Anatomical Success, Functional Challenge: Pediatric Traumatic Retinal Detachment

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ABSTRACT

Purpose: This study aims to evaluate anatomical and functional success rates, surgical approaches, and late postoperative complications in pediatric traumatic retinal detachment (RD) cases over a 12-month follow-up period.

Materials and Methods: Pediatric patients younger than 18 years, who underwent surgical treatment for RD following open globe injury (OGI) or closed globe injury (CGI) at a single center between August 2020 and January 2024, were retrospectively reviewed. Patients' demographic data, RD characteristics, surgical approaches, and postoperative outcomes were analyzed. Anatomical success was defined as retinal reattachment maintained for at least 3 months at the 12-month follow-up. Functional success was defined as best corrected visual acuity (BCVA) ≥ 5/200 at the 12-month visit.

Results: A total of 46 patients (OGI: 20, CGI: 26) with a mean age of 9.3 ± 3.6 years were included, and 78.2% of the patients were male. Anatomical success was 90% for OGI and 84.6% for CGI (p=0.821), with functional success of 40% and 50%, respectively (p=0.500). Visual acuity significantly improved in both groups (OGI: from logMAR 2.1 ± 0.8 to 1.7 ± 0.9, p = 0.030; CGI: from logMAR 2 ± 0.7 to 1.5 ± 0.8, p < 0.001). The most frequent postoperative complications were band keratopathy (20%) in the OGI group and cataract development (38.5%) in the CGI group.

Conclusion: Although anatomical success rates are high in pediatric traumatic RD, functional improvement remains limited. Therefore, enhancing preventive measures to reduce trauma-related vision loss in children is crucial.

Keyword: trauma, pediatric retinal detachment, scleral buckle, pars plana vitrectomy.

INTRODUCTION

Retinal detachment (RD) is relatively rare in children compared to adults, accounting for only approximately 3.2–6.6% of all RD cases; however, ocular trauma remains the most common cause of RD in the pediatric population.[1] According to the American Academy of Pediatrics Committee, approximately 60% of all ocular injuries occur in the pediatric age group.[2] Traumatic RD may lead to severe ocular morbidity in pediatric patients, ranging from mild vision loss to phthisis bulbi. Excluding congenital causes, traumatic RD is one of the leading causes of childhood blindness.[3]

Pediatric traumatic RD cases pose a significant threat to vision due to delayed diagnosis, associated complications, and the incomplete maturation of the visual system. Furthermore, pediatric patients have a lifelong risk of recurrent detachment, glaucoma, and cataract following RD. These factors contribute to a broad clinical spectrum, complicating the prediction of anatomical and functional outcomes.[4]

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Although anatomical recovery can be achieved in the management of trauma-related RD's, functional outcomes may be adversely affected by coexisting visual developmental disorders such as amblyopia. However, in the pediatric population, the diagnosis of amblyopia remains under-documented in the literature due to factors such as the need for subjective cooperation, age-related limitations, and challenges in long-term follow-up. This hampers the accurate evaluation and comparison of functional outcomes in pediatric traumatic RD cases.[1,4]

The etiology, anatomical characteristics, and prognosis of RD in pediatric patients differ significantly from adults, with a higher incidence of predisposing factors, especially trauma.[1,2] However, clinical features and surgical outcomes of pediatric traumatic RD cases have not been sufficiently characterized in the literature. Most studies have addressed traumatic RD in children as a subgroup within general ocular trauma or overall pediatric RD cases, thus providing limited data specifically for pediatric traumatic RD. To date, only Sarrazin et al. and Sul et al. have evaluated pediatric traumatic RD cases as a distinct group, highlighting the need for further research to better understand this subgroup.[5,6]

The aim of this study is to analyze the demographic and clinical characteristics, types of trauma, surgical approaches, and anatomical and functional outcomes in pediatric cases of traumatic retinal detachment (RD), thereby contributing to the existing literature.

METHODS

This retrospective observational study was designed as a single-center, consecutive, non-comparative case series. All pediatric patients under the age of 18 who underwent surgical treatment for retinal detachment (RD) due to ocular trauma at a single academic institution between August 2020 and January 2024 were included. The study adhered to the principles of the Declaration of Helsinki and was approved by the institutional ethics committee. Patients diagnosed with traumatic RD who completed at least one year of follow-up were included. Those with incomplete follow-up, missing clinical records, previous surgical history at another center, or extremely poor postoperative visual prognosis deemed inoperable were excluded.

Patient demographic data, type of trauma (open globe injury [OGI] or closed globe injury [CGI]), zone of injury, detailed classification of OGI, ocular injuries secondary to trauma (e.g., corneal or scleral perforation, presence of intraocular foreign body), lens status, time from trauma to surgery, and details of performed surgeries were recorded. Additionally, RD characteristics (macular involvement, tear type, presence of proliferative vitreoretinopathy [PVR] and choroidal detachment [CD]), type of vitreoretinal surgery (VRS) performed (scleral buckling [SB] alone, pars plana vitrectomy [PPV] alone, or combined PPV with SB), surgical complications, and final anatomical success rates were documented. Final anatomical success was defined as retinal reattachment maintained for at least 3 months, regardless of silicone oil (SO) tamponade removal at the 12-month follow-up visit. Functional success was defined as best corrected visual acuity (BCVA) of 5/200 or better at the 12-month examination.[7] The number of surgical procedures performed throughout the follow-up period was also recorded.

SURGICAL APPROACH AND EVALUATION

The timing of surgery was planned considering the patient's general health status and ocular readiness for surgery. Ocular trauma was classified as OGI or CGI according to the Birmingham Eye Trauma Terminology System.[8] Written informed consent was obtained from parents for all surgical procedures, and all surgeries were performed by the same surgeon (S.A.O.). Surgical technique selection was based on clinical characteristics of the patient and severity of the RD. The choice among SB, PPV, or combined surgery was not systematically analyzed due to the retrospective nature of the study and was primarily based on the surgeon's clinical judgment and individualized patient considerations.

In all PPV procedures, a standard three-port 25-gauge system was utilized. During surgery, core vitrectomy was performed using triamcinolone acetonide, posterior vitreous detachment was induced, and perfluorocarbon liquid was used to stabilize the posterior retina. Following complete shaving of the vitreous base, fluid-air exchange, subretinal fluid aspiration, and endolaser retinopexy were performed. Silicone oil (SO) with a viscosity of 5000 cst was used in all cases. In aphakic eyes, surgical iridectomy was performed at the 6 o'clock position.

In patients undergoing SB, a silicone band was placed externally around the globe to support the retina. This band

was sutured to the sclera to relieve vitreous traction and facilitate retinal reattachment. This technique specifically aimed to support the vitreous base and effectively close retinal tears.

POSTOPERATIVE FOLLOW-UP AND VISUAL REHABILITATION

Patients who underwent PPV and were cooperative were advised to maintain a prone position for one week postoperatively. To prevent anisometropia and amblyopia, individualized visual rehabilitation approaches were implemented. In patients with significant refractive differences, correction with contact lenses was preferred. Children aged 4–7 years with a high risk of amblyopia were assessed through early orthoptic evaluation, and occlusion therapy was applied when indicated. Patients at risk for strabismus development were regularly monitored, and orthoptic interventions were planned as necessary. Intraocular lens (IOL) implantation was performed based on the patient's lens capsule integrity and age, employing techniques such as in-the-bag placement, sulcus placement, or scleral fixation. Cases requiring secondary IOL implantation underwent further assessment.

In the postoperative period, patients with low visual acuity were evaluated with advanced imaging modalities. Ultrasonography was performed to assess retinal status, persistence of retinal detachment, vitreous opacities, and subretinal fluid. Optical coherence tomography was utilized to analyze central foveal thickness, macular edema, and atrophy to understand the macular factors contributing to functional outcomes.

Revision Surgery

In cases of recurrent RD, additional SB, PPV, or combined surgery was performed on patients who initially underwent PPV alone. Additional PPV was performed when necessary on patients who previously underwent combined surgery. During revision surgery, previously placed silicone oil (SO) was removed, residual vitreous cortex was cleared using triamcinolone, and epiretinal membranes were peeled when present. Subretinal fluid aspiration, relaxing retinectomies (when necessary), and additional endolaser retinopexy were performed, followed by re-injection of SO (5000 cst). Surgical decisions were individualized according to each patient's clinical condition and surgeon's assessment. In eyes with postoperative stable retinal structure, silicone oil was removed using a three-port (25-gauge) technique. The retina and tear sites were carefully evaluated, and the procedure was completed with multiple air-fluid exchanges.

Visual Acuity Assessment

Best corrected visual acuity (BCVA) was assessed using the Snellen chart at each visit, depending on the patient's cooperation. Patients who were unable to cooperate were excluded from the study. BCVA values were converted to the logarithm of the minimum angle of resolution (LogMAR) scale for statistical analyses. In cases with no light perception (NLP), electroretinography and visual evoked potential tests were performed to obtain more objective assessments. Additionally, BCVA was categorized into the following subgroups, similar to the ocular trauma scoring system:[7]

- No light perception (NLP)
- Light perception (LP)
- Hand movements (HM)
- 1/200 - 19/200
- 20/200 - 20/50
- 20/40 or better

Statistical Analysis

In the study, statistics for continuous variables were reported as mean±standard deviation or median (IQR), and descriptive statistics for categorical variables were reported as numbers and percentages. Normality of continuous variables was assessed using the Shapiro-Wilk test. Depending on the distribution, differences between two independent groups were analysed using the independent samples t-test or the Mann-Whitney U test. Differences between paired groups were assessed using the Wilcoxon signed-ranks test, depending on the distribution. Relationships between categorical variables were assessed using the Pearson chi-squared test, Fisher's exact test or Fisher-Freeman-Halton test. Statistical analyses were performed with IBM SPSS Statistics (version 28). A significance level of 95% was considered, and p-values equal to or less than 0.05 were interpreted as statistically significant.

RESULTS

A total of 46 eyes from 46 patients aged between 4 and 17 years (mean age: 9.3 ± 3.6 years; 78.2% male) were included in this study. Open globe injury occurred in 20 eyes (43.5%) and CGI in 26 eyes (56.5%). In the OGI group, penetrating injuries were identified in 13 eyes (65%), globe rupture in 3 eyes (15%), and intraocular foreign bodies (IOFB) in 4 eyes (20%) ($p = 0.387$). Among IOFB cases, 2 were metallic and 2 non-metallic; 3 IOFBs were located in the posterior segment, and 1 magnetic IOFB was found in the anterior segment. IOFB removal was achieved via PPV and magnetic extraction. Additionally, in 3 cases of globe rupture, the rupture sites were near the lateral rectus muscle insertion, requiring supplementary diathermy. Groups were similar regarding age and gender ($p > 0.05$). Most OGI injuries (55%) were located in zone 1. Descriptive characteristics of OGI and CGI groups are summarized in Table 1. Initial clinical findings revealed iridodialysis as the most common in the OGI group (30%), while CD was most frequent in the CGI group (30%).

As shown in Table 2, excluding primary globe repairs, combined surgery (PPV + SB) was performed in 70% of OGI and 61.5% of CGI cases, with no statistically significant difference ($p > 0.05$). Intraoperative complications in the OGI group primarily included progression of retinal tears (15%), choroidal hemorrhage (10%), and vitreous hemorrhage (20%). In the CGI group, common intraoperative complications were new retinal tears (12%) and iatrogenic lens injury (8%). Regarding intraoperative lens procedures, 30% of OGI patients underwent lens aspiration remaining aphakic, and another 30% received primary IOL implantation during the initial perforation repair. In contrast, lens-sparing surgery was performed in 84.6% of CGI patients, and 15.4% underwent lens aspiration and IOL implantation ($p < 0.05$). Final anatomical success rates were 90% for OGI and 84.6% for CGI ($p = 0.821$).

Functional success was 40% in the OGI group and 50% in the CGI group ($p = 0.500$). Despite revision surgeries for recurrent retinal detachment (RD), anatomical success was not achieved in 2 OGI and 4 CGI cases. Silicone oil (5000 cSt) tamponade was used in all recurrent RD cases. Visual acuity improved significantly in both groups (OGI: from LogMAR 2.1 ± 0.8 to 1.7 ± 0.9, $p = 0.030$; CGI: from LogMAR 2 ± 0.7 to 1.5 ± 0.8, $p < 0.001$). However, final best-corrected visual acuity (BCVA) did not significantly differ between groups ($p = 0.291$).

Postoperative complications were predominantly band keratopathy in the OGI group (20%) and cataract formation in the CGI group (38.5%), with no significant overall complication rate difference between groups ($p > 0.05$). The mean number of VRS performed was significantly higher in the CGI group compared to the OGI group ($p = 0.05$). Other clinical features showed no significant differences between groups.

Figure 1 illustrates the distribution of preoperative and postoperative BCVA in both groups. Preoperatively, 15 patients in the OGI group had visual acuity of HM or worse, which decreased to 9 patients postoperatively. Similarly, this decreased from 16 to 8 patients in the CGI group. Postoperatively, no patients in the OGI group achieved BCVA better than 20/40, while 4 patients in the CGI group attained BCVA better than 20/40.

DISCUSSION

This study evaluated the clinical characteristics and anatomical and functional outcomes in pediatric patients with RD following OGI and CGI. Consistent with the literature, the majority of patients were male, with a male-to-female ratio of 3.6:1.[6,8-10] This finding can be explained by the fact that male children are generally less supervised and more likely to engage in physical activities. Additionally, right and left eyes were affected with similar frequency, consistent with previous reports in the literature.[4,9,11]

Another noteworthy finding of our study is the higher frequency of CGI cases compared to OGI, contrasting with the generally reported higher incidence of OGI in the literatüre.[7,10] This discrepancy might be attributed to the fact that OGI cases typically undergo initial trauma surgery and subsequent follow-up in other institutions, whereas CGI cases, due to their higher complication risk, are often referred to our VRS center. Therefore, although our results are generally consistent with previous literature, the higher frequency of CGI cases suggests that institutional differences in data collection methods and patient referral patterns may play a significant role. Consequently, future multicenter studies could facilitate a more balanced and comprehensive assessment of both OGI and CGI cases.

Table 1. Baseline characteristics between eyes with closed and open globe injuries				
		OGI (n=20)	CGI (n=26)	p
Age (y)		8.9 ± 4 / 8.5 (5.5-11.5)	9.6 ± 3.3 / 9.5(7-12)	0.510 [a]
Males, n(%)		14 (70)	22 (84.6)	0.294 [b]
Eyes involved, n (%right eye)		8 (40)	13 (50)	0.500 [b]
BCVA (LogMAR)		2.1±0,8 / 2.3 (1.7-2.6)	2±0.7 / 2.3 (1.3-2.6)	0.927 [c]
Trauma zone, n (%)	**Zone 1**	11 (55)	-	**-**
	Zone 2	6 (30)	-	
	Zone 3	3 (15)	-	
Interval between OGI trauma and **initial surgery** (days)		1.3 ± 0.5 / 1 (1-2)	-	-
Initial surgery details	**Corneal repair surgery**	11 (55)	-	-
	Corneascleral repair surgery	3 (15)	-	
	Lens aspiration + IOL implantation	6 (30)	-	
BCVA prior to VRS (LogMAR)		1.8 ± 0.7 / 1.7 (1.3-2.3)	2 ± 0.7 / 2.3 (1.3-2.6)	0.355 [c]
Interval between trauma and VRS (days)		23.8 ± 3.6 / 24 (20-26.5)	58.5 ± 30.8 / 46 (33-65)	**<0.001**[c,*]
Associated ocular pathologies, n (%)	**Hyphema**	3 (15)	2 (7.7)	0.122[d]
	Iridodialysis	6 (30)	2 (7.7)	
	Choroidal detachment	1 (5)	3 (11.5)	
	Endophthalmitis	2 (10)	1 (3.8)	
Lens Status at VRS	**Clear, n (%)**	2 (10)	18 (69.2)	**<0.001**[d,*]
	Crystalline lens dislocation, n(%)	0 (0)	2 (7.7)	
	Cataractous lens, n (%)	12 (60)	6 (23.1)	
	Pseudophakia, n(%)	6 (30)	0 (0)	
Macula attached of RD, n (%)		12 (60)	18 (69.2)	0.515[b]
Presence of associated vitreous hemorrhage, n (%)		10 (50)	18 (69.2)	0.318[b]
Presence of Proliferative Vitreoretinopathy, n (%)	**Grade B**	5 (25)	11 (42.3)	0.474[d]
	Grade C	13 (65)	13 (50)	
	Grade D	2 (10)	2 (7.7)	
Location of retinal tear, n (%)	**Superior**	3 (15)	4(15,4)	0,145[d]
	Inferior	4 (20)	6(23,1)	
	Superior+Inferior	0 (0)	4(15,4)	
	Giant tears	5 (25)	2 (7.7)	
	Dialysis	2 (10)	2 (7.7)	
	Undetectable	6 (30)	10 (30.8)	
Total number of tears		2.6 ± 1.4 / 2 (2-4)	1.6 ± 0.7 / 1.5 (1-2)	**0.041**[c,*]

Continuous variables are presented as the mean ± standard deviation / median (quartiles). Categorical variables are presented as number (%)

[a] Independent-samples t test, [b] Pearson Chi-Square test, [c] Mann Whitney U test, [d] Fisher-Freeman-Halton test, *p<0,05

OGI, open globe injury; CGI, closed globe injury; BCVA, best-corrected visual acuity; RD, retinal detachment; IOL, intraocular lens; VRS, vitreoretinal surgery.

Table 2. Comparison of surgical procedures in open and closed globe injuries

		OGI (n=20)	CGI (n=26)	p
Surgical procedure	**Scleral buckling alone, n (%)**	3 (15)	10 (38.5)	0.052[a]
	PPV alone, n (%)	3 (15)	0 (0)	
	Scleral Buckling + PPV	14 (70)	16 (61.5)	
Intraoperative lens surgery procedure	**Lens-sparing approach**	5 (25)	22 (84,6)	**<0.001[a,*]**
	Lens aspiration + IOL implantation	3 (15)	4 (15,4)	
	Lens aspiration + Aphakia	6 (30)	0 (0)	
	Pseudophakia Achieved via Lens Aspiration in Initial Surgery	6 (30)	0 (0)	
Rate of retinal reattachment success with 1st vitreoretinal surgery, n (%)		17 (85)	16 (61.5)	0.080[b]
SOR deferred, n (%)		6 (30)	8 (30.8)	0.149[b]
Interval to SOR (days)		133 ± 20.3 / 126 (121-156)	113.5 ± 37.6 / 122.5 (85-140)	0.162[c]
Final anatomical success, n (%)		18 (90)	22 (84.6)	0.821[b]
Final functional success, n (%)		8 (40)	13 (50)	0.500[b]
Final BCVA (LogMAR)		1.7 ± 0.9 / 2 (0.9-2.3)	1.5 ± 0.8 / 1.3 (0.7-2.3)	0.291[f]
Late Complications, total (n = 32)		14 (70)	18 (69.2)	0.128[a]
Pre-phthisical eye, n (%)		3 (15)	1 (3.8)	
BSK, n (%)		4 (20)	2 (7.7)	
Glaucoma, n (%)		3 (15)	1 (3.8)	
Optic atrophy, n (%)		1 (5)	4 (15.4)	
Cataract, n (%)		3 (15)	10 (38.5)	
Total Follow-Up Duration (month)		20.4 ± 8.8 / 17 (12-26)	20.5 ± 6.6 / 20 (14-24)	0.832[d]
Total Number of Vitreoretinal Surgeries (Excluding Initial Perforation Surgery)		1.2 ± 0.4 / 1 (1-1)	1.6 ± 0.9 / 1 (1-2)	**0.050[d,*]**

Continuous variables are presented as the mean ± standard deviation / median (quartiles). Categorical variables are presented as number (%).

[a] Fisher-Freeman-Halton test, [b] Pearson Chi-Square test, [c] Independent-samples t test, [d] Fisher's Exact test, [e] Mann Whitney U test, [f] Wilcoxon U test, *p<0,05.

OGI, open globe injury; CGI, closed globe injury; PPV, pars plana vitrectomy; IOL, Intraocular Lens; SOR, silicone oil removal. BCVA, best corrected visual acuity; BSK, band-shaped keratopathy.

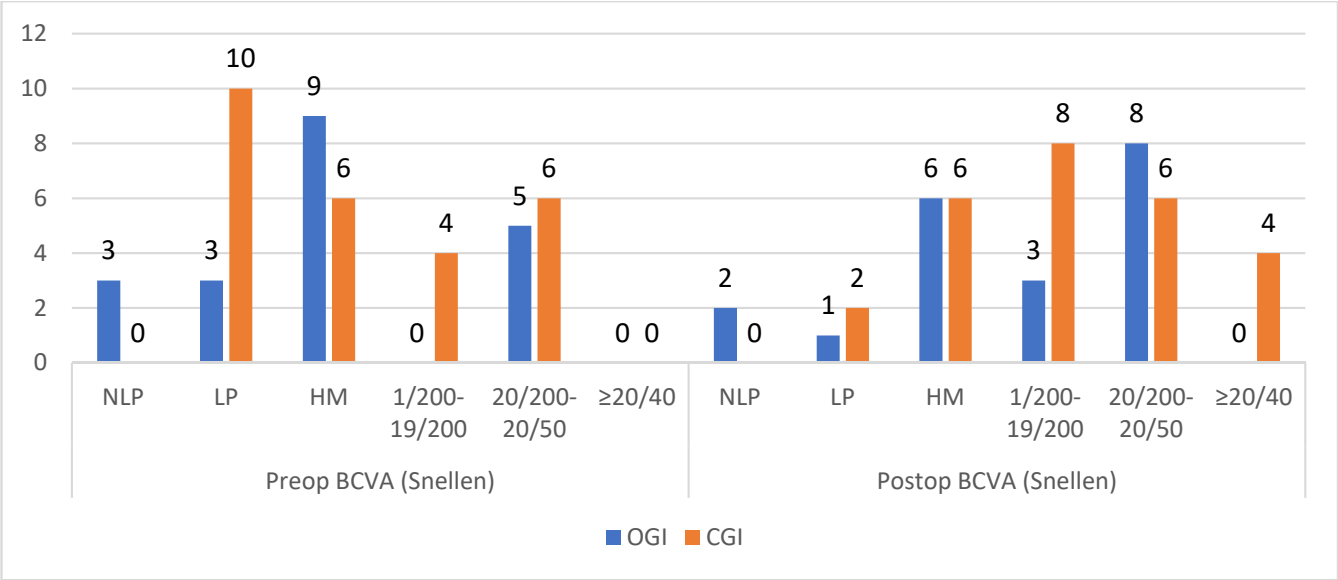

Figure 1. *Distribution of Best-Corrected Visual Acuity in Pediatric Open and Closed Globe Injuries*

Abbreviations: BCVA = best-corrected visual acuity, NLP = no light perception, LP = light perception, HM = hand movements.

In our series, patients with OGI initially underwent primary trauma repair surgery, whereas VRS was planned at initial presentation for CGI cases. Previous studies reported that approximately 50% of patients diagnosed with RD are identified at initial presentation. However, since our study exclusively included traumatic RD cases, all patients in our cohort had RD at the initial presentation.[9] Moreover, the duration between injury and clinical presentation was notably longer in the CGI group, aligning with similar findings in the literature.[6,10] CGI cases may go unnoticed during the initial trauma, and tears developing due to the structural characteristics of the vitreous can lead to slow RD progression, resulting in delayed diagnosis.

In our study, the rates of undetected retinal tears in OGI and CGI cases were 30% and 30.8%, respectively, comparable to previously reported rates of 50% and 32%.[12] Combined surgery was the most commonly performed surgical approach in our series, accounting for 70% of OGI cases and 61.5% of CGI cases. Different surgical approaches have been reported in the literature, indicating that combined surgery is typically preferred in OGI cases due to their more complex nature, whereas SB is more frequently used for CGI cases.[6,10,13,14] However, the higher preference for combined surgery observed in our CGI cases might be attributed to factors such as the presence of PVR, delayed presentations, and the high complexity of cases in our series. Nevertheless, given the retrospective nature of our study, detailed explanations regarding surgical decision-making in CGI cases remain limited, reflecting inherent constraints of retrospective data collection.

In this study, the primary surgical success rate was 71.7% (OGI: 85%, CGI: 61.5%), while the final anatomical success rate was 87% (OGI: 90%, CGI: 84.6%), and the final functional success rate was 45% (OGI: 40%, CGI: 50%). The anatomical success rates were consistent with those previously reported in the literature. However, the complex nature of pediatric cases, postoperative inflammatory responses, and the potential presence of amblyopia whose exact prevalence could not be reliably documented in our study may have contributed to the relatively lower functional success rates.[1,6,7,12-18]

Despite favorable anatomical outcomes, limited functional success may not solely reflect structural recovery but may also be influenced by concurrent visual developmental disorders such as amblyopia. The risk of developing amblyopia is particularly high in younger children with immature visual systems and macular involvement. Similar concerns regarding macular involvement and developmental vulnerability have also been highlighted in national studies.[16] Although this study did not include direct measurements of amblyopia, delays in its diagnosis and treatment may substantially hinder visual recovery.

Moreover, adherence to visual rehabilitation protocols and the ability to maintain regular follow-up in pediatric patients are critical factors influencing functional prognosis. Therefore, in pediatric traumatic RD cases, attention should be given not only to achieving anatomical success but also to implementing comprehensive strategies that support postoperative visual development.[1,6,7]

In our study, a total of 4 pre-phthisical eyes were identified, 3 in the OGI group and 1 in the CGI group, which is consistent with previously reported findings in the literature.[10,12] Overall complication rates were similar between the two groups.

The retrospective design of our study resulted in several methodological limitations. In particular, the lack of detailed data on amblyopia and other factors potentially influencing long-term visual prognosis in pediatric cases complicates the interpretation of our findings. Moreover, due to the retrospective nature, clinical factors guiding the surgical decision-making process could not be systematically or objectively analyzed. Additionally, as our study was conducted at a single center, the generalizability of our results may be limited. In particular, the lack of detailed data regarding the diagnosis and management of amblyopia limits the assessment of functional outcomes in pediatric patients. Furthermore, the single-center nature of this study restricts the generalizability of the findings to broader populations, considering potential variations in surgical approaches and patient profiles across different institutions. Future prospective, multicenter studies addressing these limitations will enhance our understanding of pediatric traumatic RD.

In conclusion, although high anatomical success rates can be achieved with surgical treatment in pediatric traumatic RD cases, visual outcomes remain limited. Major factors contributing to these outcomes include delayed diagnosis, macular involvement, PVR, and amblyopia. Early diagnosis, individualized surgical approaches, and comprehensive postoperative visual rehabilitation are essential for improved management of pediatric traumatic RD. Future prospective and multicenter studies are warranted to develop more effective treatment protocols and enhance long-term visual prognosis in this patient population.

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