



# The clinical features and the factors affecting visual prognosis in pediatric open-globe injuries

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## Abstract

**Purpose** To investigate clinical features and factors affecting visual prognosis after pediatric open-globe injuries.

**Methods** Retrospective study of 223 children with open-globe injury was conducted. Children with final logMAR visual acuity (LVA) > 0.70 were determined as poor-vision group (group 1,  $n=108$ ) and those with final LVA  $\leq 0.70$  as good-vision group (group 2,  $n=115$ ). Demographic characteristics (age, gender, and damaged eye), time between trauma and surgery, ocular trauma score (OTS), follow-up time, injury size, initial and final visual acuity levels, injury type (penetrating injury, globe rupture, perforating injury, and intraocular foreign body injury), injury localization (zone 1 = within the corneal and/or limbal area, zone 2 = within the scleral area extending 5 mm back from the limbus, and zone 3 = within the area posterior to zone 2), injury cause [metal objects (fork, knife, needle), broken glass, blunt objects (ball, punch), pen–pencil, and unidentified objects], and accompanying ocular findings of the groups were detected, and comparisons were done. Additionally, effects of age, time between trauma and surgery, OTS, injury size, follow-up time, initial LVA, injury

type, and injury zone on final LVA were analyzed in both groups.

**Results** Mean age was  $9.1 \pm 2.0$  years. There were 151 males and 72 females. Compared to group 1, group 2 had better initial and final visions ( $1.21 \pm 0.26$  vs  $0.60 \pm 0.28$ ,  $p < 0.001$  for initial LVA;  $1.00 \pm 0.32$  vs  $0.30 \pm 0.13$ ,  $p < 0.001$  for final LVA), greater OTS ( $1.72 \pm 0.53$  vs  $3.73 \pm 0.61$ ,  $p = 0.025$ ), and smaller injury size ( $10.4 \pm 3.5$  vs  $5.8 \pm 2.4$  mm,  $p = 0.002$ ). Globe rupture ( $p = 0.015$ ) and relative afferent pupillary defect (RAPD) ( $p = 0.037$ ) were higher in group 1, while penetrating injury ( $p = 0.044$ ), zone 1 involvement ( $p = 0.038$ ), and metal object injury ( $p = 0.041$ ) were higher in group 2. Based on multivariate analysis, the presences of globe rupture ( $p = 0.024$ ) and RAPD ( $p = 0.035$ ), the involvement without zone 1 ( $p = 0.042$ ), and the injury without metal object (fork, knife, needle) ( $p = 0.046$ ) were associated with poor final vision. Final LVA (for group 1 and group 2) was negatively correlated with OTS ( $r = -0.398$ ,  $p = 0.037$ ;  $r = -0.369$ ,  $p = 0.040$ ), while positively correlated with injury size ( $r = 0.412$ ,  $p = 0.031$ ;  $r = 0.318$ ,  $p = 0.046$ ) and initial LVA ( $r = 0.335$ ,  $p = 0.043$ ;  $r = 0.402$ ,  $p = 0.034$ ).

**Conclusion** In our study, poor prognostic factors affecting final vision were low OTS, poor initial vision, the presences of globe rupture and RAPD, the large injury size, the involvement without zone 1, and the injury without metal object (fork, knife, needle).

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**Keywords** Children · Ocular trauma score · Open-globe injury · Visual acuity · Visual prognosis

## Introduction

Open-globe injury (OGI) is one of the preventable causes of vision loss in children [1]. Full-thickness defect in the cornea and/or sclera is considered as an OGI [2]. In the diagnosis of OGI, patient history and clinical eye examination are important [3]. Additional diagnostic tools such as computed tomography and B-scan ultrasonography can be used in patients with OGI with suspected intraocular foreign body [4, 5]. In recent years, optical coherence tomography (OCT) has been utilized in many areas of ophthalmology due to its noncontact and noninvasive properties [6–11]. In some cases, anterior and posterior segment OCT may also be useful in the evaluation of ocular trauma [12–14]. The annual incidence of OGI is between 2.8 and 5.1 per 100,000 [15–17]. Varying levels of low vision or blindness may occur after trauma, and this condition may cause lifelong negative impacts on both children and parents [18]. Additionally, OGIs are an important public health problem as they reduce the quality of life [17, 19, 20].

Clinical findings detected after the ocular trauma may provide valuable clues in determining the visual prognosis, managing the trauma, and informing the parents about the possible consequences and processes. In addition, knowing the ocular risk factors capable of affecting the final vision may be important for visual rehabilitation. Although there were studies investigating the OGIs in children, most of them were about the epidemiology, and the studies showing the visual prognostic factors in OGIs were insufficient [17–19, 21–25]. To the best of our knowledge, this is the first study investigating the effects of age, time between trauma and surgery, ocular trauma score (OTS), injury size, follow-up time, initial vision, injury type, and injury zone on final vision in detail. In this study, we aimed to determine the clinical features and to investigate the factors affecting the visual prognosis in OGIs involving a large number of pediatric cases in a tertiary reference hospital.

## Materials and methods

This retrospective study was performed with the approval of the Izmir Tepecik Training and Research Hospital's Medical Research Ethical Committee (approval number: 2020/14–1) and in line with the ethical principles of the Declaration of Helsinki. Written consent forms were received from the participants and their parents. Initially, 257 cases aged 7–18 years and diagnosed with OGI between May 2014 and August 2020 were detected from files and system records. Children whose visual acuities could not be determined during admission and/or follow-up, the cases having multiple injury type, injury localization or injury cause, and the children with multi-system trauma accompanied by head injuries were excluded from the study. If a history of ocular trauma, cataracts, amblyopia, chronic ocular disease, or ocular surgery prior to ocular injury was detected in the medical personal history part of the file records, those cases were also excluded from the study. Data of 223 children attending to the control examination regularly, followed up for at least 6 months and having complete follow-up data, were analyzed.

Age, gender, and medical histories of cases were recorded. The damaged eye, time between trauma and surgery, OTS at presentation, follow-up time after injury, initial and final best-corrected visual acuity levels, and injury size were detected. Snellen visual acuity was converted to logarithm of the minimum angle of resolution (logMAR) unit for the statistical analysis accuracy and convenience [26]. The logMAR visual acuity (LVA) levels were considered as 2.0 at cases only counting fingers, 2.3 at children detecting hand motion, 2.7 at cases with only light perception, and 3.0 at children with no light perception [27]. The type, localization, and cause of OGI were determined. Anterior and posterior segment findings were recorded. At presentation, accompanying ocular findings such as uveal tissue damage, relative afferent pupillary defect (RAPD), lens damage, vitreous hemorrhage, and retinal detachment were evaluated. At last visit, ocular findings such as eyelid disorders, corneal opacity, lens opacity, posterior capsule opacification, and posterior segment defect were recorded.

Open-globe traumas were defined according to the Birmingham Eye Trauma Terminology system and Ocular Trauma Classification Group guidelines [2, 28]. Injury types were classified into 4 groups

as penetrating injury (only if there was an entrance wound or the same entrance-exit wound), globe rupture (if there was a full-thickness wound at the weakest point of the eyewall because of blunt trauma), perforating injury (if there were separate entrance and exit wounds), and intraocular foreign body injury (if there was a foreign body in the ocular structure) [2]. Injury localizations were divided into 3 regions as zone 1 (within the corneal and/or limbal area), zone 2 (within the scleral area extending 5 mm back from the limbus), and zone 3 (within the area posterior to zone 2) [28]. OTS was calculated according to the visual acuity level of cases at presentation and the presence of globe rupture, endophthalmitis, perforating injury, retinal detachment, and RAPD [29]. OTS was determined as score 1 (0–44 points), score 2 (45–65 points), score 3 (66–80 points), score 4 (81–91 points), or score 5 (92–100 points) based on ocular trauma raw score [29]. Causes of injury were categorized as metal objects (fork, knife, needle), broken glass, blunt objects (ball, punch), pen–pencil, and unidentified objects (if the cause of injury could not be determined). In all cases with OGI, primary globe repair  $\pm$  additional procedures (according to accompanying ocular findings, eyelid repair, anterior chamber lavage, lensectomy, anterior vitrectomy, intraocular foreign body removal, or pars plana vitrectomy) were performed under general anesthesia.

The visual acuity level of an individual may affect his/her quality of life [30–32]. Visual impairment occurring due to many causes such as trauma or amblyopia may interfere with the individual's daily life activities and visuomotor functions such as reading, learning, walking, or driving [30, 33, 34]. The Snellen visual acuity 20/100 (LVA 0.70) value is in the range of the moderate vision loss [34]. In USA, a person is considered as 'statutorily blind' by the Social Security Administration when the visual acuity is less than 20/100 [35]. In Italy, the best-corrected visual acuity requirements for driver license are at least 20/20 for binocular vision, with a minimum of 20/100 for the worse-seeing eye [36]. Similarly in Germany, binocular corrected visual acuity requirements for driver license are at least 20/40 in the best eye and 20/100 in the worse eye [36]. Additionally in the classification of amblyopia, which was another cause of visual impairment and visuomotor deficit, the cutoff visual acuity level between the moderate and severe amblyopia has been determined as

20/100 [37, 38]. Moreover in literature, the visual grade of cases with ocular trauma was classified into five categories as grade 1 ( $\geq 20/40$ ), grade 2 (20/50 to 20/100), grade 3 (19/100 to 5/200), grade 4 (4/200 to light perception), and grade 5 (no light perception) [28, 39]. In this visual acuity classification, the transition from grade 2 to grade 3 was located at the midpoint in cases with vision better than no light perception, and 20/100 visual acuity was used as the cutoff level for this transition [28, 39]. For all these reasons, final LVA  $\leq 0.70$  (Snellen visual acuity  $\geq 20/100$ ) level, at which the individual could perform daily life activities or visuomotor functions during childhood or adulthood, was considered as good vision in our study. Children with final LVA  $> 0.70$  (Snellen visual acuity  $< 20/100$ ) were determined as poor-vision group (group 1,  $n = 108$ ) and those with final LVA  $\leq 0.70$  (Snellen visual acuity  $\geq 20/100$ ) as good-vision group (group 2,  $n = 115$ ). Intragroup and intergroup comparisons were done. In addition, effects of age, time between trauma and surgery, OTS, injury size, follow-up time, initial LVA, injury type, and injury zone on final LVA were analyzed in both groups.

Statistical Package for Social Sciences (SPSS 20.0; IBM, USA) software was used for statistical data analysis. Before beginning the study, a post hoc power analysis was made, and it was detected that the number of sample size was approximately 20 to identify a statistically significant difference among the main variables, with 80% statistical power and an alpha error of 0.05. Continuous variables were given as mean  $\pm$  standard deviation (minimum–maximum) values, while count data were expressed as case number and percentage. Whether the variables complied with normal distribution in groups were determined by the Kolmogorov–Smirnov test. Since there was no normal distribution, Mann–Whitney U test, Wilcoxon test, and Kruskal–Wallis test were used in comparisons. Count data were evaluated by the Chi-square test. Univariate analysis was made to determine predictive variables associated with a final visual outcome. Additionally, multivariate logistic regression analysis was done on variables found to be significant in univariate analysis in order to better describe the effects of variables on final vision. The multivariate model was performed using logistic regression to predict poor visual outcome. The enter method was used to enter the independent variables into a multivariate

logistic regression model. The independent variables were the penetrating injury, globe rupture, zone 1 involvement, RAPD, metal object injury, and posterior segment defect, while the dependent variable was the final visual outcome. Relationships between the final LVA with the age, time between trauma and surgery, OTS, injury size, follow-up time, initial LVA, injury type, and injury zone were assessed by the Spearman's correlation analysis.  $p < 0.05$  was considered statistically significant.

## Results

The mean age of all cases was  $9.1 \pm 2.0$  years. There were 151 (67.7%) males and 72 (32.3%) females. The number of male was significantly higher in both poor-vision group (68.5% male vs 31.5% female,  $p = 0.002$ ) and good-vision group (66.9% male vs 33.1% female,  $p = 0.004$ ). Mean ages, damaged eyes, time between trauma and surgery, and follow-up time of groups were similar ( $p > 0.05$ ). In both groups, final visions were better than initial visions ( $1.00 \pm 0.32$  vs  $1.21 \pm 0.26$ ,  $p = 0.039$  for LVA in group 1;  $0.30 \pm 0.13$  vs  $0.60 \pm 0.28$ ,  $p = 0.023$  for LVA in group 2).

Compared to group 1, group 2 had better initial and final visions ( $1.21 \pm 0.26$  vs  $0.60 \pm 0.28$ ,  $p < 0.001$  for initial LVA;  $1.00 \pm 0.32$  vs  $0.30 \pm 0.13$ ,  $p < 0.001$  for final LVA), greater OTS ( $1.72 \pm 0.53$  vs  $3.73 \pm 0.61$ ,  $p = 0.025$ ), and smaller injury size ( $10.4 \pm 3.5$  vs  $5.8 \pm 2.4$  mm,  $p = 0.002$ ). Clinical characteristics of groups are given in Table 1.

In intragroup comparison, while the distribution of injury types was similar in poor-vision group ( $p = 0.492$ ), the penetrating injury was found to be most frequent (72.2%) in good-vision group ( $p = 0.031$ ). In univariate analysis, compared to group 1, group 2 had more frequent penetrating injury (45.4% vs 72.2%,  $p = 0.044$ ) and less frequent globe rupture (37.0% vs 17.4%,  $p = 0.015$ ). In intragroup comparison, while the distribution of injury localizations was similar in poor-vision group ( $p = 0.645$ ), zone 1 involvement was determined to be most frequent (65.2%) in good-vision group ( $p = 0.046$ ). Compared to group 1, group 2 had more frequent zone 1 involvement (39.8% vs 65.2%,  $p = 0.038$ ). In intragroup comparison, the distribution of accompanying ocular findings at presentation was similar in each group ( $p > 0.05$ ). The presence of RAPD was significantly higher in poor-vision group than

**Table 1** Clinical characteristics of the groups

Clinical characteristics	Poor-vision group (Group 1, $n = 108$ ) (Final LVA $> 0.70$ ) (Snellen VA $< 20/100$ )	Good-vision group (Group 2, $n = 115$ ) (Final LVA $\leq 0.70$ ) (Snellen VA $\geq 20/100$ )	$p$ (intergroup comparison)
Age (year)	$9.0 \pm 1.9$ (7–18)	$9.2 \pm 2.0$ (7–18)	0.706 <sup>b</sup>
Gender ( $n$ , %)	$p = 0.002^a$ (intragroup comparison)	$p = 0.004^a$ (intragroup comparison)	
Male ( $n = 151$ )	74 (68.5%)	77 (66.9%)	0.927 <sup>a</sup>
Female ( $n = 72$ )	34 (31.5%)	38 (33.1%)	0.867 <sup>a</sup>
Laterality ( $n$ , %)	$p = 0.751^a$ (intragroup comparison)	$p = 0.708^a$ (intragroup comparison)	
Right ( $n = 112$ )	57 (52.8%)	55 (47.8%)	0.671 <sup>a</sup>
Left ( $n = 111$ )	51 (47.2%)	60 (52.2%)	0.729 <sup>a</sup>
Time between trauma and surgery (hour)	$23.6 \pm 14.5$ (6–48)	$22.9 \pm 13.2$ (5–48)	0.687 <sup>b</sup>
Ocular trauma score (1–5)	$1.72 \pm 0.53$ (1–3)	$3.73 \pm 0.61$ (3–5)	0.025 <sup>b</sup>
Follow-up time (month)	$32.7 \pm 11.4$ (6–69)	$33.1 \pm 12.2$ (7–69)	0.472 <sup>b</sup>
Injury size (mm)	$10.4 \pm 3.5$ (5–14)	$5.8 \pm 2.4$ (3–10)	0.002 <sup>b</sup>
Visual acuity	$p = 0.039^c$ (intragroup comparison)	$p = 0.023^c$ (intragroup comparison)	
Initial LVA (Snellen VA)	$1.21 \pm 0.26$ (0.80–2.70) (20/324)	$0.60 \pm 0.28$ (0.30–1.0) (20/80)	$< 0.001^b$
Initial LVA (Snellen VA)			
Final LVA (Snellen VA)	$1.00 \pm 0.32$ (0.76–3.00) (20/200)	$0.30 \pm 0.13$ (0.10–0.70) (20/40)	$< 0.001^b$

Descriptive features were expressed as mean  $\pm$  standard deviation (minimum–maximum) values

VA Visual acuity, LVA Logarithm of the minimum angle of resolution (LogMAR)-VA,  $n$  Number of cases

<sup>a</sup>Chi-square test, <sup>b</sup>Mann–Whitney  $U$  test, <sup>c</sup>Wilcoxon test,  $p < 0.05$  statistically significant

in good-vision group (44.4% vs 17.3%,  $p=0.037$ ). There were no differences in rates of uveal tissue damage, lens damage, vitreous hemorrhage, retinal detachment, and other rare findings such as hyphema between the groups ( $p>0.05$ ). There were three cases (2.8%) with endophthalmitis in group 1 and none in group 2.

In intragroup comparison, while the distribution of injury causes was similar in poor-vision group ( $p=0.713$ ), injury with metal objects was detected to be most frequent (51.3%) in good-vision group ( $p=0.035$ ). Compared to group 1, group 2 had more frequent metal object injury (29.6% vs 51.3%,  $p=0.041$ ). In intragroup comparison, the distribution of ocular findings at last visit was similar in each group ( $p>0.05$ ). Posterior segment defect was found to be higher in group 1 than in group 2 (33.3% vs 15.7%,  $p=0.024$ ). There were no differences in rates of eyelid disorders, corneal opacity, lens opacity, posterior capsule opacification, and other rare findings such as glaucoma between the groups ( $p>0.05$ ). There were three children (2.8%) with phthisis bulbi in poor-vision group and none in good-vision group. Ocular trauma characteristics of groups are given in Table 2. Additionally, variables found to be significant in univariate analysis were included in one multivariate logistic regression analysis model to predict poor visual outcome. Penetrating injury and posterior segment defect were not statistically significant predictive factors for poor visual outcome in multivariate analysis ( $p>0.05$ ). The presences of globe rupture [odds ratio (OR)=2.713, 95% confidence interval (CI)=1.843–4.582;  $p=0.024$ ] and RAPD (OR=1.984, 95% CI=1.087–3.415;  $p=0.035$ ), the involvement without zone 1 (OR=1.562, 95% CI=1.206–3.097;  $p=0.042$ ), and the injury without metal object (fork, knife, needle) (OR=1.285, 95% CI=1.012–2.953;  $p=0.046$ ) were associated with poor final vision in multivariate analysis. The result of the multivariate logistic regression analysis is given in Table 3.

In both groups, correlations between the final LVA with the age, time between trauma and surgery, OTS, injury size, follow-up time, initial LVA, injury type, and injury zone were investigated. In groups, the final LVA was negatively correlated with OTS ( $r=-0.398$ ,  $p=0.037$  for group 1;  $r=-0.369$ ,  $p=0.040$  for group 2), while positively correlated with injury size ( $r=0.412$ ,  $p=0.031$  for group 1;  $r=0.318$ ,  $p=0.046$

for group 2) and initial LVA ( $r=0.335$ ,  $p=0.043$  for group 1;  $r=0.402$ ,  $p=0.034$  for group 2). No correlations were detected between the final LVA with the age, time between trauma and surgery, follow-up time, injury type, and injury zone in groups ( $p>0.05$ ). Correlations between the final LVA and clinical characteristics are given in Table 4.

## Discussion

Ocular trauma may cause the vision loss. Sometimes, accompanying conditions may also have a role in vision loss. For example, in the case of OGI, if concomitant corneoscleral lacerations are present, behavioral abnormalities of the tear-film-free surface may lead to a loss of protection from ultraviolet light rays, and therefore predispose to various ocular diseases and contribute to poor visual outcome [40–44]. Visual impairment that may occur after OGI in children may have some adverse effects on quality of life. Severe visual impairment in the damaged eye may affect the physical and psychological developments of children by impairing the binocular vision and may also reduce their school performance. These children may display some behaviors such as communication problems and shyness in social environments. The vision level of the damaged eye may even affect the child's career choice in the future. The physical, psychological, and financial difficulties that children with poor final vision will experience in their future lives may be more than those of children with good final vision. Children who are likely to have poor final vision after injury may need more additional intervention in the follow-up. At the same time, more frequent and longer follow-up may be required for these children. Having an idea about the possible poor final vision from the initial time may be useful in giving the preliminary information to the families, and in preparing them to the aforementioned conditions. For these reasons, knowing the prognostic factors that may affect the final visual level after OGI is valuable. In this study, in order to better determine the effects of prognostic factors on final vision, the children were evaluated in two groups as poor- and good-vision group according to the final visual acuity.

In literature, mean ages of children with OGI were stated as 6.6–11.6 years [1, 3, 19, 23, 25, 45]. In our study, mean ages were  $9.0 \pm 1.9$  years in poor-vision

**Table 2** Ocular trauma characteristics of the groups

Ocular trauma characteristics	Poor-vision group (Group 1, $n = 108$ ) (Final LVA $> 0.70$ ) (Snellen VA $< 20/100$ )	Good-vision group (Group 2, $n = 115$ ) (Final LVA $\leq 0.70$ ) (Snellen VA $\geq 20/100$ )	$p$ for univariate analysis (intergroup comparison)
Types of injury ( $n, \%$ )	$p = 0.492^b$ (intragroup comparison)	$p = 0.031^b$ (intragroup comparison)	
Penetrating injury	49 (45.4%)	83 (72.2%)	0.044 <sup>a</sup>
Globe rupture	40 (37.0%)	20 (17.4%)	0.015 <sup>a</sup>
Perforating injury	10 (9.3%)	6 (5.2%)	0.277 <sup>a</sup>
Intraocular foreign body injury	9 (8.3%)	6 (5.2%)	0.386 <sup>a</sup>
Zones of injury ( $n, \%$ )	$p = 0.645^b$ (intragroup comparison)	$p = 0.046^b$ (intragroup comparison)	
Zone 1	43 (39.8%)	75 (65.2%)	0.038 <sup>a</sup>
Zone 2	39 (36.1%)	26 (22.6%)	0.123 <sup>a</sup>
Zone 3	26 (24.1%)	14 (12.2%)	0.074 <sup>a</sup>
Accompanying ocular findings at presentation ( $n, \%$ )	$p = 0.578^b$ (intragroup comparison)	$p = 0.613^b$ (intragroup comparison)	
Uveal tissue damage	42 (38.8%)	34 (29.5%)	0.351 <sup>a</sup>
Relative afferent pupillary defect	48 (44.4%)	20 (17.3%)	0.037 <sup>a</sup>
Lens damage	19 (17.6%)	15 (13.0%)	0.482 <sup>a</sup>
Vitreous hemorrhage	32 (29.6%)	24 (20.8%)	0.273 <sup>a</sup>
Retinal detachment	14 (12.9%)	6 (5.2%)	0.085 <sup>a</sup>
Other rare findings [hyphema + endophthalmitis]	7 (6.5%) [4 + 3]	5 (4.3%) [5 + 0]	0.502 <sup>a</sup>
Causes of ocular injury ( $n, \%$ )	$p = 0.713^b$ (intragroup comparison)	$p = 0.035^b$ (intragroup comparison)	
Metal objects (fork, knife, needle)	32 (29.6%)	59 (51.3%)	0.041 <sup>a</sup>
Broken glass	23 (21.3%)	21 (18.3%)	0.639 <sup>a</sup>
Blunt objects (ball, punch)	20 (18.5%)	16 (13.9%)	0.427 <sup>a</sup>
Pen–pencil	18 (16.7%)	11 (9.6%)	0.166 <sup>a</sup>
Unidentified	15 (13.9%)	8 (6.9%)	0.125 <sup>a</sup>
Ocular findings at last visit ( $n, \%$ )	$p = 0.394^b$ (intragroup comparison)	$p = 0.107^b$ (intragroup comparison)	
Eyelid disorders	34 (31.5%)	31 (26.9%)	0.680 <sup>a</sup>
Corneal opacity	43 (39.8%)	48 (41.7%)	0.847 <sup>a</sup>
Lens opacity	17 (15.7%)	19 (16.5%)	0.887 <sup>a</sup>
Posterior capsule opacification	13 (12.0%)	9 (7.8%)	0.466 <sup>a</sup>
Posterior segment defect	36 (33.3%)	18 (15.7%)	0.024 <sup>a</sup>
Other rare findings [glaucoma + phthisis bulbi]	8 (7.4%) [5 + 3]	7 (6.1%) [7 + 0]	0.708 <sup>a</sup>

VA Visual acuity, LVA: Logarithm of the minimum angle of resolution (LogMAR)-VA,  $n$  Number of cases

<sup>a</sup>Chi-square test, <sup>b</sup>Kruskal–Wallis test for intragroup comparison,  $p < 0.05$  statistically significant

group and  $9.2 \pm 2.0$  years in good-vision group, and they were consistent with the literature. These ages are the time period at which children act independently without parental supervision. Therefore, children may be more prone to trauma during this period.

The age less than 6 years old at presentation was reported to be associated with lower final visual acuity [3]. We found no correlation between the age and final visual acuity in both groups. Similarly, AIDa-hash et al. determined no relationship between the

**Table 3** Multivariate prediction model for poor visual outcome

Ocular trauma characteristics	Poor-vision group (Group 1, <i>n</i> = 108) (Final LVA > 0.70) (Snellen VA < 20/100)	Good-vision group (Group 2, <i>n</i> = 115) (Final LVA ≤ 0.70) (Snellen VA ≥ 20/100)	Multivariate analysis	
			OR (95% CI)	<i>p</i> -value
Penetrating injury (+) ref	49 (45.4%)	83 (72.2%)		
Penetrating injury (–)	59 (54.6%)	32 (27.8%)	0.548 (1.007–1.659)	0.063
Globe rupture (–) ref	68 (63.0%)	95 (82.6%)		
Globe rupture (+)	40 (37.0%)	20 (17.4%)	2.713 (1.843–4.582)	0.024
Zone 1 involvement (+) ref	43 (39.8%)	75 (65.2%)		
Zone 1 involvement (–)	65 (60.2%)	40 (34.8%)	1.562 (1.206–3.097)	0.042
Relative afferent pupillary defect (–) ref	60 (55.6%)	95 (82.7%)		
Relative afferent pupillary defect (+)	48 (44.4%)	20 (17.3%)	1.984 (1.087–3.415)	0.035
Metal object injury (+) ref	32 (29.6%)	59 (51.3%)		
Metal object injury (–)	76 (70.4%)	56 (48.7%)	1.285 (1.012–2.953)	0.046
Posterior segment defect (–) ref	72 (66.7%)	97 (84.3%)		
Posterior segment defect (+)	36 (33.3%)	18 (15.7%)	0.561 (1.004–1.518)	0.054

*ref* reference group for the model, *p* < 0.05 statistically significant. A multivariate logistic regression analysis was done on variables found to be significant in univariate analysis  
 VA Visual acuity, LVA Logarithm of the minimum angle of resolution (LogMAR)-VA, OR Odds ratio, CI confidence interval

**Table 4** Correlations between the final LVA and clinical characteristics for the groups

Clinical characteristics	Final LVA in poor-vision group (group 1)		Final LVA in good-vision group (group 2)	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
Age	–0.052	0.716	–0.081	0.648
Time between trauma and surgery	0.254	0.148	0.185	0.293
Ocular trauma score	–0.398	0.037	–0.369	0.040
Injury size	0.412	0.031	0.318	0.046
Follow-up time	0.097	0.594	0.072	0.711
Initial LVA	0.335	0.043	0.402	0.034
Injury type	0.208	0.185	0.262	0.128
Injury zone	0.273	0.096	0.239	0.153

LVA Logarithm of the minimum angle of resolution (LogMAR) visual acuity, *r* Spearman’s correlation coefficient, *p* < 0.05 statistically significant

final visual acuity and age [45]. All cases in our study were 7 years of age or older at presentation, and this condition might be the reason why we could not find any correlation between the age and final visual acuity. Pediatric OGIs were detected with a higher rate (58–82%) in males [1, 3, 22, 25, 45]. In our study, rates of males were 68.5% in group 1 and 66.9% in group 2, and they were consistent with the literature. The reason for the higher rate of males may be that males are more active during games, sports, or fights, and thus they may become more prone to trauma. In pediatric OGIs, the involvement rate of the right eye was reported to be similar to that of the left eye [3, 17, 19]. We also found no significant difference between the involvement rates of the right and left eyes.

In children with OGI, ensuring the globe integrity with surgery as soon as possible may be important in preventing the complications and blindness. In our study, time between trauma and surgery was similar in both groups, and surgical repairs of all cases were performed within the first 48 h. We detected no correlation between time to surgery and final visual acuity in both groups. This result may

be related to the relatively early surgical intervention. Similarly, Ozturk et al. determined no relationship between the final visual acuity and time to surgery [1]. In cases with ocular trauma, OTS is useful both in evaluating visual results and informing patients [28]. OTS was stated to have a sensitivity of 97.4% in predicting visual survival [46]. In our study, good-vision group had higher OTS than poor-vision group. Additionally, we found that final vision worsened as OTS decreased in both groups. In literature, the higher OTS at presentation was reported to be associated with the better final vision [1, 47].

In previous studies, pediatric cases were followed up between 11.1 and 21.7 months after OGI [1, 17, 45]. Our follow-up times were longer, and they were  $32.7 \pm 11.4$  months in poor-vision group and  $33.1 \pm 12.2$  months in good-vision group. Unlike previous studies [1, 17, 45], the effect of follow-up time on final visual acuity was also assessed in both groups in our study. We found no relationship between the final visual acuity and follow-up time in groups. The injury size may affect the course of wound healing and the final vision. AIDahash et al. stated that there was a better visual prognosis in OGIs smaller than 10 mm [45]. Ozturk et al. reported that large injury size indicated poor visual prognosis [1]. In our study, injury sizes were  $10.4 \pm 3.5$  mm in poor-vision group and  $5.8 \pm 2.4$  mm in good-vision group, and the difference was statistically significant. In addition, we found that final vision worsened as injury size increased in both groups. This result may be associated with the increases in both the inflammatory response and ocular complications after large OGIs.

In children with OGI, appropriate medical and surgical treatments may be beneficial in providing the visual improvement. In literature, after treatment, the final visions were shown to be better than the initial visions in cases with OGI [1, 17]. Similarly, we determined that final visions were better than the initial visions in both groups. Additionally, initial visual acuity levels of patients with OGI may give an idea about their final visions. In our study, good-vision group had better initial and final visions compared to poor-vision group. Also, we detected that final vision worsened as initial vision worsened in groups. It was reported that low initial vision could create poor visual prognosis [1], while high initial vision could create good visual prognosis [45, 47].

Depending on the type of ocular injury, the visual prognosis may change. In literature, it was shown that the most common type of OGIs occurred as penetrating injury [17, 19, 47], and its frequency was 54.0–86.6% [1, 17, 23, 47]. In addition, penetrating injuries were reported to have better visual outcomes than the other injury types [21, 47]. In our study, penetrating injury was the most frequent injury type (72.2%) in good-vision group. In univariate analysis, we found that poor-vision group had significantly less frequent penetrating injury and more frequent globe rupture compared to good-vision group. Penetrating injury was not statistically significant predictive factor for poor visual outcome in multivariate analysis. On the other hand, the presence of globe rupture was associated with poor final vision in multivariate analysis in our study. OGI was stated to occur most frequently in zone 1 [1, 17, 23, 47]. Ozturk et al. determined no relationship between the injury localization and final vision [1]. However, Batur et al. showed that children with zone 1 involvement had better final visions [17]. In our study, zone 1 involvement was the most frequent injury localization (65.2%) in good-vision group. In univariate analysis, we found that poor-vision group had significantly lower zone 1 involvement compared to good-vision group. Additionally, the involvement without zone 1 was associated with poor final vision in multivariate analysis. Worse visual outcomes were reported in ocular injuries with the zone 3 involvement or the extending toward the posterior of the globe [48, 49]. In injuries involving the posterior of the globe, even if there is anatomical improvement, vision loss may be seen due to retinal or optic nerve damage [48, 50].

Some accompanying ocular findings at presentation may have a negative effect on visual prognosis. The pupil status may be a guide in predicting the retinal or optic nerve function after eye injuries. The presence of RAPD in patients with ocular injury was stated to be an indicator of poor final vision [49, 51, 52]. Additionally, the presence of lens damage, vitreous hemorrhage, retinal detachment, or endophthalmitis in ocular injury cases may indicate poor prognosis [1, 47]. In univariate analysis, we detected that poor-vision group had significantly more frequent RAPD (44.4% vs 17.3%) compared to good-vision group. Additionally, the presence of RAPD was associated with poor final vision in multivariate analysis. Also, there were three cases (2.8%) with



endophthalmitis in poor-vision group and none in good-vision group. However, in our study, rates of uveal tissue damage, lens damage, vitreous hemorrhage, and retinal detachment were similar in both groups.

OGI was reported to occur most frequently with metal or sharp objects [21, 45, 47]. In our study, injury with sharp metal object (fork, knife, needle) was the most frequent injury cause (51.3%) in good-vision group. In univariate analysis, we found that poor-vision group had significantly less frequent metal object injury (fork, knife, needle) compared to good-vision group. Additionally, the injury without metal object (fork, knife, needle) was associated with poor final vision in multivariate analysis. Depending on the causes of ocular injury, the clinical course may be affected. Injuries with sharp objects can cause less ocular damage as they can occur with lower energy. On the other hand, injuries with blunt objects can cause more severe ocular damage such as globe rupture, as they can require higher energy [47, 53, 54]. The visual prognosis was determined to be better in injuries with sharp objects [1]. Despite appropriate and effective trauma management, low vision level may be permanent in children. Compared to adults, children were thought to be more prone to the development of complications because of the features of eye structures and the strong inflammatory responses [25, 45, 55]. It was reported that conditions such as corneal opacity [55, 56], lens opacity [57–59], posterior segment defects [25, 45, 60], or phthisis bulbi [25, 56] might occur after globe injuries in children. Eyelid disorders, corneal opacity, lens opacity, posterior capsule opacification, posterior segment defect, and glaucoma were among the ocular findings detected at the last visit in our study. In univariate analysis, we found that poor-vision group had more frequent posterior segment defect (33.3% vs 15.7%) compared to good-vision group. On the other hand, posterior segment defect was not statistically significant predictive factor for poor visual outcome in multivariate analysis. Also, there were three children (2.8%) with phthisis bulbi in group 1 and none in group 2.

This study had some limitations. Data were collected retrospectively. There might be some ocular conditions or diseases affecting vision, which were not written in the file records belonging to the pre-traumatic period. Children aged 0–6 years were not

included in this study, since their visual acuities could not be determined accurately during the admission and/or follow-up due to low cooperation. In summary, as far as we know, this is the first study investigating the effects of age, time between trauma and surgery, OTS, injury size, follow-up time, initial vision, injury type, and injury zone on final vision in detail after pediatric OGIs. In our study, poor prognostic factors affecting final vision were low OTS, poor initial vision, the presences of globe rupture and RAPD, the large injury size, the involvement without zone 1, and the injury without metal object (fork, knife, needle). Additionally, in both groups final vision worsened as OTS decreased, injury size increased, and initial vision worsened. There were no correlations between the final visual acuity with the age, time between trauma and surgery, follow-up time, injury type, and injury zone in both groups. These prognostic factors may be useful in managing trauma and informing parents about the possible consequences.

**Author's contribution** All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by HÖ and BÖ. The first draft of the manuscript was written by HÖ, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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#### Declarations

**Conflict of interest** The authors declare no conflict of interest. There are no relevant financial or nonfinancial competing interests to report.

**Consent to participate and consent to publish** Informed consent was obtained from all individual participants included in the study. Written informed consent was obtained from the parents.

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This study was performed with approval of Izmir Tepecik Training and Research Hospital's Medical Research Ethical Committee (Approval Number: 2020/14-1) and in line with ethical principles of the Declaration of Helsinki.

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