



Clinical characteristics and outcomes of open globe injuries in Japan

Yoshifumi Okamoto^{1,2,8} · Shohei Morikawa^{1,8} · Fumiki Okamoto^{1,8} · Naoki Inomoto^{3,8} · Hiroto Ishikawa^{4,8} · Tetsuo Ueda^{5,8} · Taiji Sakamoto^{6,8} · Kazuhiko Sugitani^{7,8} · Tetsuro Oshika^{1,8}

Received: 10 February 2018 / Accepted: 22 October 2018 / Published online: 8 November 2018
© Japanese Ophthalmological Society 2018

Abstract

Purpose To describe the epidemiology and clinical outcomes of open globe injuries (OGIs) in Japan over 10 years, and examine preoperative factors influencing the visual prognosis after surgery.

Study Design Retrospective, observational, multicenter case-series study.

Methods Patients' data were entered into a computerized database for review and statistical analyses. The following parameters were assessed; age, gender, initial and final visual acuity, duration between onset and surgery, presence of lens in the eye, characteristics of injury, presence of ocular complications, and number of surgeries.

Results The records of 374 eyes with OGI were enrolled. The average age of the patients was 56.8 ± 22.1 years, and the majority of patients were men (73.5%). Compared to the overall cohort, work-related OGI was the most common, associated with significantly better final visual acuity, whereas patients with fall-down OGI showed significantly worse final visual acuity ($P < 0.05$). Among the types of injury, both the initial and final visual acuity were significantly worse in the rupture group than in the laceration group. Multiple liner regression analyses revealed that the final visual acuity was significantly associated with initial visual acuity, type of injury (rupture), retinal detachment, and proliferative vitreoretinopathy.

Conclusion To predict the visual outcome in patients with OGI, ophthalmologists need to pay attention not only to the initial visual acuity but also to initial ocular conditions, such as the presence of ocular complications.

Keywords Endophthalmitis · Laceration · Open globe injury · Rupture

The members of the Japan-Clinical Research of Study (J-CREST) Group are listed in Acknowledgements section.

Corresponding author: Yoshifumi Okamoto

✉ Yoshifumi Okamoto
y-okamoto@md.tsukuba.ac.jp

¹ Department of Ophthalmology, Faculty of Medicine, University of Tsukuba, 1-1-1 Tennoudai, Tsukuba, Ibaraki 305-8575, Japan

² Department of Ophthalmology, Mito Kyodo General Hospital, Mito, Ibaraki, Japan

³ Department of Ophthalmology, Institute of Biomedical Sciences, Tokushima University Graduate School, Tokushima, Japan

⁴ Department of Ophthalmology, Hyogo College of Medicine, Nishinomiya, Hyogo, Japan

Introduction

Ocular trauma is a major cause of blindness in developing countries, whereas in developed countries it is comparably rare and preventable [1–8]. According to the classification of ocular traumas outlined in the Birmingham Eye Trauma Terminology System, open globe injury (OGI) is the most

⁵ Department of Ophthalmology, Nara Medical University, Kashihara, Nara, Japan

⁶ Department of Ophthalmology, Kagoshima University Graduate School of Medical and Dental Sciences, Sakuragaoka, Kagoshima, Japan

⁷ Department of Ophthalmology and Visual Science, Nagoya City University Graduate School of Medical Sciences, Nagoya, Japan

⁸ Japan-Clinical Research of Study (J-CREST) Group, Tokyo, Japan

vision-threatening condition [9]. Many reports describe the epidemiology and clinical outcomes in patients with OGI from different countries [1–8]. Moreover, in Japan, some studies have evaluated the prognostic factors in patients with OGI [10, 11]. However, these were single-center studies, and thus, their results might not reflect epidemiological trends because of the small number of cases.

The purpose of this retrospective study was to evaluate the epidemiology and clinical outcomes of patients with OGI treated at multiple centers in Japan.

Patients and methods

This study was a retrospective chart review of 374 eyes of 373 patients who had been diagnosed as open globe eye injury and had surgery performed at nine hospitals (University of Tsukuba, Tokushima University Graduate School, Hyogo College of Medicine, Nara Medical University, Kagoshima University Graduate School of Medical and Dental Sciences, Nagoya City University Graduate School of Medical Sciences, Shiga University of Medical Science, Sapporo City General Hospital, and Faculty of Medical Sciences University of Fukui) all involved in the Japan Clinical Retina Study (J-CREST) between January 1, 2005, to January 31, 2015. The J-CREST group was formed for the purpose of analyzing disease statistics and pathological conditions by accumulating and sharing data among multiple centers in Japan. This study was approved by the Institutional Review Boards at all institutions involved and adhered to the tenets of the Declaration of Helsinki.

All surgery involved pars plana vitrectomy, using contact lenses or a wide-angle viewing system to facilitate posterior visualization. Various vitrectomy system gauges (i.e., 20, 23, and 25 gauge vitrectomy) were selected due to this being a multicenter study and the long-term period of observation. Exclusion criteria were patients who received enucleation or suturing without vitreous surgery. For further analysis, the obtained data were classified into two categories based on the type of OGI (rupture and laceration) and the initial visual acuity [no light perception (NLP) at presentation and over light perception (LP) at presentation]. Additionally, OGI was classified into four groups according to the causes of injury, and the characteristics of each of the four groups were compared with those of the overall cohort. Data obtained from the medical records included age, gender, type of injury (rupture or laceration), best-corrected visual acuity (BCVA) at the initial and final presentation, duration between onset of injury and operation, presence of lens, wound length, zone of injury, number of surgical procedures, presence of ocular complications (i.e., iridodialysis, vitreous hemorrhage, retinal detachment, choroidal hemorrhage, proliferative

vitreoretinopathy, and endophthalmitis), follow-up period, and causes of injury. The presence of ocular complications was determined at initial presentation or intraoperatively. Wound length was measured using graduated spatula intraoperatively.

BCVA was converted from decimal values to logarithm of the minimum angle of resolution (logMAR) values for statistical analysis. The BCVA of counting fingers, hand motion, light perception, and no light perception were assigned logMAR values of 1.85, 2.3, 2.8, and 2.9, respectively [12, 13].

The mean scores and standard deviations were calculated for patient's age, logMAR visual acuity, duration between onset of injury and operation, wound length, and follow-up period. The Student's t-test was performed to compare the age, initial and final BCVA, duration between onset of injury and surgery, wound length, and follow-up period between the rupture vs. laceration group and NLP at presentation vs. over LP at presentation group. The chi-square test was performed to compare gender, number of NLP at first and final presentation, type of injury (rupture or laceration), presence of lens, zone of injury, and presence of ocular complications between the two groups. Similarly, Dunnett's test was conducted to compare the parameters between the overall cohort and the four groups classified based on the cause of injury (work, falling-down, traffic accident, or sports-related injury). The relationships between the final BCVA and patient's age, gender, initial BCVA, type of injury (rupture or laceration), duration between onset of injury and operation, presence of lens, wound length, zone of injury, number of surgical procedures (one/two or more), and ocular complications (iridodialysis, vitreous hemorrhage, retinal detachment, choroidal hemorrhage, proliferative vitreoretinopathy and endophthalmitis) were examined with simple linear regression analysis. Also, multiple linear regression analysis was used to compare final BCVA and all other parameters.

Classification of OGI

Kuhn et al. classified OGIs into rupture and laceration, using the trauma classification of the Birmingham Eye Trauma Terminology (BETT) [9]. A "rupture" type of injury was defined as trauma caused by blunt objects, leading to a full-thickness wound, with an "inside-out" mechanism of injury. A transient elevation in intraocular pressure caused the globe to rupture at a weak point. In contrast, a "laceration" type of injury was caused by sharp objects, leading to a full-thickness wound with an "outside-in" type of injury. For clarifying the issue, "laceration" included three types of injuries which were penetrating (only the entrance wound is present), perforating (both entrance and exit wounds are present), and intraocular foreign body in the present study.

Presence of lens

The state of lens was defined by two conditions—presence and absence. Presence indicated that the crystalline or intraocular lens could be confirmed by slit-lamp examination at presentation or by using a microscope intraoperatively in the eye.

Zone of injury

Zone of injury was defined by the location of the full-thickness wound and comprised three parts—zones I, II, and III). Zone I was at the opening of the cornea or corneoscleral limbus, zone II at the anterior 5 mm of the sclera (between zones I and III), and zone III at more than 5 mm posterior to the corneoscleral limbus.

Results

A total of 374 eyes of 373 patients with OGI were reviewed. The average age of the patients was 56.8 ± 22.1 years (range, 2–101 years), and they included 274 men (73.5%) and 99 women (26.5%). Table 1 shows the characteristics of the patients with OGI, and the comparisons between the rupture and laceration groups. The initial BCVA in patients

with OGI was 2.2 ± 0.9 and the final BCVA was 1.3 ± 1.2 , indicating that the BCVA was significantly improved by vitreoretinal surgery ($P < 0.001$). The number of NLP was 81 eyes at initial presentation (21.7%) and 78 eyes at final presentation (20.9%)—53 of the 81 eyes with NLP at initial presentation (65.4%) did not reacquire visual function despite repeated vitreoretinal surgery. In 281 eyes (81.0%), the crystalline or intraocular lens could be confirmed in the eye, whereas in 66 eyes (19.0%), the lens was not confirmed. Wound length was 7.4 ± 6.1 mm. With regard to the zone of injuries, 146 eyes (40.9%) were in zone I, 88 eyes (24.6%) were in zone II, and the remaining 123 eyes (34.5%) were in zone III. With regard to ocular complications at initial presentation, iridodialysis was observed in 114 eyes (41.3%), vitreous hemorrhage in 236 eyes (68.8%), retinal detachment in 132 eyes (37.5%), choroidal hemorrhage in 52 eyes (19.4%), proliferative vitreoretinopathy in 24 eyes (8.7%), and endophthalmitis in 19 eyes (5.2%).

Of the 374 eyes with OGI, 205 eyes (54.8%) presented with rupture and 169 eyes (45.2%) with laceration. Compared to the laceration group, more women ($P < 0.001$) and elderly patients ($P < 0.001$) constituted the rupture group. Both initial ($P < 0.001$) and final BCVA ($P < 0.001$) were significantly worse in the rupture group than in the laceration group (Fig. 1), and both the number of NLPs at the initial ($P < 0.001$) and final presentation ($P < 0.001$)

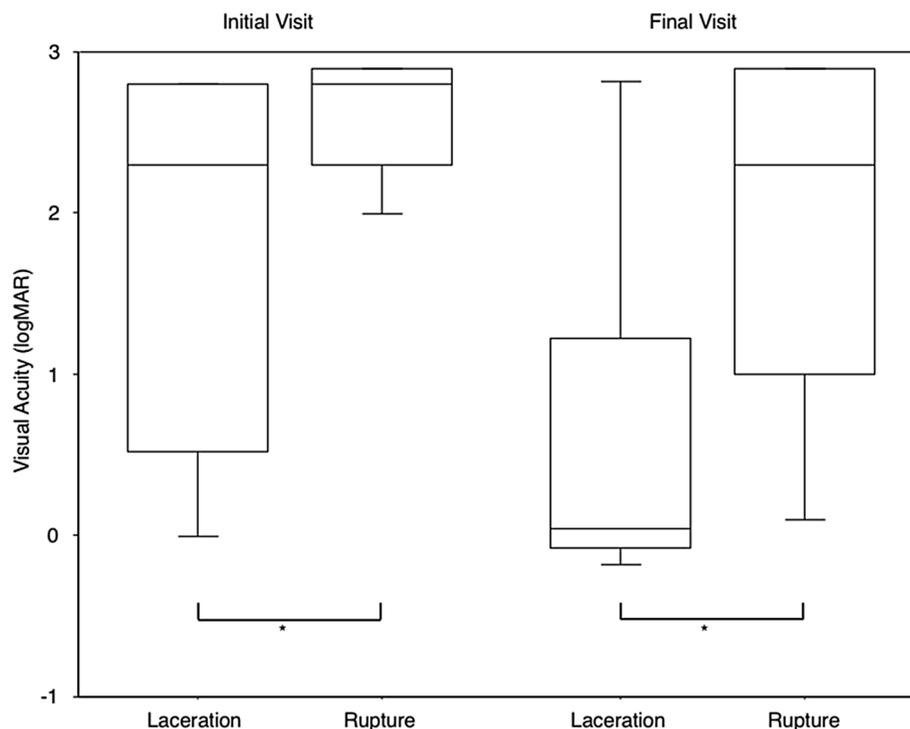
Table 1 Comparison of various parameters between the rupture and laceration groups

Parameters	All (n = 374)	Rupture group (n = 205)	Laceration group (n = 169)	P value
Age (years)	56.8 ± 22.1	63.9 ± 21.3	48.3 ± 19.9	<0.001*
Gender (male/female)	275/99	126/79	149/20	<0.001*
Initial visual acuity (logMAR)	2.2 ± 0.9	2.6 ± 0.6	1.7 ± 1.1	<0.001*
Number of patients with NLP at presentation	81	69	12	<0.001*
Final visual acuity (logMAR)	1.3 ± 1.2	1.9 ± 1.1	0.7 ± 1.1	<0.001*
Number of patients with NLP at final presentation	78	61	17	<0.001*
Duration between onset of injury and operation (days)	1.4 ± 6.0	1.7 ± 7.3	1.1 ± 4.0	0.33
Presence of lens (+/−)	281/66	128/59	153/7	<0.001*
Wound length (mm)	7.4 ± 6.1	10.3 ± 6.2	3.9 ± 3.5	<0.001*
Zone of injury (I/II/III)	146/88/123	46/61/88	100/27/35	<0.001*
Number of surgical procedures (one/two or more)	240/120	131/71	109/53	0.63
Iridodialysis (+/−)	114/162	53/93	61/70	0.08
VH (+/−)	236/107	155/26	81/81	<0.001*
RD (+/−)	132/220	97/91	35/129	<0.001*
CH (+/−)	52/216	42/97	10/119	<0.001*
PVR (+/−)	24/252	17/131	8/121	0.13
EO (+/−)	19/349	2/198	17/151	<0.001*
Follow-up period (months)	17.3 ± 33.2	17.8 ± 41.2	14.7 ± 16.1	0.36

Values are presented as the mean \pm standard deviation. *Significant difference between the rupture and laceration groups (Student's t-test and chi-square test)

LogMAR: logarithm of the minimum angle of resolution; IOL: intraocular lens; VH: vitreous hemorrhage; RD: retinal detachment; CH: choroidal hemorrhage; PVR: proliferative vitreoretinopathy; EO: endophthalmitis

Fig. 1 Comparison of visual acuity based on type of injury. The initial and final visual acuity is significantly worse in the rupture group than in the laceration group ($P < 0.001$). LogMAR: logarithm of the minimum angle of resolution



were significantly higher in the rupture group. With regard to the presence of lens, the patients in the rupture group were significantly more likely to have an absent crystalline or intraocular lens ($P < 0.001$). Wound length was significantly larger in the rupture group, which had a tendency to be located in zone III; in contrast, the wound in the laceration group tended to be located in zone I ($P < 0.001$). The incidence of vitreous hemorrhage ($P < 0.001$), retinal detachment ($P < 0.001$), and choroidal hemorrhage ($P < 0.001$) were significantly higher in patients in the rupture group than in the laceration group, whereas the incidence of endophthalmitis was significantly lower in the rupture group than in the laceration group ($P < 0.001$).

According to simple linear regression analyses, the final BCVA was significantly correlated with age (coefficient = 0.02, $P < 0.001$), initial BCVA (coefficient = 0.81, $P < 0.001$), wound length (coefficient = 0.10, $P < 0.001$). Furthermore, the final BCVA was significantly different with gender (coefficient = -0.64, $P < 0.001$), type of injury (coefficient = 1.12, $P < 0.001$), presence of lens (coefficient = -0.50, $P < 0.001$), zone of injury (coefficient = 0.47, $P < 0.001$), and presence of iridodialysis (coefficient = -0.32, $P = 0.03$), vitreous hemorrhage (coefficient = 1.25, $P < 0.001$), retinal detachment (coefficient = 1.31, $P < 0.001$), choroidal hemorrhage (coefficient = 1.01, $P < 0.001$), and proliferative vitreoretinopathy (coefficient = 1.29, $P < 0.001$) (Table 2). According to multiple linear regression analyses, the final BCVA was significantly correlated with initial BCVA (coefficient = 0.32, $P < 0.001$), type of injury

(coefficient = 0.47, $P = 0.01$), presence of retinal detachment (coefficient = 0.55, $P < 0.001$), and presence of proliferative vitreoretinopathy (coefficient = 0.76, $P = 0.04$), (Table 2).

Table 3 shows the clinical characteristics of various parameters in patients with NLP at initial presentation. On comparing the NLP and over LP groups, the clinical characteristics in the NLP group were found to be significantly female ($P < 0.001$) and elderly ($P < 0.001$) dominant. The final BCVA was significantly worse in the NLP group than in the over LP group ($P < 0.001$). With regard to the presence of lens, the patients in the NLP group were significantly more likely to have an absent crystalline or intraocular lens ($P = 0.003$). Wound length was significantly larger in the NLP group, where the wound tended to be located in zone III; in contrast, in the over LP group, the wound tended to be located in zone I ($P < 0.001$). In the NLP group, ocular complications such as vitreous hemorrhage ($P < 0.001$), retinal detachment ($P < 0.001$), choroidal hemorrhage ($P < 0.001$), and proliferative vitreoretinopathy ($P = 0.04$) had a significantly higher incidence in the NLP group than in the over LP group.

Table 4 shows the comparison of various characteristics between the overall cohort and the four groups classified on the basis of the cause of injury. OGI were work-related in 170 patients (45.5%), the most frequent cause of injury. OGI were fall-down in 120 patients (32.1%), traffic accident-related in 14 patients (3.7%), and sports-related in 13 patients (3.5%). Patients in whom the OGI were work related were predominantly men and younger ($P < 0.05$)

Table 2 Relationship between final visual acuity and preoperative parameters in open globe injuries

Preoperative parameters	Final visual acuity				
	Simple liner regression analysis		Multiple liner regression analysis		
	Coefficient	P value	Coefficient	95% CI	P value
Age (years)	0.02	<0.001*	0.004	−0.003 to 0.01	0.30
Gender (male/female)	−0.64	<0.001*	0.07	−0.27 to 0.41	0.70
Initial visual acuity (logMAR)	0.81	<0.001*	0.32	0.14 to 0.49	<0.001**
Type of injury (rupture or laceration)	1.12	<0.001*	0.47	0.10 to 0.84	0.01**
Duration between onset of injury and operation (days)	0.01	0.34	−0.003	−0.02 to 0.02	0.75
Presence of lens (+/−)	−0.50	<0.001*	−0.18	−0.37 to 0.002	0.06
Wound length (mm)	0.10	<0.001*	0.01	−0.02 to 0.04	0.39
Zone of injury (I/II/III)	0.47	<0.001*	0.006	−0.15 to 0.17	0.94
Number of surgical procedures (one/two or more)	0.08	0.59	0.004	−0.26 to 0.27	0.98
Iridodialysis (+/−)	−0.32	0.03*	0.10	−0.15 to 0.35	0.43
VH (+/−)	1.25	<0.001*	0.18	−0.15 to 0.50	0.28
RD (+/−)	1.31	<0.001*	0.55	0.25 to 0.86	<0.001**
CH (+/−)	1.01	<0.001*	−0.16	−0.53 to 0.20	0.38
PVR (+/−)	1.29	<0.001*	0.76	0.02 to 1.49	0.04**
EO (+/−)	−0.47	0.11	0.06	−0.53 to 0.65	0.84

*Significant difference or correlation between the parameters (simple liner regression analysis)

**Significant correlation between the parameters (multiple liner regression analysis)

CI: confidence interval; LogMAR: logarithm of the minimum angle of resolution; IOL: intraocular lens; VH: vitreous hemorrhage; RD: retinal detachment; CH: choroidal hemorrhage; PVR: proliferative vitreoretinopathy; EO: endophthalmitis

Table 3 Clinical characteristics of various parameters in patients with no light perception at initial presentation

Parameters	All (n = 374)	NLP at presentation group (n = 81)	Over LP at presentation group (n = 293)	P value
Age (years)	56.8 ± 22.1	66.4 ± 31.6	54.2 ± 21.2	<0.001*
Gender (male/female)	275/99	45/36	229/63	<0.001*
Initial visual acuity (logMAR)	2.2 ± 0.9	2.9	1.9 ± 1.0	–
Type of injury (rupture or laceration)	205/169	69/12	136/157	<0.001*
Final visual acuity (logMAR)	1.3 ± 1.2	2.7 ± 1.2	1.0 ± 1.1	<0.001*
Duration between onset of injury and operation (days)	1.4 ± 6.0	0.7 ± 4.2	1.6 ± 6.6	0.25
Presence of lens (+/−)	281/66	51/23	230/43	0.003*
Wound length (mm)	7.4 ± 6.1	11.8 ± 4.7	6.5 ± 5.6	<0.001*
Zone of injury (I/II/III)	146/88/123	18/23/37	128/65/86	0.04*
Number of surgical procedures (one/two or more)	240/120	61/17	179/103	0.01*
Iridodialysis (+/−)	114/162	22/24	89/138	0.28
VH (+/−)	236/107	68/6	182/101	<0.001*
RD (+/−)	132/220	48/23	84/197	<0.001*
CH (+/−)	52/216	21/20	31/196	<0.001*
PVR (+/−)	24/252	7/34	17/218	0.04*
EO (+/−)	19/349	2/76	17/273	0.24
Follow-up period (months)	17.3 ± 33.2	22.1 ± 22.8	16.2 ± 19.7	0.02*

Values are presented as the mean ± standard deviation. *Significant difference between NLP at presentation group and over LP at presentation group (Student's t-test and chi-square test)

NLP: no light perception; LP: light perception; LogMAR: logarithm of the minimum angle of resolution; IOL: intraocular lens; VH: vitreous hemorrhage; RD: retinal detachment; CH: choroidal hemorrhage; PVR: proliferative vitreoretinopathy; EO: endophthalmitis

Table 4 Comparison of various parameters among the groups with cause of injury

Parameters	All (n = 374)	Work-related group (n = 170)	Fall-down group (n = 120)	Traffic accident-related group (n = 14)	Sports-related group (n = 13)
Age (years)	56.8 ± 22.1	49.9 ± 17.2*	73.7 ± 15.9*	50.4 ± 25.4	44.2 ± 17.5
Gender (male/female)	275/99	161/9*	53/67*	11/3	13/0
Initial visual acuity (logMAR)	2.2 ± 0.9	1.8 ± 1.1*	2.6 ± 0.6*	2.6 ± 0.5	2.5 ± 0.5
Type of injury (rupture or laceration)	205/169	46/124*	109/11*	9/5	6/7
Number of patients with NLP at presentation	81	12	51	2	1
Final visual acuity (logMAR)	1.3 ± 1.2	0.8 ± 1.1*	2.2 ± 1.0*	0.9 ± 1.2	1.2 ± 1.2
Number of patients with NLP at final presentation	78	18	46	1	2
Duration between onset of injury and operation (days)	1.4 ± 6.0	1.6 ± 8.1	1.4 ± 3.8	0.6 ± 1.7	0.6 ± 1.2
Presence of lens (+/-)	281/66	150/11*	73/43*	11/2	9/1
Wound length (mm)	7.4 ± 6.1	4.9 ± 4.6*	10.3 ± 5.9*	8.2 ± 7.1	8.5 ± 6.0
Zone of injury (I/II/III)	146/88/123	93/37/35*	20/36/61*	3/4/6	5/2/2
Number of surgical procedures (one/two or more)	240/120	105/58	89/29	9/5	5/7
Iridodialysis (+/-)	114/162	61/73	27/54	4/8	4/5
VH (+/-)	236/107	93/69*	103/8*	6/7	1/6*
RD (+/-)	132/220	39/127	59/47	4/9	7/6
CH (+/-)	52/216	13/115	27/49*	2/11	1/10
PVR (+/-)	24/252	11/121	6/70	1/12	2/11
EO (+/-)	19/349	12/158	1/115	0/14	3/10*
Follow-up period (months)	17.3 ± 33.2	20.2 ± 43.6	11.8 ± 16.3	17.4 ± 25.3	23.7 ± 15.4

Values are presented as the mean ± standard deviation. *Statistically significant difference compared with the overall cohort

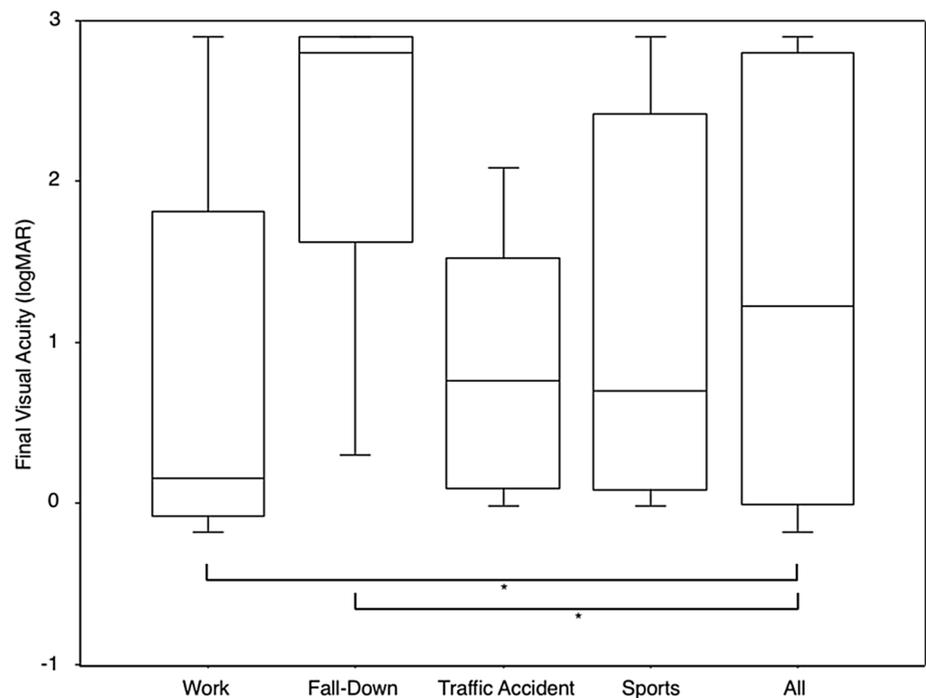
LogMAR: logarithm of the minimum angle of resolution; IOL: intraocular lens; VH: vitreous hemorrhage; RD: retinal detachment; CH: choroidal hemorrhage; PVR: proliferative vitreoretinopathy; EO: endophthalmitis

compared to the patients in whom the OGIs were fall-down who were predominantly women and elderly ($P < 0.05$). Both the initial and final BCVA were significantly better in the work-related group ($P < 0.05$) than in the fall-down group ($P < 0.05$; Fig. 2). Furthermore, compared to the overall cohort, the patients in the work-related cause of injury group were significantly more likely to have lacerations ($P < 0.05$) and presence of crystalline or intraocular lens ($P < 0.05$), whereas the patients in the fall-down group were significantly more likely to have rupture ($P < 0.05$) and absence of crystalline lens or intraocular lens ($P < 0.05$). The zone of injury was significantly different between patients in the work-related and fall-down groups and the overall cohort; in addition, wound length was shorter in the work-related ($P < 0.05$) and longer ($P < 0.05$) in the fall-down injury groups. The incidence of vitreous ($P < 0.05$) and choroidal hemorrhage ($P < 0.05$) in patients in the fall-down injury group was significantly higher. The incidence of vitreous hemorrhage in the work and sports-related injury groups was significantly lower than in the overall cohort ($P < 0.05$). Finally, the incidence of endophthalmitis in the sports-related injury group was significantly lower than that in the overall cohort ($P < 0.05$).

Discussion

OGI is the most severe, albeit in a rare form, ocular injury, and its incidence ranges from 1.6 to 4.5 per 100,000 [14–18]. We extracted a large number of OGI cases registered in the J-CREST database, and investigated the epidemiology and clinical characteristics of these cases. In the present study, men constituted 73.5% of the cohort. This is consistent with the results of previous studies (73–80%) [5, 7, 19–22]. The higher percentage of men in studies of OGI might be related to their greater tendency to engage in aggressive or high-risk behavior [23]. The average age of the patients was 56.8 years, higher than in several previous epidemiologic reports of OGI (24–46 years) [7, 15, 22, 24]. In some countries, the major causes of OGI were found to be in-home accidents in children and work-related injuries [6, 22, 25, 26]. The increased average age of the patients in this study could be attributed to the small number of children and large number of elderly women included. In addition, the increased average age of the patients with OGI may be related to the geographic origin of these patients, as Japan's life expectancy has been on the rise. The proportion of work-related OGIs in developed

Fig. 2 Comparison of final visual acuity among the groups with cause of injury. Work-related open globe injury is associated with significantly better final visual acuity than the overall cohort, whereas patients with fall-down open globe injury show significantly worse final visual acuity ($P < 0.05$). LogMAR: logarithm of the minimum angle of resolution



countries was less frequent than in developing countries [8, 21, 26–29]. The proportion of work-related OGI in this study was similar to that reported in a developed region such as Hong Kong [5]. The work environment and demographic composition of developing countries differ from that of developed countries. In developing countries, the percentage of primary industry workers is high, and the working conditions, including safety, are poor. In developed countries, there's a decline in the working population owing to aging of the society, which could be related to the decrease in work-related OGI; consequently, in developed countries, the majority of OGI in the elderly are falling-down related [15].

The type of injury is directly linked to visual prognosis. In the present study, the visual prognosis for ruptures is significantly poorer than for lacerations. This study showed that patients with rupture were more likely to present with NLP, prolapse of the lens, larger wounds, ZONE III injuries, and ocular complications (i.e., vitreous hemorrhage, retinal detachment, and choroidal hemorrhage). This is consistent with the findings of a previous report [30]. Interestingly, endophthalmitis had a significantly low rate of incidence, found only in two patients with rupture (0.01%). The eyes in patients with rupture seem to be less likely to be exposed to contamination risk, because rupture is almost always caused by blunt trauma. In this study, endophthalmitis was observed in 19 eyes (5.2%). Previous reports reveal that the probability of endophthalmitis in OGI was 0.9–14.3% [31–33, 45]. Intraocular foreign body which was included in the types of laceration had

higher prevalence rate, possibly because the foreign body introduced the bacteria into the eye [33].

Many previous studies have attempted to identify the prognostic factors of visual outcome in patients with OGIs [34–36]. In the present study, simple linear regression analyses showed that age, gender, initial BCVA, type of injury, presence of lens, wound length, zone of injury, iridodialysis, vitreous hemorrhage, retinal detachment, choroidal hemorrhage, and proliferative vitreoretinopathy were all associated with the final visual outcome, whereas multiple linear regression analysis showed that initial BCVA, type of injury, retinal detachment, and proliferative vitreoretinopathy were associated with the final BCVA. In simple linear regression analyses, the final BCVA was not significantly correlated with the number of surgical procedures (coefficient = 0.08, $P = 0.59$, Table 2). Some reports recommend early vitrectomy which provides a better visual outcome, while others recommend a two-stage approach [37–40]. Until now, there was no unified opinion on the number of surgical operations. Since the parameters of OGI are highly interrelated, multivariate analysis might be more suitable for identifying prognostic factors than univariate analysis. However, none of the previous study results are in agreement with all the prognostic factors identified by multivariate analyses in this study. The results of Lin et al. partially support this study in that the initial BCVA and retinal detachment were strongly correlated with final BCVA by multivariate analysis [36].

Initial BCVA is one of the most important prognostic factors in OGI [34–36]. However, patients with severe OGI and NLP occasionally recover their LP or better vision [41, 42].

In the present study, 53 of 81 eyes with NLP at initial presentation (65.4%) could not reacquire visual function despite several vitreoretinal surgeries, which indicates that 28 eyes (35.6%) recovered visual function from NLP to LP or better. The visual recovery rate from NLP to LP or better after globe rupture was higher in our study than in those reported previously (4–33%) [34, 41–50]. Eyes that underwent pars plana vitrectomy were significantly more likely to achieve LP or better final vision than those that did not (odds ratio: 257) [51]. Therefore, the high recovery rate observed in this study may be related to the fact that all the patients in this study received pars plana vitrectomy for OGI. Compared to patients with over LP at presentation, patients with NLP at presentation were significantly women and older, who exhibited rupture, absence of lens, larger wounds, and tendency of zone III injuries. These characteristics also apply to patients with fall-down OGI; in fact, several patients with fall-down OGI present with NLP at initial presentation in this study. Moreover, all ocular complications except iridodialysis and endophthalmitis (i.e., vitreous hemorrhage, retinal detachment, choroidal hemorrhage, and proliferative vitreoretinopathy) were found in NLP patients at presentation. These ocular complications are reported to exacerbate the visual prognosis [34, 36].

Frequent causes of OGI include work-related accidents, fall-down, traffic accidents, sports injuries, and assault [18, 21, 35, 52–55]. Similar to those reported in the literature, this report shows that work-related accidents were the most common cause of OGI followed by accidental fall-down injuries [5]. Different causes of OGI lead to different characteristics in patients with OGI. For example, work-related OGI was prevalent in 72–98% of men aged between 34.5 and 35.8 years [21, 56, 57], which can be attributed to physical work being more prevalent in men. Similar to the results of this study, in a previous study, fall-down OGIs were found to be more common in women and elderly subjects (58.8% women; average, 65.8 years) [35], which may be related to the prevalence of connective tissue disease and osteoporosis in the elderly, increasing the risk of fall-down, and these patients often have considerable medical comorbidities. In another study, in patients with work-related OGIs, both the preoperative and final best-corrected BCVA were better in the non-work-related group [56]. Bauza et al. found a significant difference in the type and zone of injury, as well as presence of ocular complications such as expulsive hemorrhage, between work and non-work-related OGIs [21]. In contrast, patients in the fall-down OGI group showed rupture, tendency towards zone III injuries and larger wounds, which indicates that the incidence of expected retinal and choroidal damage will inevitably worsen the visual outcomes [35]. In this study, work-related OGIs showed the best prognosis, whereas fall-down OGIs showed the worst. Four of the five (age, initial BCVA, type of injury, and presence of retinal

detachment) poor prognostic factors determined by multivariate analysis tended to be related to fall-down OGI rather than work-related OGI; furthermore, fall-down OGI was characterized by older age, worse initial BCVA, rupture, and increased retinal detachment compared to work-related OGI.

This study has several limitations. First, it was a retrospective study, some data were missing, and sample size was relatively small. Future studies with larger sample sizes are required to validate these results. Furthermore, in multicenter studies like this one, differences in protocol exist among facilities, such as surgical management methods and follow-up intervals for each patient, which may have influenced the final BCVA.

In conclusion, we retrospectively assessed OGIs in a multicenter study in Japan. In patients with OGI, the initial BCVA was poor, but it improved significantly after surgical intervention. However, the improvement in BCVA was often limited, and 78 of the 374 eyes (20.9%) showed NLP at final presentation. Of the four major causes of OGI, work-related OGI was the most common and was associated with the best visual outcome, whereas fall-down OGI was associated with the worst visual outcome. Poor initial BCVA, rupture, and the presence of retinal detachment and proliferative vitreoretinopathy correlated strongly with poor final visual outcome on multivariate analysis.

Acknowledgements Other members of J-CREST who contributed to this study are Osamu Sawada (Japan-Clinical Research of Study (J-CREST) group; Department of Ophthalmology, Shiga University of Medical Science, Otsu, Japan), Junya Mori (Japan-Clinical Research of Study (J-CREST) group; Department of Ophthalmology, Sapporo City General Hospital, Sapporo, Japan), Yoshihiro Takamura (Japan-Clinical Research of Study (J-CREST) group; Department of Ophthalmology, Faculty of Medical Sciences University of Fukui, Yoshida-gun, Japan), Yoshinori Mitamura (Department of Ophthalmology, Institute of Biomedical Sciences, Tokushima University Graduate School, Tokushima, Japan; Japan-Clinical Research of Study (J-CREST) group), Fumi Gomi (Department of Ophthalmology, Hyogo College of Medicine, Nishinomiya, Hyogo, Japan; Japan-Clinical Research of Study (J-CREST) group), Kozo Harimoto (Japan-Clinical Research of Study (J-CREST) group; Department of Ophthalmology, National Defense Medical College, Japan), Masaru Takeuchi (Japan-Clinical Research of Study (J-CREST) group; Department of Ophthalmology, National Defense Medical College, Japan), Nahoko Ogata (Department of Ophthalmology, Nara Medical University, Kashihara, Nara, Japan; Japan-Clinical Research of Study (J-CREST) group), Toshifumi Yamashita (Department of Ophthalmology, Kagoshima University Graduate School of Medical and Dental Sciences, Sakuragaoka, Kagoshima, Japan; Japan-Clinical Research of Study (J-CREST) group), Hiroki Otsuka (Department of Ophthalmology, Kagoshima University Graduate School of Medical and Dental Sciences, Sakuragaoka, Kagoshima, Japan; Japan-Clinical Research of Study (J-CREST) group), Seiji Sameshima (Department of Ophthalmology, Kagoshima University Graduate School of Medical and Dental Sciences, Sakuragaoka, Kagoshima, Japan; Japan-Clinical Research of Study (J-CREST) group), Hideki Shiihara (Department of Ophthalmology, Kagoshima University Graduate School of Medical and Dental Sciences, Sakuragaoka, Kagoshima, Japan; Japan-Clinical Research of Study (J-CREST) group), Yoshio Hirano (Department of Ophthalmology and Visual

Science, Nagoya City University Graduate School of Medical Sciences, Nagoya, Japan; Japan-Clinical Research of Study (J-CREST) group), Tsutomu Yasukawa (Department of Ophthalmology and Visual Science, Nagoya City University Graduate School of Medical Sciences, Nagoya, Japan; Japan-Clinical Research of Study (J-CREST) group), Masahito Ohji (Japan-Clinical Research of Study (J-CREST) group; Department of Ophthalmology, Shiga University of Medical Science, Otsu, Japan), and Takamasa Kinoshita (Department of Ophthalmology, Sapporo City General Hospital, Sapporo, Japan; Department of Ophthalmology, Faculty of Medical Sciences University of Fukui, Yoshida-gun, Japan).

Author contributions Design of the study (YO, SM, FO, TO); conduct of the study (YO, SM, FO); data collection (SM, YO, NI, HI, TU, TS, KS, HO); management, analysis, and interpretation of the data (YO, SM, FO); preparation of the manuscript (YO, SM); review of the manuscript (SM, YO, FO, NI, HI, TU, TS, KS, TO); and approval of the manuscript (YO, TO). This study was approved by the Institutional Review Board at the Tsukuba University Hospital and was in adherence to the tenets of the Declaration of Helsinki.

Conflicts of interest Y. Okamoto, None; S. Morikawa, None; F. Okamoto, None; N. Inomoto, None; H. Ishikawa, None; T. Ueda, None; T. Sakamoto, None; K. Sugitani, None; T. Oshika, None.

References

- Nirmalan PK, Katz J, Tielsch JM, Robin AL, Thulasiraj RD, Krishnadas R, et al. Aravind Comprehensive Eye Survey. Ocular trauma in a rural south Indian population: the Aravind Comprehensive Eye Survey. *Ophthalmology*. 2004;111:1778–81.
- Klopfert J, Tielsch JM, Vitale S, See LC, Canner JK. Ocular trauma in the United States. Eye injuries resulting in hospitalization, 1984 through 1987. *Arch Ophthalmol*. 1992;110:838–42.
- McCarty CA, Fu CL, Taylor HR. Epidemiology of ocular trauma in Australia. *Ophthalmology*. 1999;106:1847–52.
- Morris DS, Willis S, Minassian D, Foot B, Desai P, MacEwen CJ. The incidence of serious eye injury in Scotland: a prospective study. *Eye (Lond)*. 2014;28:34–40.
- Li EY, Chan TC, Liu AT, Yuen HK. Epidemiology of open-globe injuries in Hong Kong. *Asia Pac J Ophthalmol (Phila)*. 2017;6:54–8.
- Wang W, Zhou Y, Zeng J, Shi M, Chen B. Epidemiology and clinical characteristics of patients hospitalized for ocular trauma in South-Central China. *Acta Ophthalmol*. 2017;95:e503–10.
- Makhrash MA, Gosadi IM. Open globe eye injury characteristics and prognostic factors in Jazan, Saudi Arabia. *Saudi Med J*. 2016;37:1328–33.
- Fea A, Bosone A, Rolle T, Grignolo FM. Eye injuries in an Italian urban population: report of 10620 cases admitted to an eye emergency department in Torino. *Graefes Arch Clin Exp Ophthalmol*. 2008;246:175–9.
- Kuhn F, Morris R, Witherspoon CD. Birmingham eye trauma terminology (BETT): terminology and classification of mechanical eye injuries. *Ophthalmol Clin North Am*. 2002;15:139–43.
- Toride A, Toshida H, Matsui A, Matsuzaki Y, Honda R, Ohta T, et al. Visual outcome after emergency surgery for open globe eye injury in Japan. *Clin Ophthalmol*. 2016;10:1731–6.
- Kaneko H, Asami T, Sugita T, Tsunekawa T, Matsuura T, Takayama K, et al. Better visual outcome by intraocular lens ejection in geriatric patients with ruptured ocular injuries. *PLoS One*. 2017;12:e0170094.
- Schulze-Bonsel K, Feltgen N, Burau H, Hansen L, Bach M. Visual acuities “hand motion” and “counting fingers” can be quantified with the Freiburg visual acuity test. *Invest Ophthalmol Vis Sci*. 2006;47:1236–40.
- Grover S, Fishman GA, Anderson RJ, Tozatti MS, Heckenlively JR, Weleber RG, et al. Visual acuity impairment in patients with retinitis pigmentosa at age 45 years or older. *Ophthalmology*. 1999;106:1780–5.
- Fong LP. Eye injuries in Victoria, Australia. *Med J Aust*. 1995;16(162):64–8.
- Wong TY, Tielsch JM. A population-based study on the incidence of severe ocular trauma in Singapore. *Am J Ophthalmol*. 1999;128:345–51.
- Négre AD, Thylefors B. The global impact of eye injuries. *Ophthalmic Epidemiol*. 1998;5:143–69.
- Punnonen E. Epidemiological and social aspects of perforating eye injuries. *Acta Ophthalmol (Copenh)*. 1989;67:492–8.
- Saharavand A, Haavisto AK, Holopainen JM, Leivo T. Ocular traumas in working age adults in Finland—Helsinki Ocular Trauma Study. *Acta Ophthalmol*. 2017;95:288–94.
- Emami-Naeini P, Bauza AM, Langer PD, Zarbin MA, Bhagat N. Gender disparities in open globe injuries: ten-year review of an urban population. *Br J Med Res*. 2013;3:1380–7.
- Casson RJ, Walker JC, Newland HS. Four-year review of open eye injuries at the Royal Adelaide Hospital. *Clin Exp Ophthalmol*. 2002;30:15–8.
- Bauza AM, Emami P, Son JH, Langer P, Zarbin M, Bhagat N. Work-related open-globe injuries: demographics and clinical characteristics. *Eur J Ophthalmol*. 2013;23:242–8.
- Beshay N, Keay L, Dunn H, Kamalden TA, Hoskin AK, Watson SL. The epidemiology of open globe injuries presenting to a tertiary referral eye hospital in Australia. *Injury*. 2017;48:1348–54.
- Koo L, Kapadia MK, Singh RP, Sheridan R, Hatton MP. Gender differences in etiology and outcome of open globe injuries. *J Trauma*. 2005;59:175–8.
- Altıntaş L, Altıntaş O, Yüksel N, Pirhan D, Ozkan B, Çağlar Y. Pattern of open eye injuries in northwest Turkey. *Ulus Travma Acil Cerrahi Derg*. 2011;17:334–9.
- Cillino S, Casuccio A, Di Pace F, Pillitteri F, Cillino G. A five-year retrospective study of the epidemiological characteristics and visual outcomes of patients hospitalized for ocular trauma in a Mediterranean area. *BMC Ophthalmol*. 2008;8:6.
- Haring RS, Canner JK, Haider AH, Schneider EB. Ocular injury in the United States: Emergency department visits from 2006–2011. *Injury*. 2016;47:104–8.
- Soliman MM, Macky TA. Pattern of ocular trauma in Egypt. *Graefes Arch Clin Exp Ophthalmol*. 2008;246:205–12.
- Chang CH, Chen CL, Ho CK, Lai YH, Hu RC, Yen YL. Hospitalized eye injury in a large industrial city of South-Eastern Asia. *Graefes Arch Clin Exp Ophthalmol*. 2008;246:223–8.
- Mansouri M, Faghihi H, Hajizadeh F, Rasoulnejad SA, Rajabi MT, Tabatabaey A, et al. Epidemiology of open-globe injuries in Iran: analysis of 2,340 cases in 5 years (report no. 1). *Retina*. 2009;29:1141–9.
- Kuhn F, Maisiak R, Mann L, Mester V, Morris R, Witherspoon CD. The ocular trauma score (OTS) ophthalmology clinics of North America. 2002;15:163–5.
- Man CYW, Steel D. Visual outcome after open globe injury: a comparison of two prognostic models—the Ocular Trauma Score and the Classification and Regression Tree. *Eye (Lond)*. 2010;24:84–9.
- Entezari M, Rabei HM, Badalabadi MM, Mohebbi M. Visual outcome and ocular survival in open-globe injuries. *Injury*. 2006;37:633–7.

33. Szijártó Z, Gaál V, Kovács B, Kuhn F. Prognosis of penetrating eye injuries with posterior segment intraocular foreign body. *Graefes Arch Clin Exp Ophthalmol*. 2008;246:161–5.
34. Rofail M, Lee GA, O'Rourke P. Prognostic indicators for open globe injury. *Clin Exp Ophthalmol*. 2006;34:783–6.
35. Emami-Naeini P, Ragam A, Bauza AM, Soni N, Langer P, Zarbin MA, et al. Characteristics, outcomes, and prognostic indicators of fall-related open globe injuries. *Retina*. 2013;33:2075–9.
36. Lin H, Lema GM, Yoganathan P. Prognostic indicators of visual acuity after open globe injury and retinal detachment repair. *Retina*. 2016;36:750–7.
37. Ramsay RC, Cantrill HL, Knobloch WH. Vitrectomy for double penetrating ocular injuries. *Am J Ophthalmol*. 1985;100:586–9.
38. Meredith TA, Gordon PA. Pars plana vitrectomy for severe penetrating injury with posterior segment involvement. *Am J Ophthalmol*. 1987;103:549–54.
39. Coleman DJ. Early vitrectomy in the management of the severely traumatized eye. *Am J Ophthalmol*. 1982;93:543–51.
40. Spiegel D, Nasemann J, Nawrocki J, Gabel VP. Severe ocular trauma managed with primary pars plana vitrectomy and silicone oil. *Retina*. 1997;17:275–85.
41. Salehi-Had H, Andreoli CM, Andreoli MT, Kloek CE, Mukai S. Visual outcomes of vitreoretinal surgery in eyes with severe open-globe injury presenting with no light perception vision. *Graefes Arch Clin Exp Ophthalmol*. 2009;247:477–83.
42. Shiraki N, Wakabayashi T, Sato T, Sakaguchi H, Nishida K. Intraoperative B-scan ultrasonography and pars plana vitrectomy for severe open globe injury with hemorrhagic retinal and choroidal detachment. *Graefes Arch Clin Exp Ophthalmol*. 2017;255:2287–91.
43. Hui Y, Wang L, Shan W. Exploratory vitrectomy for traumatized eyes with no light perception and dense vitreous hemorrhage. *Zhonghua Yan Ke Za Zhi*. 1996;32:450–2 (in Chinese).
44. Matthews GP, Das A, Brown S. Visual outcome and ocular survival in patients with retinal detachments secondary to open- or closed-globe injuries. *Ophthalmic Surg Lasers*. 1998;29:48–54.
45. Schmidt GW, Broman AT, Hindman HB, Grant MP. Vision survival after open globe injury predicted by classification and regression tree analysis. *Ophthalmology*. 2008;115:202–9.
46. Weichel ED, Colyer MH, Ludlow SE, Bower KS, Eiseman AS. Combat ocular trauma visual outcomes during operations iraqi and enduring freedom. *Ophthalmology*. 2008;115:2235–45.
47. Heidari E, Taheri N. Surgical treatment of severely traumatized eyes with no light perception. *Retina*. 2010;30:294–9.
48. Feng K, Shen L, Pang X, Jiang Y, Nie H, Wang Z, et al. Case-control study of risk factors for no light perception after open-globe injury: Eye injury vitrectomy study. *Retina*. 2011;31:1988–96.
49. Agrawal R, Wei HS, Teoh S. Predictive factors for final outcome of severely traumatized eyes with no light perception. *BMC Ophthalmol*. 2012;12:16.
50. Soni NG, Bauza AM, Son JH, Langer PD, Zarbin MA, Bhagat N. Open globe ocular trauma: functional outcome of eyes with no light perception at initial presentation. *Retina*. 2013;33:380–6.
51. Bhagat N, Turbin R, Langer P, Soni NG, Bauza AM, Son JH, et al. Approach to management of eyes with no light perception after open globe injury. *J Ophthalmic Vis Res*. 2016;11:313–8.
52. Orr CK, Bauza A, Langer PD, Zarbin MA, Bhagat N. Open-globe injuries with motor vehicle accidents: a 12-year review. *Graefes Arch Clin Exp Ophthalmol*. 2015;253:1313–7.
53. Park SJ, Park KH, Heo JW, Woo SJ. Visual and anatomic outcomes of golf ball-related ocular injuries. *Eye*. 2014;28:312–7.
54. Bauza AM, Emami-Naeini P, Soni N, Holland BK, Langer P, Zarbin M, et al. A 10-year review of assault-related open-globe injuries at an urban hospital. *Graefes Arch Clin Exp Ophthalmol*. 2013;251:653–9.
55. Okamoto Y, Morikawa S, Okamoto F, Mitamura Y, Ishikawa H, Ueda T, et al. Traffic accident-related open globe injuries. *Retina*. 2017. <https://doi.org/10.1097/iae.0000000000002012> (Epub ahead of print).
56. Kanoff JM, Turalba AV, Andreoli MT, Andreoli CM. Characteristics and outcomes of work-related open globe injuries. *Am J Ophthalmol*. 2010;150:265–9.
57. Vasu U, Vasnaik A, Battu RR, Kurian M, George S. Occupational open globe injuries. *Indian J Ophthalmol*. 2001;49:43–7.