



Characteristics of Open-globe Eye Injuries with Respect to Zone of Injury

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Author's contributions

This work was carried out in collaboration between all authors. Author YT wrote the manuscript and performed the statistical analysis. Author NGS collected data and wrote the manuscript. Author AMB collected data, author MAZ edited the manuscript. Author NB designed the study and wrote the manuscript. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: To describe the demographics, characteristics and outcomes of open-globe injuries (OGI) with respect to zone of injury.

Methods: Medical records of all patients presenting with OGIs to University Hospital, Newark, NJ between January 2001 and December 2008 with a follow-up of at least 3 months were reviewed. Demographics, characteristics of the trauma and outcomes were compared with respect to the zone of injury; location of injury is confined to the cornea and limbus in zone 1 (Z1), <5 mm posterior to the limbus in zone 2 (Z2) and >5mm posterior to the limbus in zone 3 (Z3).

Results: Of the 309 patients (310 eyes) identified, 228 (74%) were male. The mean age at presentation was 35.3 years (1-96). Mean follow-up was 22.8 months (3-108 months). Most of the eyes presented with Z1 injury: 141 eyes (46%) Z1 injury, 83 (27%) Z2 and 86 (28%) Z3. Rupture was the most common type of injury in Z2 and Z3 injuries. Nineteen (86%) of 22 eyes with an intraocular foreign body (IOFB) had a Z1 injury. 32 (42%) of 77 eyes with Z3 injury had no light perception (NLP) at presentation, compared with 9 (8%) of 119 Z1 and 13 (17%) of 78 Z2-injured eyes. Four percent of Z1, 11% of Z2 and 18% of Z3-injured eyes had a final vision (VA) of NLP. Primary enucleation was undertaken in 10

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eyes (9 were Z2 injured eyes). Secondary enucleation was performed in 12 (9%) of 141 Z1, 7 of 82 (9%) of Z2 and 22 (26%) of 78 Z3 eyes. Thirty (36%) of 86 Z3 injuries resulted in primary or secondary enucleation. The final Snellen VA was 1.05, 1.41, and 2.19 respectively in Z1, Z2 and Z3-injured eyes. Posterior segment surgery was performed in 30% Z1, 39% Z2 and 49% Z3-injured eyes. Retinal detachment (RD) was diagnosed in 11% Z1, 27% Z2 and 40% Z3 injuries.

Conclusion: Z1 injury may be associated with a better visual prognosis than Z2 and Z3 injuries. The visual prognosis of Z3 injured eyes is poor with one-third of these eyes being enucleated.

Keywords: Ocular trauma; zone of injury; open globe; prognosis; ruptured globe.

1. INTRODUCTION

Eye injury is a major cause of visual impairment and blindness in the United States [1]. More than 2.4 million eye injuries occur per year and nearly 1 million people living in the United States have become visually impaired as a result of an eye injury. Eye injury is also one of the most common causes of monocular blindness. Disabling work-related eye injuries have an estimated total cost to society of nearly 4 billion dollars each year.

Numerous studies in the open-globe trauma literature identify prognostic indicators of poor visual outcomes [2-22]. These indicators include but are not limited to poor initial VA, presence of an afferent pupillary defect (APD), blunt injury, vitreous hemorrhage (VH) and size of laceration [19-22]. Ocular Trauma Score (OTS) was developed by Kuhn et al. [3] using databases of the United States and Hungarian Eye Injury Registries. Variables including poor initial VA, globe rupture, endophthalmitis, perforating injury, RD and APD are used to calculate OTS to predict visual prognosis [3]. This prognostic model has been validated by many studies with open globe injuries (OGIs) [2,4-7,18,23]. However, the location of injury was not included as a prognostic indicator in this model.

Many studies report a worse visual prognosis with posterior segment injuries compared to the anterior ones [8,9,19-22]. Pieramici and associates reported that the most posterior open-globe injuries were approximately five times more likely than the most anterior open-globe injuries to have a final visual outcome worse than 20/40 [8]. Thakker and Raymore specifically reported that 45% of patients with Z1 trauma achieved a VA better than 20/50, compared with only 23.3% of patients with Z2 and Z3 trauma [13]. Sternberg and coworkers reported that injuries anterior to the rectus muscle were 5.83 times more likely to leave a patient with a VA of 20/800 or better than those posterior to the rectus muscle [19]. Therefore, location of injury may have a significant impact on visual outcomes. In this study, we explore the prognostic importance of injury location with respect to Z1, Z2 and Z3 on anatomic and functional outcomes following open-globe ocular trauma [24].

2. MATERIALS AND METHODS

This retrospective cohort study was approved by the University of Medicine and Dentistry of New Jersey's Institutional Review Board. The study included all subjects who sustained an open-globe eye injury between January 1, 2001 and December 31, 2008 and presented to the University Hospital in Newark, NJ with a follow-up of at least 3 months.

A full-thickness wound of the eyewall, involving sclera and/or cornea was necessary for a case to be considered an open-globe injury [24]. Patients' medical charts were reviewed, including initial ophthalmology consultation notes, hospital records, operative reports and follow-up outpatient records. Demographic factors including each patient's age, race and gender were recorded along with clinical information such as cause of injury, initial VA, presence of an APD, location of injury, type of injury, lens status, presence of IOFB, types of surgeries required, length of hospital stay and final VA.

The location of the wound was classified in accordance with the Ocular Trauma Classification Group: Z1 - confined to the cornea and limbus; Z2 - 5 mm or less posterior to the limbus; Z3 - greater than 5mm posterior to the limbus [24] (Fig. 1). If an injury involved more than one zone, it was classified as the greater zone. The posterior segment of the eye was defined as the area posterior to the lens including the sclera, choroid, retina, optic disc, and vitreous humor. The type of injury was defined according to the Birmingham Eye Trauma Terminology (BETT): a rupture is a full-thickness wound to the eyewall due to blunt trauma; a laceration is a full-thickness wound due to a sharp object; lacerations are penetrating if only an entrance wound is present; lacerations are perforating if both entrance and exit wounds are present; the presence of an IOFB qualifies the injury as a penetrating injury [25]. The Snellen chart VA was converted to logMAR for analysis of VA. Patients who underwent enucleation were considered no light-perception (NLP) when final VA calculations were performed. GraphPad in Stat 3 was used for statistical analysis of the comparison of means.

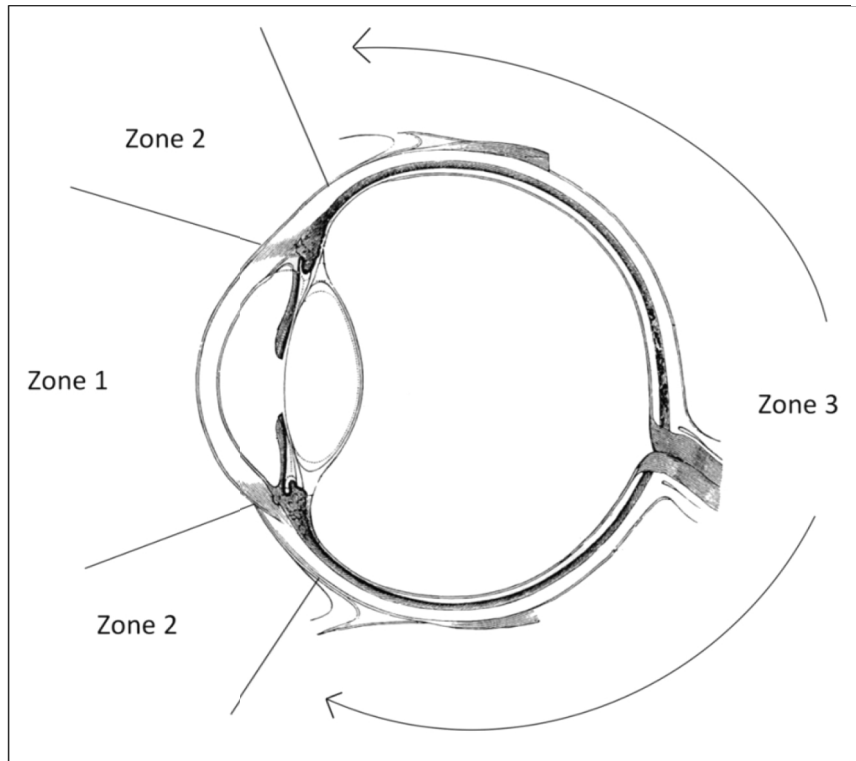


Fig. 1. Zone classification of location of wound injury. (adapted from popular science monthly volume 45)

3. RESULTS

A total of 310 eyes from 309 subjects presented to University Hospital in Newark, NJ between January 1, 2001 and December 31, 2008 with OGIs with documented site of injury and a follow-up of 3 months. One patient suffered bilateral open-globe injuries. Average follow-up was 22.8 months (range 3 - 108 months).

Two hundred twenty-eight patients (74%) were male; of patients age 65 years and older, only 12 (37%) of 32 patients were male. The mean age was 35.3 years (range 1 - 96 years). One hundred forty-one eyes (45%) sustained Z1 injury; 83 (27%) Z2 injury and 86 (28%) Z3 injury. One male patient suffered bilateral open-globe injuries, both in Z3.

Thirty-eight (27%) of 141 eyes with Z1 injury had a rupture, compared to 37 (45%) of 83 with Z2 and 42 (49%) of 86 eyes with Z3 injury. Only five eyes had perforating injuries and they all resulted in Z3 injuries. In patients of age 18 or less, rupture was the most common cause in Z1 injuries (13 (43%) of 30 eyes) and laceration was most common in Z3 injuries (7 (64%) of 11 eyes). In patients above age 18, laceration was the most common mechanism of injury in Z1 and Z2-injured eyes (86 (77%) of 111 and 36 (55%) of 66 eyes, respectively) and Z3 injuries had roughly equal numbers of lacerations and ruptures. Zone 1 injuries were most commonly due to work-related accidents while Z2 and Z3 injuries were most commonly due to assault in our series as shown in Table 1.

Primary globe repair was performed in 96% (299 of 310) eyes: 140 (99%) of 141 Z1 injuries, in 82 (99%) of 83 Z2 injuries and in 77 (90%) of 86 Z3 injuries. A bandage contact lens was placed in one eye with Z1 injury with Siedel negative corneal laceration. Ten eyes (1 with Z2 and 9 with Z3 OGI) were primarily enucleated due to such severe injury that tissue closure was not deemed possible. Most of the primary globe repairs, 268 (89%) of 301 cases were performed within 24 hours of injury and 290 (96%) cases within 3 days of injury.

Table 1. Causes of open-globe eye trauma with respect to the zone of injury in a cohort presenting to the University Hospital in Newark, NJ

	Zone 1 (n^a=141)	Zone 2 (n=83)	Zone 3 (n=86)	All Eyes (n=310)
Eyes with Known Cause of Injury	134	79	84	297
Place of Injury	Zone 1	Zone 2	Zone 3	All Eyes
Workplace	57 (43%)	24 (30%)	11 (13%)	92 (31%)
Non-workplace	77 (57%)	55 (71%)	73 (87%)	205 (69%)
Specific Cause of Injury	Zone 1	Zone 2	Zone 3	All Eyes
Assault	12 (9%)	20 (25%)	37 (44%)	71 (24%)
Nail-gun	27 (20%)	13 (16%)	3 (4%)	43 (14%)
Firework	0	0	3 (4%)	3 (1%)
Traffic Accident	7 (5%)	4 (5%)	9 (11%)	20 (7%)
GSW	4 (3%)	2 (3%)	5 (6%)	11 (4%)
Fall	8 (6%)	10 (13%)	12 (14%)	30 (10%)
Other	76 (57%)	30 (38%)	15 (17%)	119 (40%)

^an= number of eyes; GSW, gunshot wound

Nineteen (86%) of 22 eyes with an IOFB had a Z1 injury; one (5%) of 22 had a Z2 injury and 2 (9%) of 22 had a Z3 injury. All IOFB's were noted in male subjects with a mean age of 32.6

years. Twelve (63%) of 19 IOFBs in Z1 eyes were found in the vitreous cavity; all IOFB's in eyes with Z2 or Z3 injury were located in the posterior segment.

Hyphema was noted in 183 (53%) of 310 eyes at presentation and was more common in Z3 injuries, 64 (74%) of 86 eyes. Hyphema sometimes made it difficult to assess the status of the lens at presentation. Aphakia was present in 17 (23%) of 71 eyes with Z3 injury and in only 14 (10%) of 137 and 17 (19%) of 71 eyes with Z1 and Z2 injuries, respectively. The lens in these eyes was either extruded at the time of injury or subluxed. Of the 224 phakic eyes, 104 (46%) eyes were noted to have cataractous changes at presentation and 26 (25%) of these 104 eyes underwent cataract removal during primary wound closure. The status of the lens at presentation could not be evaluated in 20 (6%) of 310 total eyes due to media opacities.

The presence of an IOFB in the posterior chamber was the most common indication for primary PPV in Z1 injuries, while VH and RD were the most common indications for primary PPV in Z2 and Z3 injuries, respectively. Overall, PPV was performed as a primary or secondary procedure in 116 eyes: in 42 (30%) of 141 Z1, 32 (39%) of 82 Z2-injured eyes and 42 (54%) of 76 Z3-injured eyes. RD was noted in 25 (18%) of 138 Z1, in 26 (33%) of 80 Z2 and in 43 (60%) of 72 Z3 injuries, respectively.

Penetrating keratoplasty (PKP) was performed in 8 (6%) of 141 Z1, in 6 (7%) of 82 Z2, and in 3 (4%) of 78 Z3 injuries. All these eyes had presented with a corneal laceration. Fifty-nine (71%) of 83 Z2 injuries and 30 (35%) of 86 Z3 injuries involved a corneal injury. The complications and surgeries associated with each zone of injury are described in Table 2. The demographics with complications and surgeries are noted in Table 3.

Table 2. Complication and surgery rates in eyes sustaining open-globe trauma with respect to the zone of injury

	Zone 1 (n^a=141)	Zone 2 (n=83)	Zone 3 (n=86)
Hyphema	47 (33%)	53 (64%)	64 (74%)
Aphakia	14 (10%)	17 (19%)	17 (23%)
Cataract	73 (64%)	27 (48%)	29 (54%)
Retinal Detachment	25 (18%)	26 (33%)	40 (56%)
Pars Plana Vitrectomy	42 (30%)	32 (39%)	42 (54%)
Primary Pars Plana Vitrectomy	13 (9%)	4 (5%)	3 (4%)
Penetrating Keratoplasty	8 (6%)	6 (7%)	3 (3%)
Cataract Extraction ^b	72 (63%)	23 (41%)	26 (48%)

^a n = number of eyes. Eyes undergoing primary enucleation were not included in calculations for retinal detachment, pars plana vitrectomy, cataract extraction and penetrating keratoplasty. Percentages for all data were calculated from eyes with a known status for each complication.

^b = Only initially phakic eyes were included in the denominator

Infectious endophthalmitis was seen in seven eyes (five with Z1 injuries, one Z2 and one Z3 injury). An IOFB was found in three of these patients, all with Z1 injury. All endophthalmitis patients were male. The infection was diagnosed at presentation in 5 eyes (all with Z1 injury, 3 with IOFB's), at 1 month after injury in 1 eye (Zone 3) and at 1.5 months after injury in 1 eye (Zone 2). Organisms responsible for endophthalmitis in Z1 injury included *Bacillus* species, *S. morbillorum* and *E. vulneris*; *S. hominis* in a Z2 -injured eye and a few Gram-positive cocci in a Z3-injured eye. All endophthalmitis eyes received intravenous vancomycin

and ceftazidime upon admission and intravitreal vancomycin and ceftazidime once endophthalmitis was diagnosed. Two eyes both with Z1 injury, received intravitreal amphotericin B as well for suspicion of fungal endophthalmitis. Patients with endophthalmitis had an average initial VA of 1.75 logMAR (~counting finger (CF) at 4 feet) and final VA of 1.41 logMAR (~ 20/400).

Table 3. Characteristics and outcomes of eyes after posterior open-globe injury with respect to corneal involvement of wound

	Zone 2		Zone 3	
	Scleral	Corneoscleral	Scleral	Corneoscleral
n ^a	24	59	56	30
Age	41.08 (SD - 22.13)	35.80 (SD - 22.47)	37.89 (SD - 18.05)	34.83 (SD - 17.94)
Gender				
Male	17	45	40	26
Female	7	14	16	4
Lens Status				
Phakic	14	42	36	18
Aphakic	5	8	11	5
Dislocated Lens	1	1	1	0
Pseudophakic	3	3	0	1
Dislocated IOL ^b	1	2	0	1
Unknown	0	3	8	5
Presenting VA ^c	1.98	1.9	2.42	2.46
Final VA	1.09	1.54	2.17	2.23
OTS Raw Score	54.88	60.05	43.29	47.54
IOFB ^d	1	0	4	0
RD ^e	6 of 23 known	20 of 57 known	34 of 52 known	18 of 29 known
HC ^f	5 of 23 known	15 of 58 known	30 of 53 known	13 of 29 known
# Surgeries after OGR ^g	0.71	1.1	1.27	1.47
Corneal Transplant	0	6 of 82 known	0	3 of 78 known
Enucleation	2	6	19	11

^an = number of patients; ^bIOL = Intraocular Lens; ^cVA = Visual Acuity; ^dIOFB = Intraocular Foreign Body; ^eRD = Retinal Detachment; ^fHC = Hemorrhagic Choroidals and ^gOGR= Open Globe Repair

VA at presentation was the worst in eyes with Z3 injury. The average presenting VA was 1.68 logMAR (~CF at 4 feet) for Z1, 1.93 logMAR (~ CF at 2 feet) for Z2 and 2.43 logMAR (~ CF at 1 foot) for Z3. Furthermore, 32 (42%) of 77 eyes with Z3 injury had NLP at presentation, compared with 9 (8%) of 119 Z1-injured eyes and 13 (17%) of 78 Z2-injured eyes.

The average final VA's were 1.05 logMAR (20/200), 1.41 logMAR (~ 20/400) and 2.19 logMAR (~ CF at 1.3 feet) for Z1, Z2 and Z3, respectively. The enucleated eyes were assumed to have a VA of NLP. Four percent of Z1, 11% of Z2 and 18% of Z3-injured eyes had a final VA of NLP. Final VA's achieved by eyes in this study are shown in Fig. 2.

Primary enucleation was performed in nine eyes (one with Z2 injury and eight with Z3 injury). Secondary enucleation was performed in 12 (9%) of 141 Z1-injured eyes, 7 of 82 (9%) of Z2-injured eyes and 22 (26%) of 78 Z3-injured eyes, with the most common indication being a blind, painful eye. Thirty (36%) of 86 Z3 injuries resulted in primary or secondary enucleation. No cases of sympathetic ophthalmia were noted in the study.

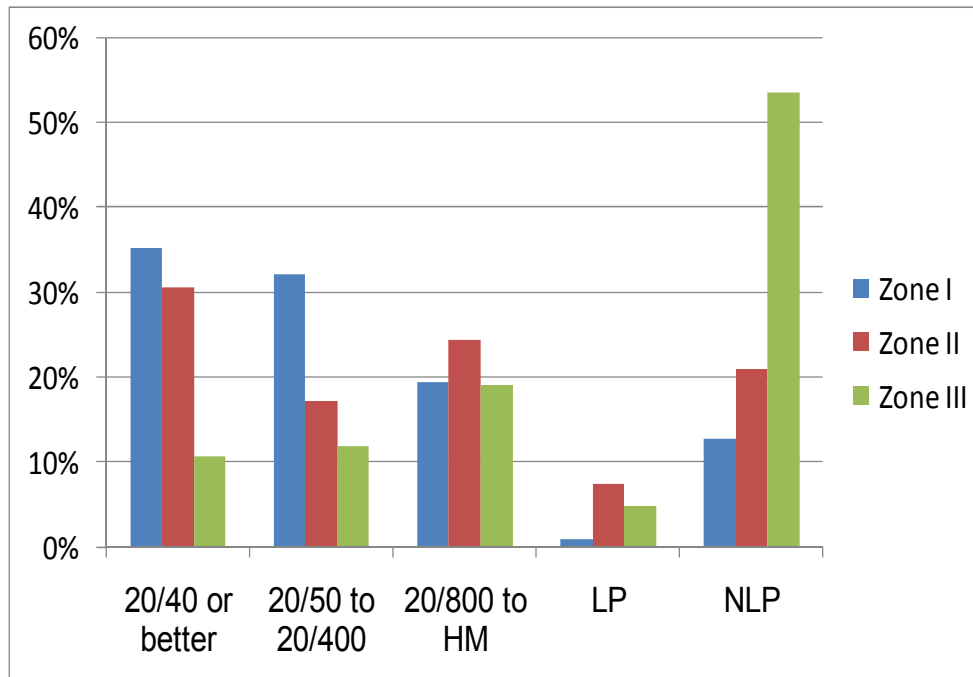


Fig. 2. Visual outcomes: Final visual acuity in eyes with open-globe Injury with respect to zone of injury

(All enucleated eyes were assumed to be NLP)

4. DISCUSSION

Prior to the establishment of standardized “zones of injury” by the Ocular Trauma Classification Group in 1997, wound location was described as either anterior or posterior or corneal or scleral and wound length was used to specify the extent of injury [19-22,24]. Ocular Trauma Classification Group descriptors not only make communication regarding the location of injury more precise but also allow for better estimation of the prognosis in open-globe injuries. In our study, more eyes with Z1 injury than Z2 or Z3 had better final visual acuity. Z1 injury may have the best visual prognosis among all three zones, with Z3 having the worst visual prognosis with one-third of these eyes being enucleated.

Lacerations were more common in Z1 than in Z3 injuries, and ruptures more common in Z3 than Z1 injuries in our study. However, when the sample was stratified according to age, rupture was found to be more common in Z1 than in Z3 injuries in children and teenagers less than 18 years of age. This result may be due to structural differences between the eyes of adults and children; the adults had a higher incidence of previous ocular surgeries.

Initial VA has been reported to be an important prognostic indicator of final VA [9,19-22]. Sternberg et al. reported that an eye with a presenting VA of 20/800 or better was 7.9 times more likely than one with a presenting VA worse than 20/800 to have a final VA of 20/50 or better [19]. They also found that in eyes with poor vision, a laceration limited to the cornea was the best prognostic factor for good final vision [19]. Initial and final VA in our study was in fact, better in Z1 than Z2 or Z3 injury. Ruptures, thought to cause worse visual outcomes than lacerations were noted more often in Z2 and Z3 injuries in our study [3,26]. Therefore, a combination of injury location, type of injury and initial VA may have influenced the final visual outcome.

Eyes with NLP vision at presentation typically carry poor visual prognoses [27]. However, Salehi et al. [27] reported that 26.1% of patients presenting with NLP prior to primary repair recovered to light perception (LP) or better. Similarly, 28% of all eyes with NLP at presentation improved to LP or better in our cohort. Eyes with presenting VA of NLP with Z1 and Z2 injuries were more likely to have visual outcomes of LP or better at final follow-up than those with Z3 injuries (33%, 54% and 16% of eyes, respectively). There was a 25% primary enucleation rate in Z3-injured eyes presenting with NLP, compared to 0% and 8% for Z1 and Z2-injured eyes, respectively.

Endophthalmitis was a rare complication, 7 (2%) of 310 eyes, in our study population. This finding is consistent with previous studies in which the rates of post-traumatic endophthalmitis range from 0% to 13% [2,5,10,12,16,26,28,29]. Three cases occurred in eyes that had IOFB's and were all Z1-injured eyes. The presence of an IOFB may increase the risk of endophthalmitis [16,28-30]. In our study an IOFB was found in 3 (43%) of 7 eyes with endophthalmitis (one additional patient removed a piece of glass from the eye prior to presentation).

PPV has been noted to be a negative prognostic indicator for final VA in open-globe injuries [9]. Although Z1 injuries involve primarily the anterior globe, many eyes (30%) with Z1 injuries required vitrectomy in our study, mainly for VH, RD and IOFB. IOFB's were also much more common with Z1 injuries; approximately two-thirds of IOFB's in Z1-injured eyes were located in the posterior chamber. These eyes underwent PPV at the time of the initial globe repair, which may have contributed to the high rate of primary PPV's among eyes with Z1 injuries. In fact, a posterior segment IOFB was present in 10 (67%) of the 15 Z1 eyes that underwent PPV.

Enucleation was much more commonly performed in Z3-injured eyes than Z1 and Z2-injured eyes. It is worth noting that approximately 1 in 3 Z3 injuries resulted in enucleation, attesting to the grim prognosis of this type of injury. The high rate of enucleation is directly related to the higher percentage of eyes with a final VA of NLP in Z3 injuries (17.9%) as compared to Z1 (9%) and Z2 (10%) injuries. Pain was the most common reason for secondary enucleation in NLP eyes in this study.

Our study, overall, suggests that the initial and final VA gets worse as the site of injury extends posteriorly. Also, the risk of final VA being NLP or undergoing enucleation seemed to be higher in Z3 injured eyes compared to Z1 and Z2.

The wide range of injury mechanisms, relatively brief follow-up period and retrospective nature of this study are characteristics common to many ocular trauma case series. There are many confounding factors that influence the outcome in such traumatic eye injuries. This study provides insight into the functional and anatomic outcomes in open-globe trauma with respect to the zone of injury.

5. CONCLUSION

This study suggests a trend for poorer visual outcome as the site of injury extends posteriorly. Half of the Z3 injured eyes, in this case series, had a final visual acuity of no light perception and one-third of these eyes underwent enucleation.

CONSENT AND ETHICAL APPROVAL

The study was performed with informed consent and following all the guidelines for experimental investigations required by the Institutional Review Board at the University of Medicine and Dentistry of New Jersey (UMDNJ).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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