospective study adhered to the tenets of the Declaration of Helsinki, received full ethical approval from the research ethics committees, and was approved by the institutional review committees and the teaching departments of the three institutions enrolled (no reference numbers were provided for retrospective studies by these institutions). Written informed consent was obtained from all patients in accordance with the institutional guidelines.

Consent for publication

Written consent was obtained from all patients.

Availability of data and materials

The dataset supporting the conclusions of this article is available in the Retina Specialist repository file in http:// www.oftalmologiainteralabc.com/retinaspecialists. The dataset supporting the conclusions of this article is included within the article.

Competing interests

The authors declare that they have no competing interests.

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Authors’ contributions

MAQR, study conception, writing the manuscript, dataset interpretation, statistical analysis interpretation, final revision, conclusions; EAQG, figures artwork, tables, and graphics; JHKL, photographic material compilation; FEC, photographic material compilation; JGMN, statistical analysis, tables, graphs; MAQG, assistant surgeon; ARA, statistical analysis, tables, graphs; BMA, surgeon and material compilation; MM, photographic material compilation, final revision; VLG, statistical and clinical correlation, final revision, and figure text editing; and FGW, final revision. All authors have approved the manuscript for submission.

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Figures

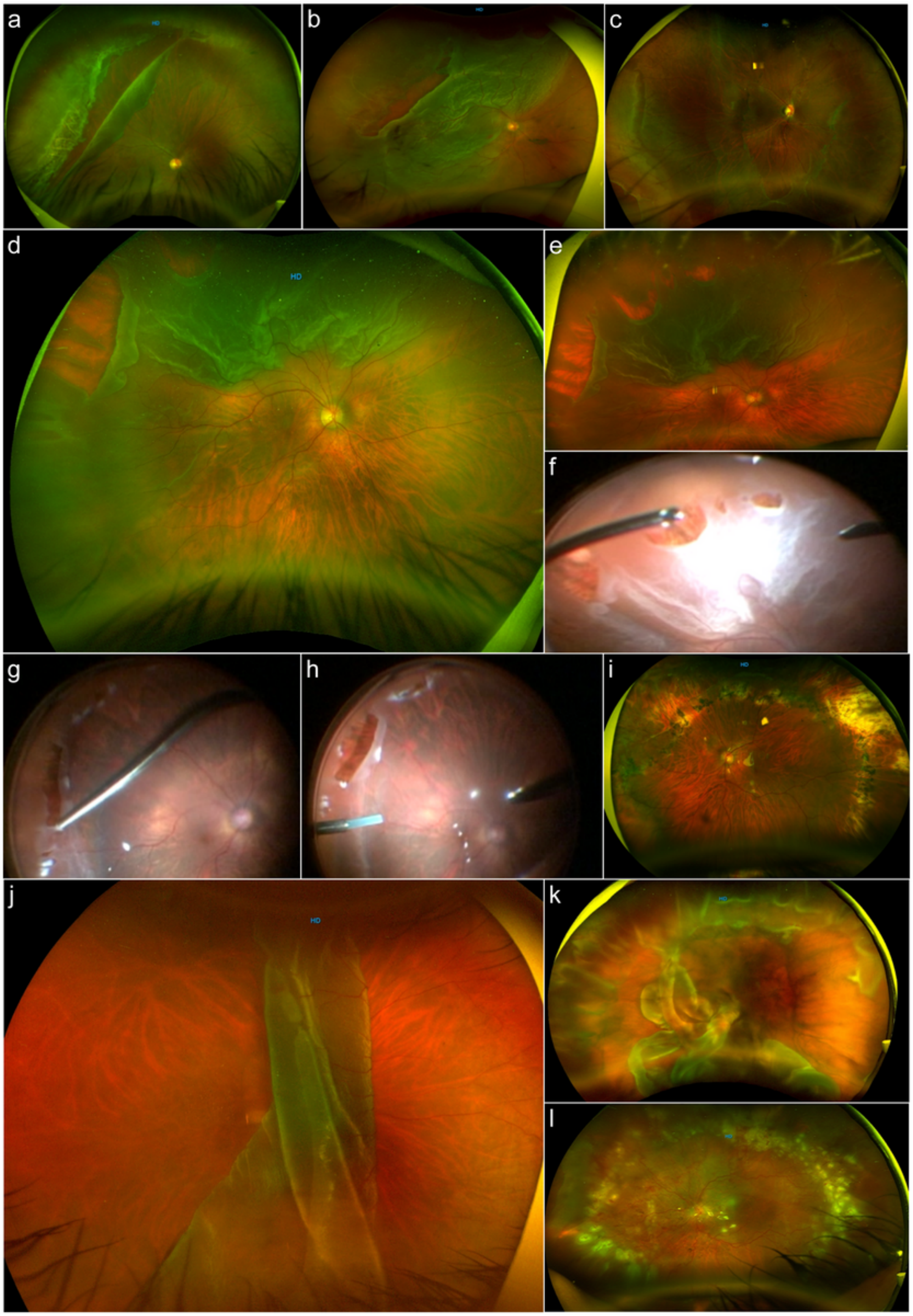

Figure 1

Types of giant retinal tears. a: An image depicting a giant retinal tear (GRT) associated rhegmatogenous retinal detachment (RRD) from the 8 to 1 o'clock meridian; the retina and macula remain attached. The GRT is located in the preequatorial zone, the anterior border of the retina has a tear over a well-defined area of lattice degeneration associated with vitreous traction, and the posterior border of the GRT shows some rolled back edges, nasal to the GRT. There is a small retinal tear extension. There are well-defined white without pressure (WWOP) areas of retinal appearance throughout the retina periphery. b: A one-quadrant macula-off GRT-associated RRD with an additional rhegmatogenous lesion over the temporal horn of the tear. c: A GRT, inferiorly located in the presence of macula-on RRD with imminent macula involvement. There are extensive WWOP-associated degeneration areas. d: A partitioning GRT-associated macula-off RRD, the posterior border of the main tear shows proliferative vitreoretinopathy grade b with some retina wrinkling and rolled back posterior edge. e: A more peripheral wide-angle color picture of the previous image depicting more clearly the horse-tears in a zipper-type coalition due to severe vitreoretinal traction. f: Previous case surgical image where peripheral vitreous and fluid-to-fluid endodrainage are performed. g: Endodiathermy marking of the extensive retinal lesions. h: Sequential image showing perfluorocarbon liquid assisted endodrainage. i: An image corresponding to the previous case 3 years postoperatively for GRT-associated RRD. j: A macula-off GRT >180° is folded over posteriorly due to complete posterior vitreous detachment. k: Days after a failed vitrectomy and buckled case with a recurrent posteriorly slipped RRD. l: The previous case that has undergone vitrectomy revision; the retina looks completely reattached, and the eye is silicon oil-filled.

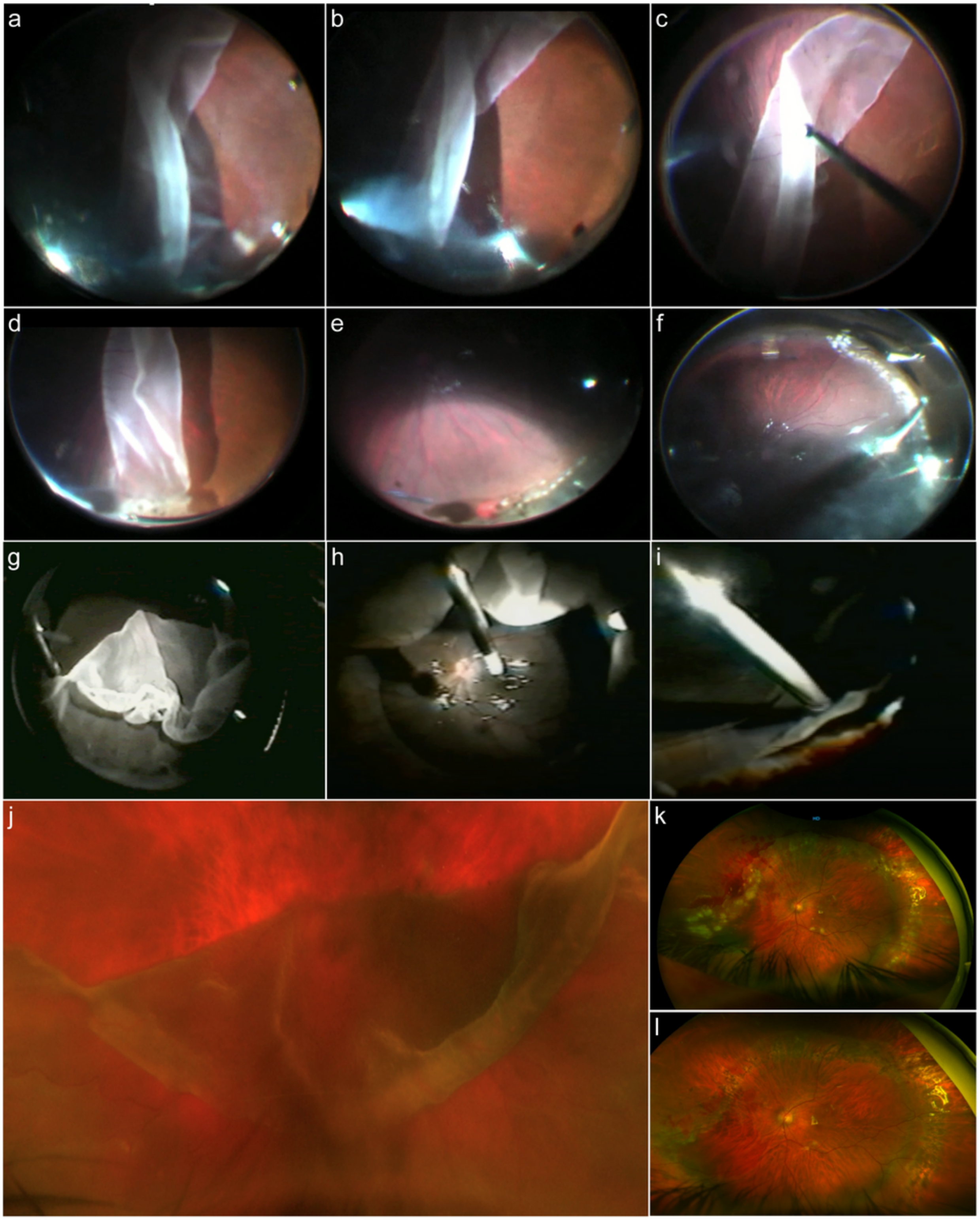

Figure 2

Surgical approaches. a: Surgical image sequence of giant retinal tear (GRT) anterior vitrectomy in a case with GRT-associated rhegmatogenous retinal detachment (RRD) and posterior retina flap folded over posteriorly. b: Image shows a free posterior flap of the retina once the vitreous has been released. c: Posterior retina flap careful manipulation. d: Careful anterior vitrectomy at the level of GRT lateral horn. e: Endophotocoagulation of the lateral horn and posterior GRT edge once the retina has been attached assisted with perfluorocarbon liquids. f: Careful fluid-gas exchange with slow endodrainage at the superior border of the GRT. g: Folded and inverted posterior edge of a superior >180° GRT associated RRD. h: Manipulation and unfolding of the retina at the time of assisted perfluorocarbon liquids injection. i: Trimming of the anterior retina flap along with anterior anomalous condensed vitreous. j: Folded over posterior retinal flap of >180° superior GRT; there is an inversion of the posterior edge and lateral posterior extension of the lateral horn tear. k: Early postoperative eye that has undergone primary vitrectomy complimented with a high-profile supplement scleral buckle and silicone oil tamponade. l: The previous case 4 months after silicon removal.

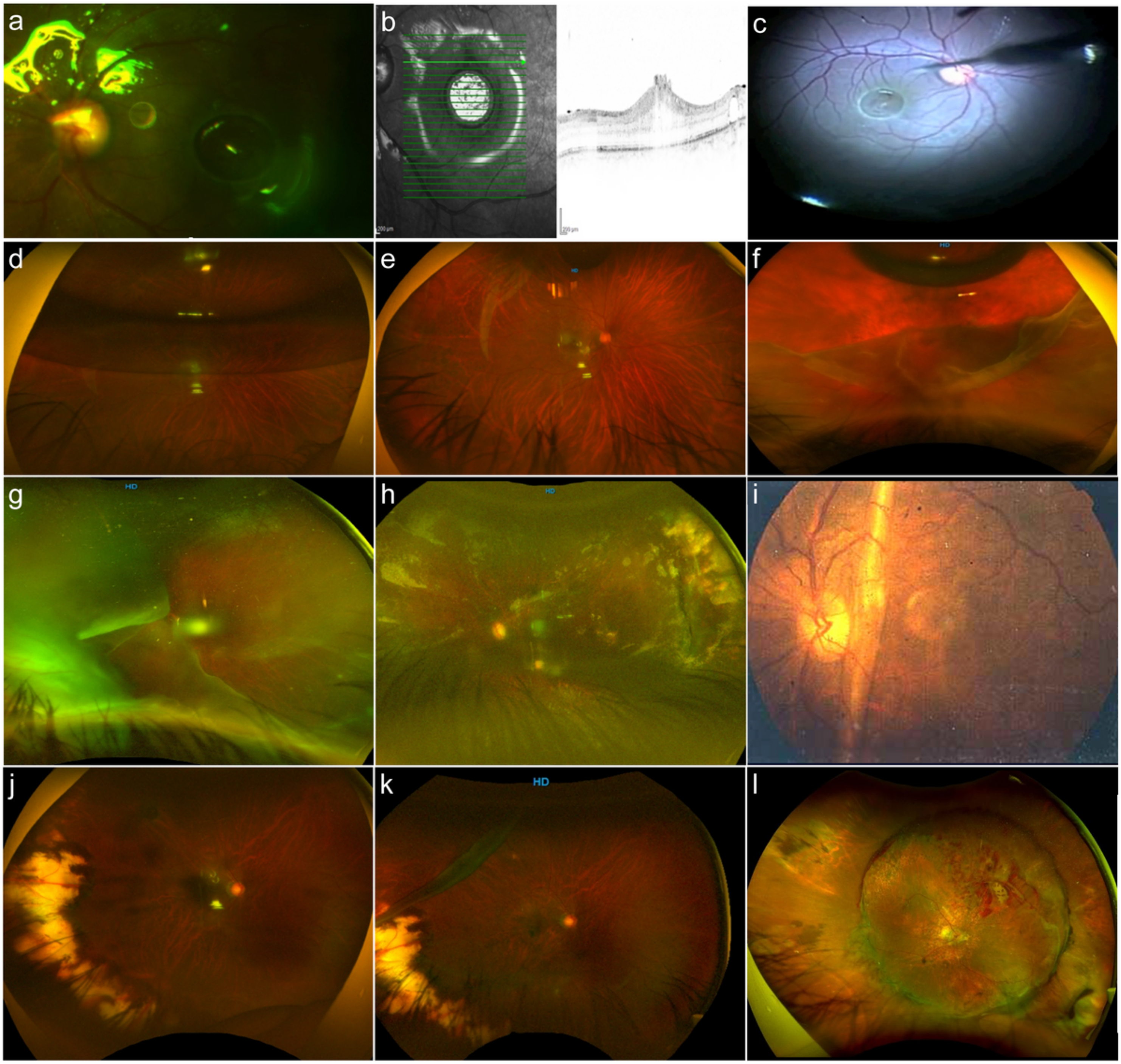

Figure 3

Giant retinal tears complications. a: Discrete amount of subretinal perfluorocarbon liquid at the level of the macula. b: Corresponding spectral-domain optical coherence tomography (SD-OCT) B scan image depicting the presence of retinal macula edema and defects around due to the presence of perfluorocarbon liquid. c: The surgical intraocular 41-G needle pointed to the subretinal perfluorocarbon liquid bubble extraction. d: Postoperative 40% gas-filled eye with some posterior retinal flap slippery. e: A light posterior slippery of the posterior retina; however, there is a remarkable retinal fold of the superior edge of the giant retinal tear (GRT), and the retina remains attached. f: A 10% gas-filled eye with a reopened GRT-associated rhegmatogenous retinal detachment (RRD) and some degree of PVR. g: A temporal GRT with the detached retina folded over the optic nerve. h: The post operated eye of the previous image with cloudy media and evidence of attached retina. i: Very old collection image of an eye belonging to this set of patients with GRT showing a macular vertical full-thickness vertical fold after primary vitrectomy with a complimented scleral buckle. j: The postoperative eye 8 months after vitrectomy and scleral buckle for temporal side macula-on GRT. k: The same patient in the previous image having a recurrent RRD due to a new GRT superior to the previous lesion and having a previous vitrectomy with a scleral buckle. l: A case in the early postoperative period depicting evidence of a totally attached retina, high scleral buckle, and evidence of bleeding along the posterior edge of the giant retinal tear.

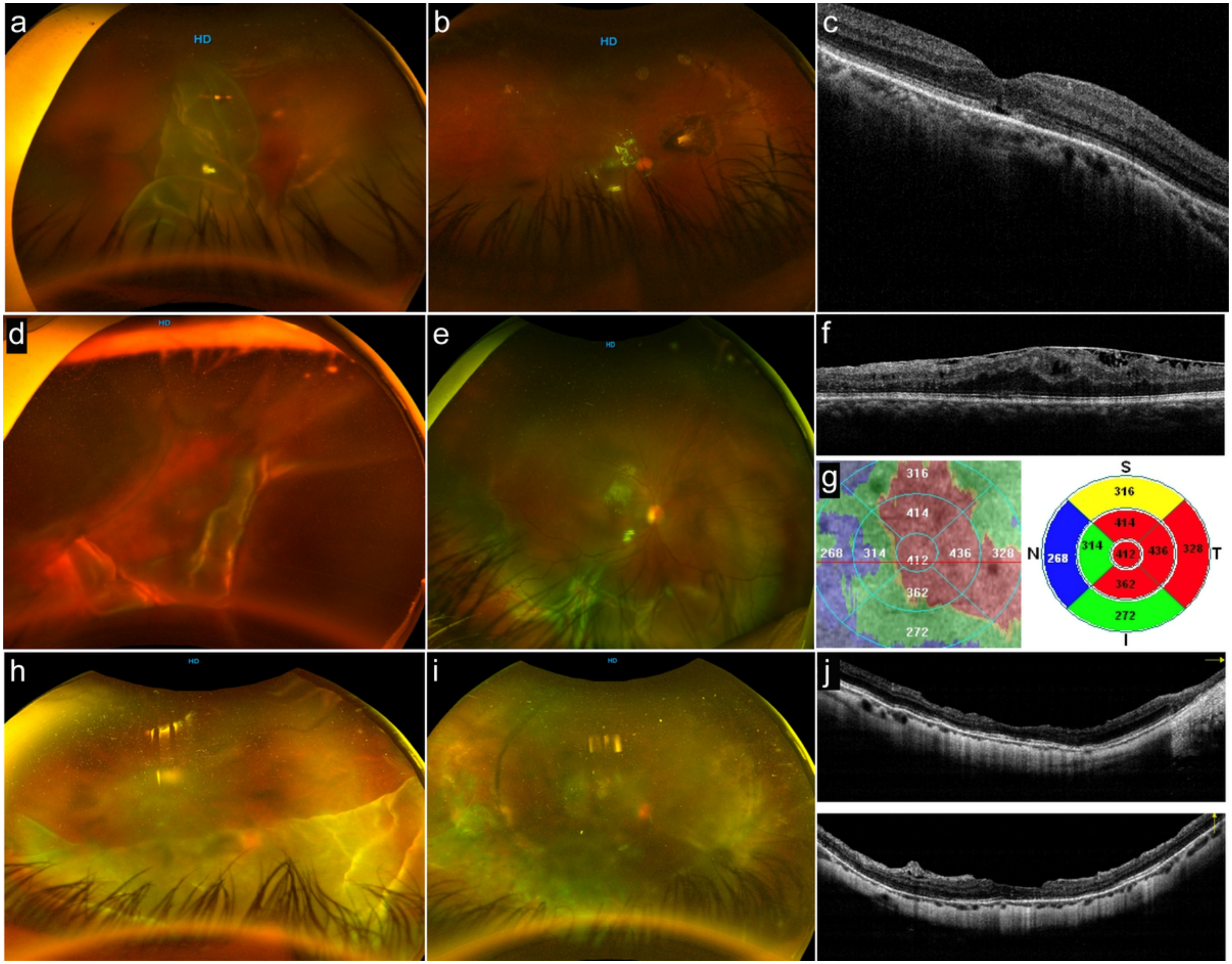

Figure 4

Postoperative optical coherence tomographies (OCTs) (part 1). a: Preoperative status of an eye with giant retinal tear (GRT) from >180° in extension showing a complete posterior vitreous detachment and rolled-back posterior retina flap. b: The postoperative status with a totally reattached retina and without evidence of macular epiretinal membrane (ERM) proliferation. c: The long-term postoperative horizontal B-scan spectral-domain (SD)-OCT image; the foveal contour is normal, central subfoveal thickness is within normal range, and the internal segment/external segment (IS/OS) (ellipsoid band) and external limiting membrane (ELM) line show subfoveal reflectance discontinuities. d: Optos image showing a complex GRT with opaque media; there is superior lateral posterior retinal tear extension, and the posterior retina looks folded over. e: The postoperative status of the eye; the eye has undergone primary vitrectomy and gas tamponade. The inferior retina exhibits a full-thickness retinal fold due to posterior retina slippage and evidence of radial fold due to posterior PVR. f: Macular expression of extended posterior PVR to the macula in the form of ERM proliferation; this corresponding SD-OCT horizontal B-scan shows wrinkling of the superficial layers of the macula, the external layers are difficult to identify, the IO/OS band and ELM show discontinuities, and some amount of residual subretinal fluid is seen. g: Composite image showing a topographic irregular thickening of the macula. h: Optos image of a superior GRT >180° folded over itself, obscuring the macula status. i: The postoperative status of the eye with a 360° buckle and silicone oil as tamponade with evidence of irregular but confluent 360° endolaser retinopexy. j: A crossline SD-OCT through the center of the fovea once the silicon has been removed. The horizontal and vertical B-scan show an irregular foveal contour, with some diffuse irregular retinal thinning, some posterior vitreous cortical remnants, and some extrafoveal dissociated optic nerve layer defects.

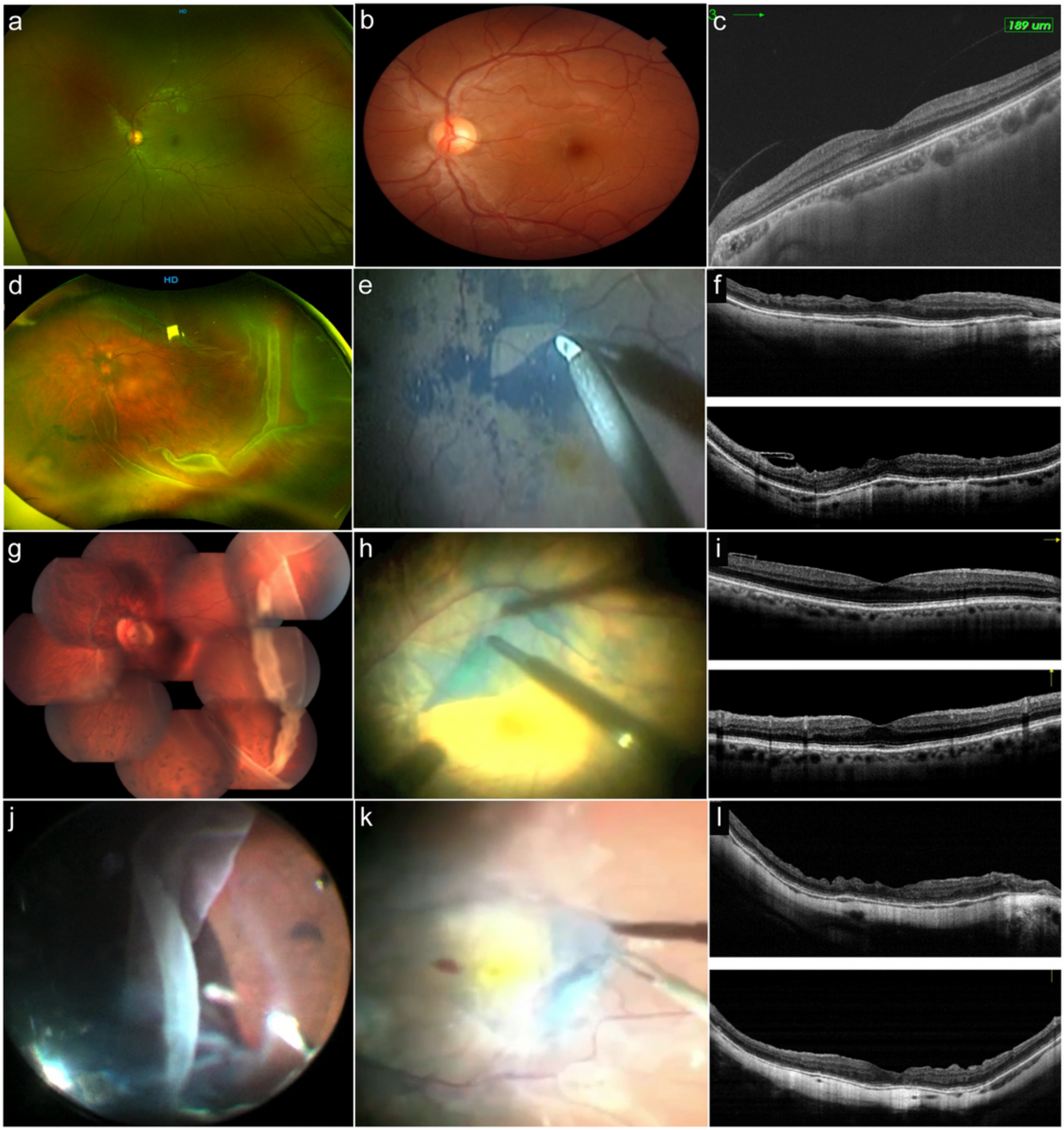

Figure 5

Postoperative optical coherence tomographies (OCTs) (part 2). a: Control normal wide-field Optos fundus photo. b: Magnified detail of the normal 30° wide color fundus. c: Spectralis normal control spectral-domain optical coherence tomography (SD-OCT) through the center of the fovea B horizontal scan. d: Temporal giant retinal tear (GRT) case with macula on rhegmatogenous retinal detachment (RRD) that has developed epiretinal membrane (ERM) proliferation after the surgical procedure. e: Surgical view of the Brilliant Blue G-stained internal limiting membrane removal technique. f: The previous case showing crossline SD-OCT horizontal and vertical B scans depicting abnormal foveal contour and dissociated optic nerve fiver layers (DONFL) defects; Henle fiber layer and outer nuclear layer are abnormal; the external limiting membrane line (ELM) and the inner segment/outer segment (ellipsoid band) look preserved. g: Image of composite >180° GRT figure with some subretinal blood over the posterior pole, the eye has undergone uneventful primary vitrectomy and endolaser retinopexy; and after 8 weeks it has developed a secondary epiretinal membrane proliferation over the macula. h: ERM and internal limiting membrane (ILM) en-bloc membrane removal technique. i: Postoperative crossline SD-OCT 14 months after ERM removal; the horizontal B scan shows a normal foveal profile, with ILM remnants temporal to the center of the fovea. j: The same clinical case as the corresponding in Figure 1a, where the traction vitreous releases from the anterior retinal flap of a GRT. k: Stained ERM of the previous case. l: Crossline SD-OCT horizontal and vertical through the center of the fovea of the previous case where the normal foveal profile is lost; there are both horizontal and vertical scan DONFL defects and some discontinuities on the ELM line and the ellipsoid band.

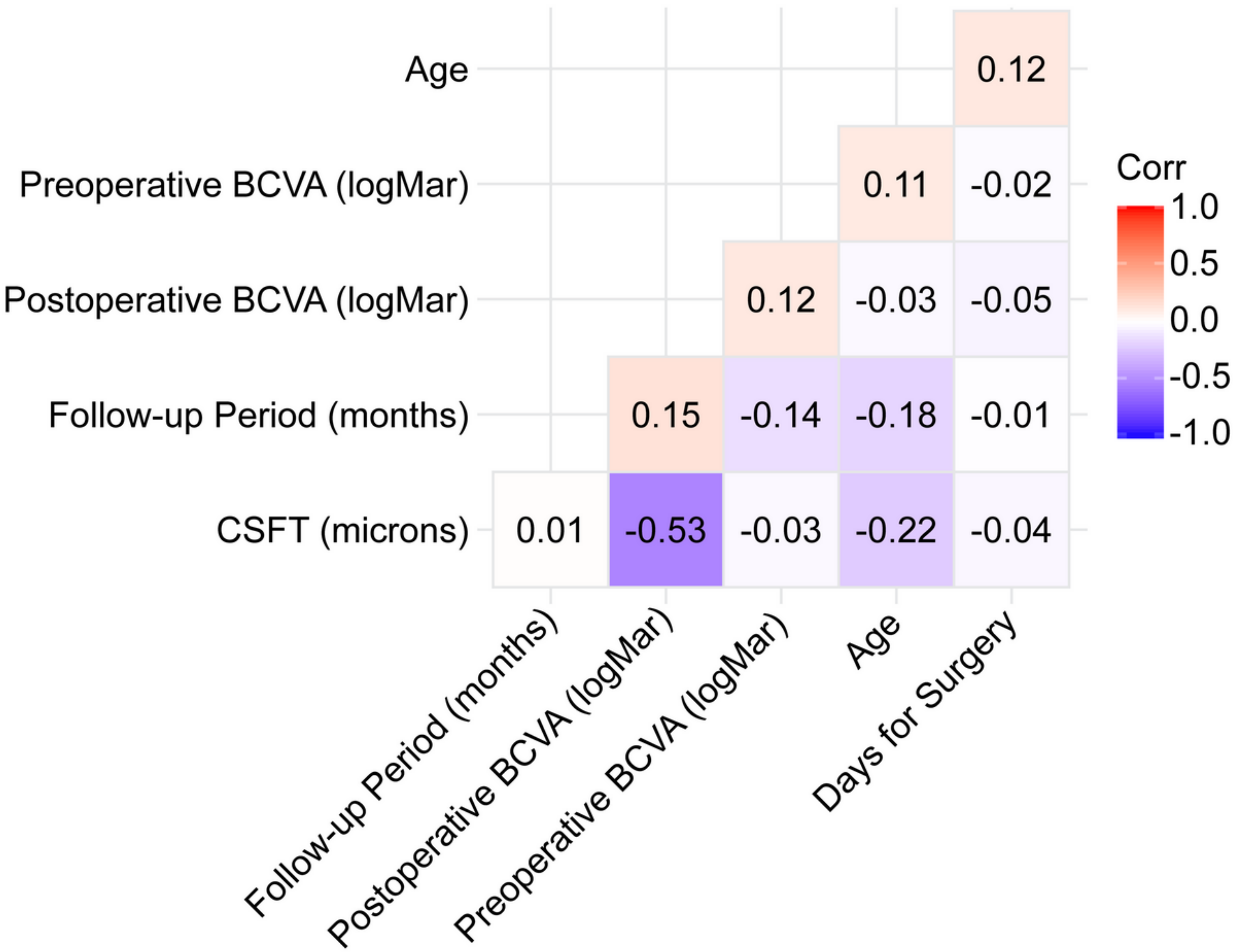

Figure 6

The Spearman’s rank correlation coefficient. The Spearman's rank correlation coefficient test shows a moderate negative correlation (rho = −0.53; p < 0.01) of the postoperative best-corrected visual acuity (BCVA) (logMAR) with the central subfoveal thickness in microns.

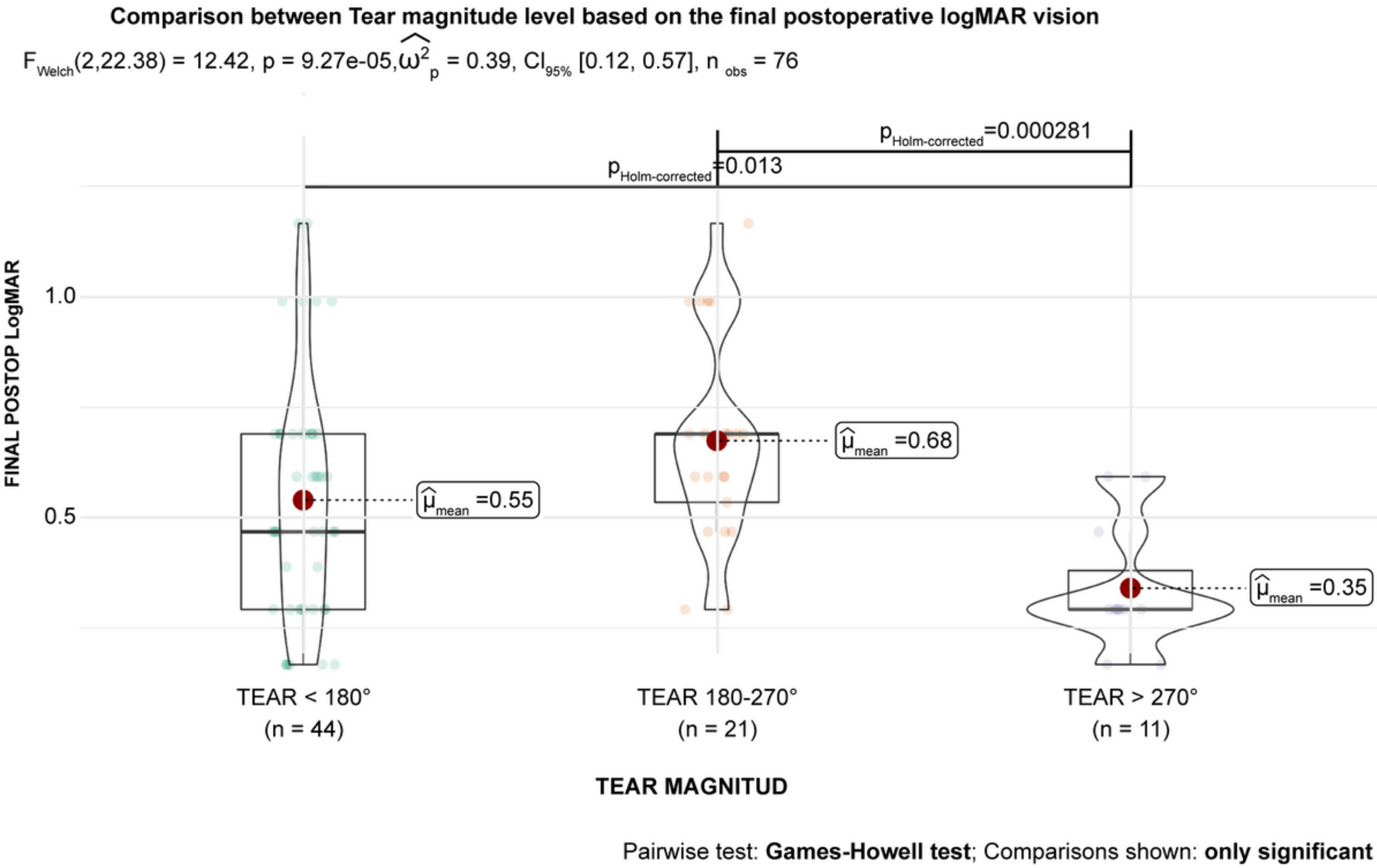

Figure 7

Tear magnitude level based on the final postoperative best-corrected visual acuity (BCVA) in logMAR units. This figure suggests that the tear 180–270° category of tear magnitude does not significantly predict final postoperative BCVA in logMAR units (B = 0.09; t [69] = 1.57; p = .120). Based on this sample, this suggests that moving from the tear 270° category of tear magnitude does not significantly predict final postoperative BCVA in logMAR units (B = −0.11; t [69] = −1.43; p = .157) or have a significant effect on the mean of final postoperative BCVA in logMAR units.

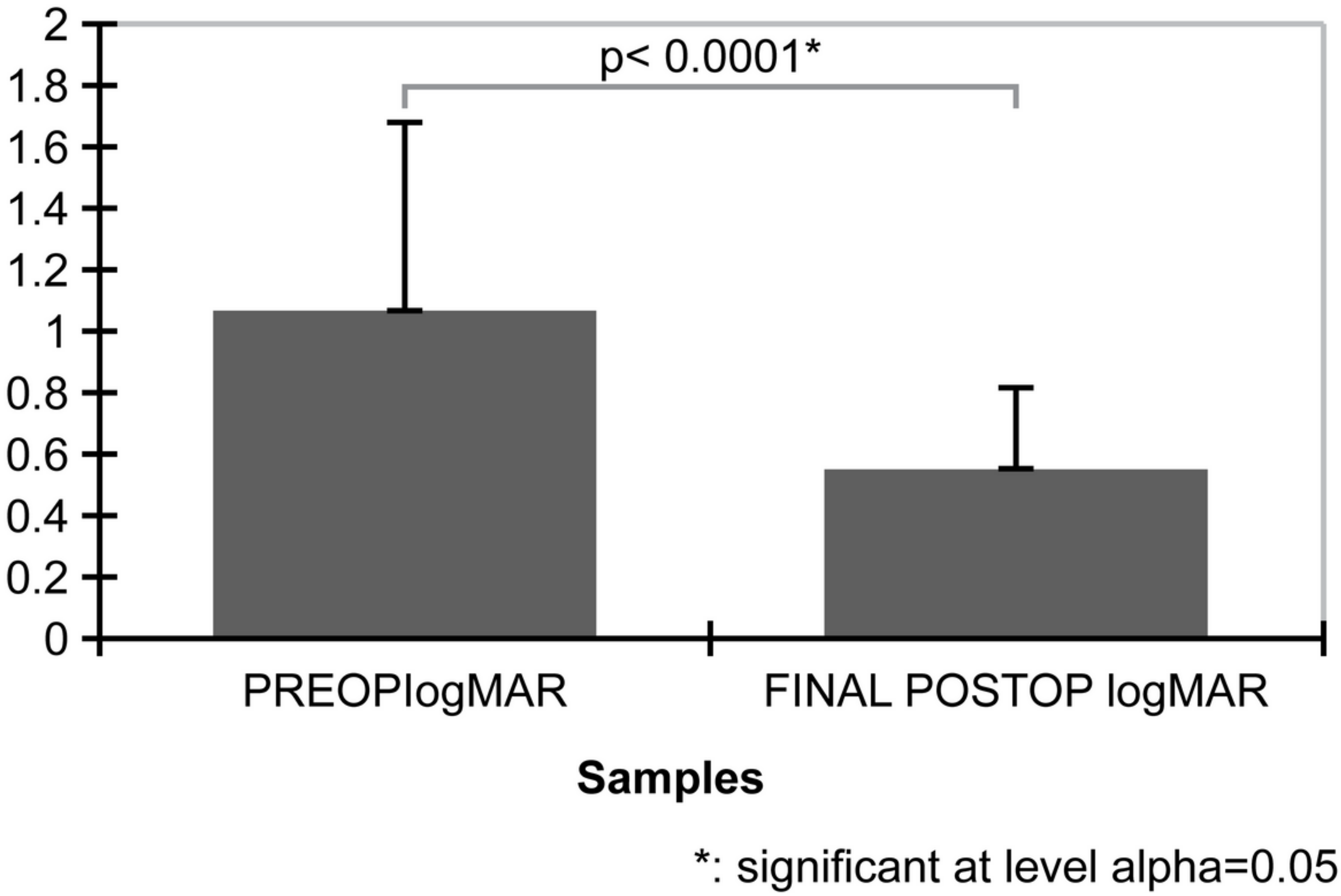

Figure 8

Bar plot mean preoperative best-corrected visual acuity (BCVA) and final postoperative BCVA in logMAR units. The result of the two-tailed paired samples t-test is significant based on an alpha value of 0.05 ($t_{[75]} = 6.88$; $p < .001$), indicating that the null hypothesis can be rejected. Thus, the difference in the mean preoperative BCVA in logMAR units and the mean of final postoperative BCVA in logMAR units is significantly different from zero. The mean preoperative logMAR is significantly higher than the mean final postoperative BCVA in logMAR units.

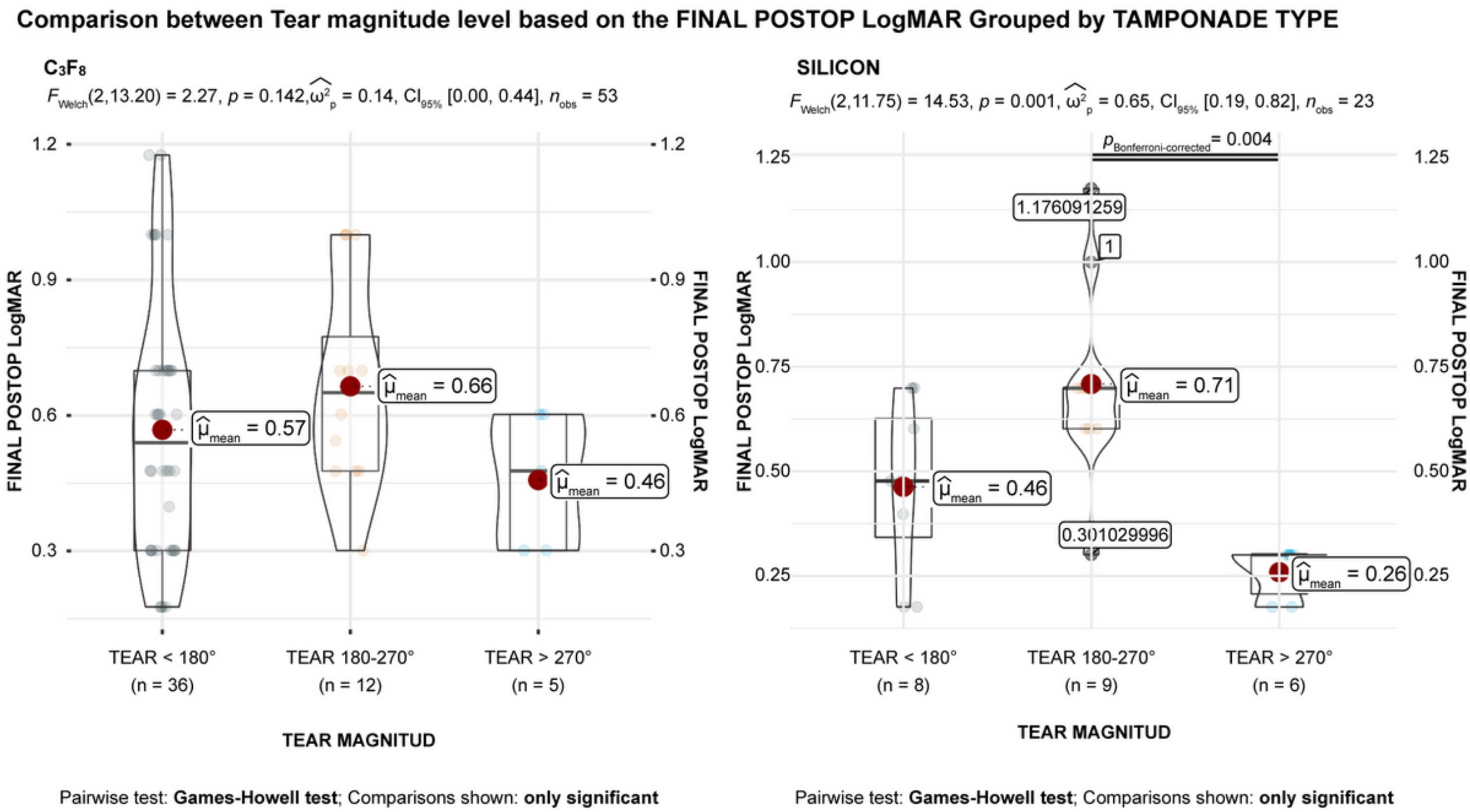

Figure 9

The means comparisons between tear magnitude and tamponade type. Tamponade type is significantly related to preoperative best-corrected visual acuity (BCVA) and final postoperative BCVA in logMAR units (F [2, 71] = 4.01; p = .022). The main effect for the within-subjects factor is significant (F [1, 71] = 39.19; p < .001), indicating significant differences between the values of preoperative BCVA and final postoperative BCVA in logMAR units after controlling for tear magnitude and tamponade type. The interaction effect between the within-subjects factor and tear magnitude is significant (F [2, 71] = 8.66; p < .001), indicating that the relationship between preoperative BCVA and final postoperative BCVA in logMAR units differs significantly between the levels of tear magnitude. The interaction effect between the within-subjects factor and tamponade type is not significant (F [2, 71] = 1.71; p = .188), indicating that the relationship between preoperative BCVA and final postoperative BCVA in logMAR units is similar between the levels of tamponade type.

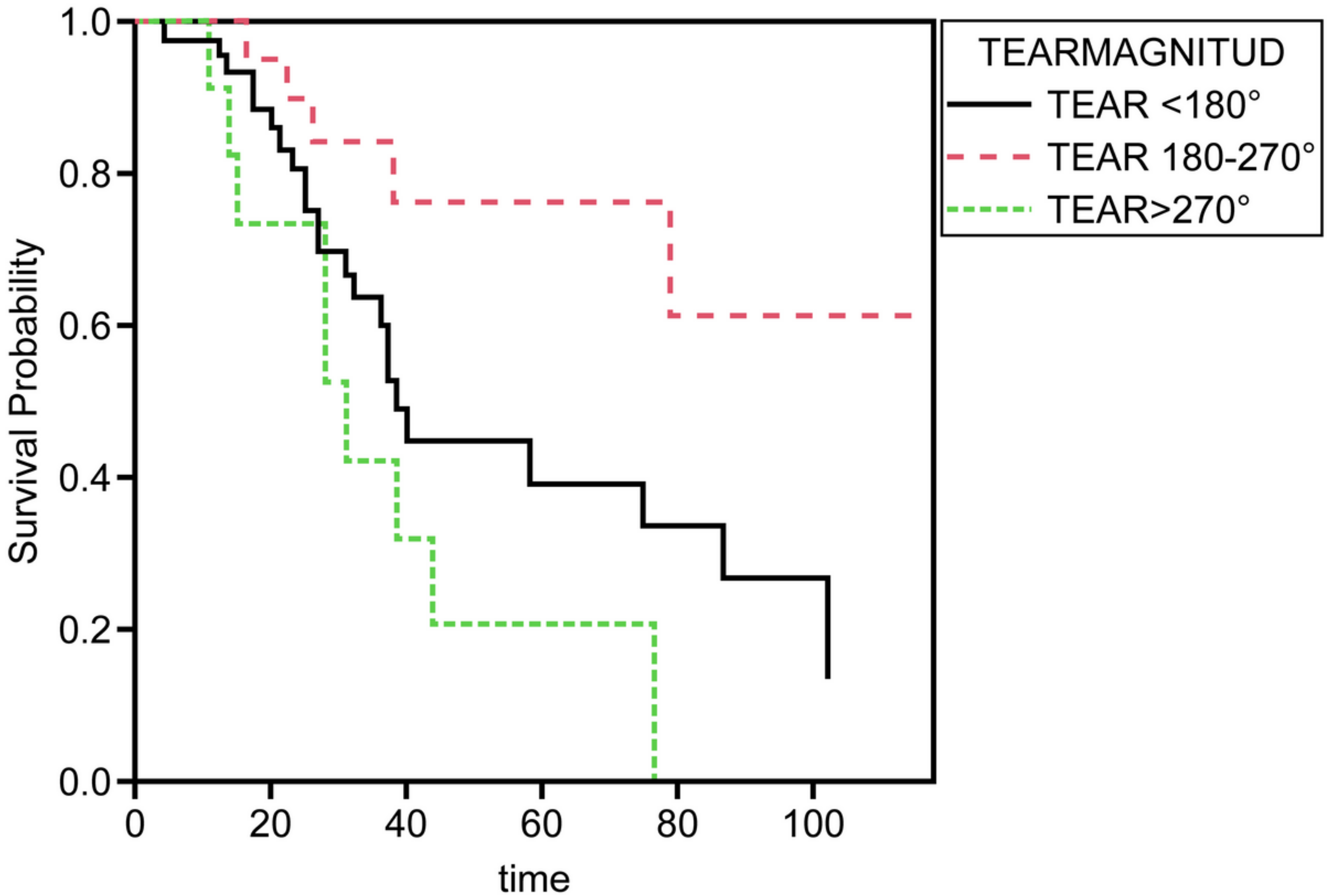

Figure 10

Kaplan–Meier survival plots. A Kaplan–Meier survival probability plot is included for tear magnitude. Each plot represents the survival probabilities of the different groups over time.