

ARTICLE



A comparison of primary and secondary eye removal after open globe injury: A multi-centre study

Mark Krakauer¹✉, Erin Jennings¹, Lalita Gupta², Zhuangjun Si³, Daohai Yu⁴, Xiaoning Lu⁴, Mark A. Prendes² and Hassan Shah³

© The Author(s), under exclusive licence to The Royal College of Ophthalmologists 2022

BACKGROUND/OBJECTIVES: Our goal was to compare the characteristics and surgical outcomes of patients who underwent primary eye removal surgery after open globe injury with those who underwent secondary eye removal surgery after open globe repair.

SUBJECTS/METHODS: This was a retrospective review of subjects who underwent evisceration or enucleation within 3 months of an open globe injury, at three Level I trauma centres in three U.S. cities between July 2014 and July 2020.

RESULTS: 19 patients underwent primary eye removal and 20 underwent secondary eye removal. The most common mechanism of trauma in patients who underwent primary eye removal was gunshot. Compared to the secondary eye removal group, patients who underwent primary eye removal were significantly more likely to be male; have longer hospital stays; be discharged to another care facility rather than home; have facial fractures; suffer intracranial injury; and be unable to consent themselves for surgery. Both groups had a low surgical complication rate with one case of socket contracture in each group.

CONCLUSIONS: The standard of care for an open globe injury is prompt repair, but there are occasions when the globe is so damaged that it is deemed unreparable. We found that globes that required primary eye removal were more often due to gunshot wounds, and that there was greater morbidity associated with these injuries. The authors' preferred surgical approach was evisceration with placement of a silicone sphere; patient outcomes demonstrate that this method was found to be safe, with a low complication and infection rate.

Eye (2023) 37:1249–1253; <https://doi.org/10.1038/s41433-022-02098-z>

INTRODUCTION

In the United States, approximately 2 million eye injuries occur each year [1]. Open globe injuries had an annual incidence rate of 4.49 per 100,000, accounting for \$793 million in total charges in the U.S. over a recent nine year period [2]. The standard of care for open globe injuries is to promptly repair the corneoscleral laceration, in order to restore the globe's integrity. However, there are instances where the injury is so severe that the globe is not repairable.

Rates of primary eye removal for open globe injuries range widely. Civilian studies have reported rates of 0% to 9% [3–6], while military studies have reported rates as high as 38% [7–9]. This is likely due to a greater proportion of missile and blast injuries resulting in more severe injury. This subset of open globe injuries—those that are unreparable—has not been extensively studied. Holmes et al. reported on British military patients who underwent eye removal during the Iraq and Afghanistan wars: 5/14 eviscerations were performed primarily without implants, and 5/6 enucleations were performed primarily, three with implants [10].

Surgeons are faced with several treatment decisions in this scenario, including timing of surgery, whether to preserve the sclera (eviscerate) or not (enucleate), whether to place an implant

primarily, and the type of implant. There is currently no consensus on whether evisceration or enucleation is superior in the setting of ocular trauma, with some preferring enucleation [4], and others preferring evisceration [6]. Historically, 2 weeks has been cited as the timeframe within which to remove an eye with no visual potential after penetrating injury, in order to prevent sympathetic ophthalmia, although this is controversial [4, 11]. The goal of this study was to describe the preoperative characteristics and surgical outcomes of patients who underwent primary eye removal—patients with open globes who underwent evisceration or enucleation without prior globe repair. In order to see if their characteristics and outcomes were distinctive amongst ocular trauma patients, we compared them to patients who underwent secondary eye removal—patients whose open globes were repaired and then went on to have evisceration or enucleation. We also present our general surgical approach, including technique, timing and implant choice in this setting.

METHODS

This was a retrospective review of subjects who underwent eye removal surgery at three urban, Level I trauma centres in three different U.S. cities

¹Department of Ophthalmology, Lewis Katz School of Medicine at Temple University, Philadelphia, PA, USA. ²Department of Ophthalmology and Visual Sciences, Case Western Reserve/University Hospitals Eye Institute, Cleveland, OH, USA. ³Department of Ophthalmology and Visual Sciences, University of Chicago Pritzker School of Medicine, Chicago, IL, USA. ⁴Center for Biostatistics and Epidemiology, Department of Biomedical Education and Data Science, Lewis Katz School of Medicine at Temple University, Philadelphia, PA, USA. ✉email: mark.krakauer@gmail.com

Table 1. Patient characteristics by eye removal type ($n = 39$).

Variable	Primary ($n = 19$)	Secondary ($n = 20$)	<i>p</i> -value
Surgery Type, <i>N</i> (%)			
Enucleation with implant	3 (15.8%)	2 (10.0%)	
Enucleation without implant	1 (5.3%)	0 (0.0%)	
Evisceration with implant	13 (68.4%)	18 (90.0%)	
Evisceration without implant	2 (10.5%)	0 (0.0%)	
Gender, <i>N</i> (%)			
F	2 (10.5%)	8 (40.0%)	0.048
M	17 (89.5%)	12 (60.0%)	
Age (years)			
Median (range)	28.0 (13.0, 65.0)	41.5 (17.0, 87.0)	0.052
Days to removal			
Median (Range)	6.0 (0.0, 91.0)	19.5 (2.0, 83.0)	0.002
Duration of follow up (days)			
Median (range)	68.0 (10.0, 1346.0)	64.5 (7.0, 1346.0)	0.58

between July 2014 and July 2020. The study was approved by the institutional review board (IRB) of each institution and conducted in accordance with the Health Insurance Portability and Accountability Act (HIPAA) and the Declaration of Helsinki. Written informed consent for inclusion in the study was waived due to the retrospective nature of the study; written informed consent was obtained for the use of patient photographs for publication.

A search of the electronic medical records for the Current Procedural Technology Codes for enucleation (65101, 65103, 65105) and evisceration (65091, 65093) was performed at each institution, and patients who had an open globe injury within 3 months of eye removal surgery were included. Pertinent data were extracted from the medical records, including patient demographics, hospital course, type of surgery performed, and post-operative course including complications such as infection, implant extrusion, socket contracture causing inability to wear a conformer or prosthesis, or sympathetic ophthalmia. Concomitant injuries such as facial fractures, intracranial injury (e.g., intracranial bleeding), or damage to the contralateral eye (defined as impaired vision at last follow up visit) were also recorded.

Patients were divided into two groups for comparative analysis: the primary eye removal group consisted of patients who underwent evisceration or enucleation without prior repair of the open globe, as it was deemed unreparable by the referring ophthalmologist. The secondary eye removal group consisted of patients who underwent evisceration or enucleation within 3 months of prior open globe repair, either because the eye could not be fully repaired, had recalcitrant pain, and/or to reduce the risk of sympathetic ophthalmia in the fellow eye, in which case, the eye was removed within two weeks of the trauma.

Data were reported as counts and percentages for categorical variables and median (range) for continuous variables by group (eye removal type: primary vs. secondary) for all patients. Comparisons between eye removal groups were performed using the Fisher exact or Chi-Square test for categorical variables and the Wilcoxon rank-sum test for continuous variables due to the small sample size/non-normal nature of the underlying data. Multiple testing adjustments were not made due to the exploratory nature of this study. *P*-values less than 0.05 were considered statistically significant. SAS version 9.4 (SAS Institute Inc., Cary, NC) was used for all the data analyses.

Surgeries were performed by the same attending surgeon at each centre: M.K. at Temple University Hospital in Philadelphia, H.S. at University of Chicago Medical Centre, and M.A.P. at University Hospitals Cleveland Medical Centre, using a similar surgical approach. For patients in the primary eye removal group, the goal was to perform surgery as soon as the patient was medically stable. Evisceration was performed in a standard fashion: scleral tissue was preserved, and if the posterior sclera was intact, four posterior sclerotomy incisions were made in order to place the implant. The anterior sclera was then sutured closed, followed by Tenon's fascia, followed by the conjunctiva. A conformer, suture tarsorrhaphy, and pressure patch were then placed. In cases where there was not enough sclera remaining to cover an implant, enucleation was performed, and an implant wrapped in cadaver sclera was placed, sutured to the extraocular

muscles if they were identifiable. Patients received broad-spectrum systemic antibiotics (typically cefazolin) perioperatively and for 1 week after surgery. The suture tarsorrhaphy was removed one week after surgery, and the patients were referred to an ocularist for prosthesis construction 2 months later.

RESULTS

There were 39 eyes that underwent primary or secondary eye removal within 3 months of open globe injury; of these, 23 were at University of Chicago, 12 were at Temple University, and four were at University Hospitals Cleveland. Nineteen eyes were removed primarily: 15 (79%) by evisceration and four (21%) by enucleation (Table 1); three in this group did not receive implants due to concern by the neurosurgical team for the implant acting as a nidus for infection when there was a concomitant orbital roof fracture with cerebrospinal fluid leak. The implant used in 13/16 cases was a 19 mm silicone sphere. There were two cases with an 18 mm silicone sphere, one with a 19 mm SuPor sphere, and one with a 20 mm MedPor sphere. The median number of days to eye removal was 6.0 (range 0–91). The median number of days of follow up was 68.0 (range 10–1346). One patient had a postoperative complication: socket contracture causing inability to wear a prosthesis, although this patient opted not to have surgery to address this. No secondary socket or implant surgeries were performed. The three patients who did not have an implant placed at the time of surgery were still able to wear a conformer or prosthesis, and opted not to have an implant placed secondarily. Figures 1 and 2 present two patients from the primary eye removal group.

Twenty eyes underwent secondary removal within 3 months of open globe repair: 18 (90%) by evisceration and two (10%) by enucleation; all of these patients received a 19 mm silicone sphere implant. The median number of days to eye removal was 19.5 (range 2–83). The median number of days of follow up was 64.5 (range 7–1346). One patient had a postoperative complication: socket contracture causing inability to wear a prosthesis, although this patient also opted not to have surgery to address this. No secondary socket or implant surgeries were performed.

Inter-group comparisons

17/19 (89.5%) in the primary removal group were men compared to 12/20 (60.0%) in the secondary removal group ($p = 0.048$). 28.0 years was the median age in the primary removal group compared to 41.5 in the secondary removal group ($p = 0.052$).

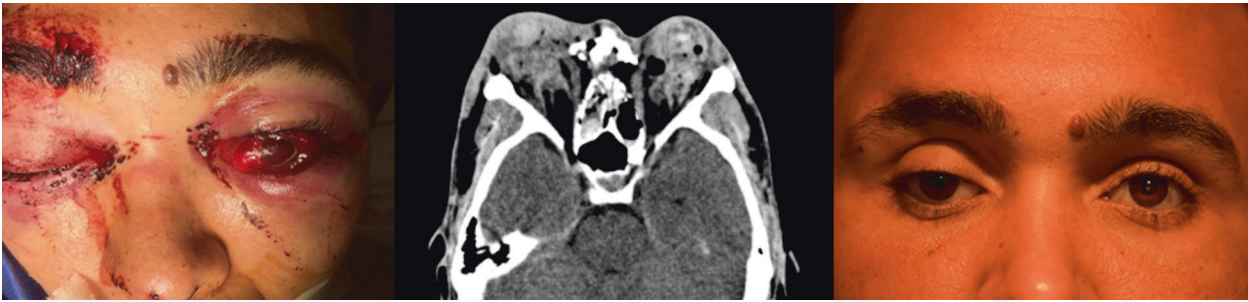


Fig. 1 Bilateral open globe injury from gunshot wound. Left and Center. 29-year-old man with gunshot wound through the temple that traversed both orbits. The right open globe injury was repaired on the day of admission, but the left was unreparable. Right (secondary eye removal group) and left (primary eye removal group) evisceration with 19 mm silicone sphere implant was performed 5 days after admission. **Right.** Two years postoperatively, the patient wears ocular prostheses.

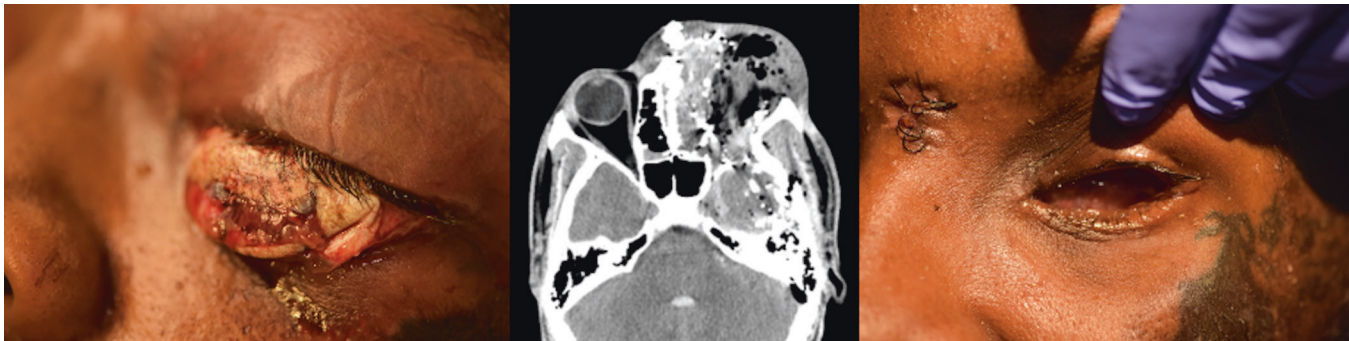


Fig. 2 Open globe injury from gunshot wound. Left and Center. 27-year-old man with gunshot wound to glabella resulting in expulsion of left eye contents. Evisceration with 19 mm silicone sphere implant was performed 4 days after admission. **Right.** One month postoperatively, the patient wears a conformer.

Patients who had primary removal had longer hospital stays than patients who had secondary removal (median 17.0 days vs. 4.0, $p = 0.0002$). 17/20 (85.0%) of patients who had secondary removal were discharged home (as opposed to another facility such as a rehabilitation centre) compared to 9/19 (47.4%) patients in the primary removal group ($p = 0.012$).

16/19 (84.2%) primary eye removals were from gunshot injuries compared to 4/20 (20.0%) secondary removals ($p < 0.0001$). 50% of secondary removals were due to blunt trauma, either by fall or assault, while it was not the mechanism of injury for any patient in the primary removal group (Table 2). 18/19 (94.7%) had facial fractures and 16/19 (84.2%) had intracranial injuries, such as intracranial bleeding, in the primary removal group, compared to 11/20 (55.0%) and 2/20 (10.0%) in the secondary removal group ($p = 0.006$ and $p < 0.0001$), respectively. 5/19 (26.3%) patients in the primary removal group sustained contralateral eye injury, while only 1/20 (5.0%) in the secondary removal group did ($p = 0.056$).

Almost all patients who underwent secondary removal consented for themselves (95.0%), while only 26.3% of patients in the primary eye removal group were able to, and consent was given by a family member or guardian of the patient ($p < 0.0001$). Despite the serious nature of their trauma, no patients in either group expired during the study period. Only two (10.8%) patients in the primary removal group and five (25.0%) patients in the secondary removal group wore prostheses at their most recent office visit; 13 (68.4%) wore conformers in the primary removal group and 10 (50.0%) in the secondary removal group did. The median lengths of follow up for the two groups were not statistically significantly different: 68.0 days for primary removal vs. 64.5 days for secondary removal ($p = 0.58$). No patient had a known occurrence of postoperative infection, implant extrusion, sympathetic ophthalmia or death.

DISCUSSION

Ocular trauma is a significant cause of morbidity and visual impairment [12, 13], and recently there have been calls for increasing research on this topic [14, 15]. A recent analysis of the Nationwide Emergency Department Sample found an overall annual incidence rate of 4.49 open globe injuries per 100,000 in the U.S [2]. There are occasions when an open globe injury is so severe that it is deemed unreparable; in these cases, it is prudent to remove the ocular contents that have extruded into the orbit. Few prior studies have described this group of patients [6, 10], and there is no standard of care as to whether to perform enucleation or evisceration, when to perform eye removal, whether to place an implant, and what outcomes can be expected [16].

In our study, gunshot injury was far more common in the primary eye removal group, and blunt trauma was more common in the secondary eye removal group. Patients in the primary eye removal group tended to be younger and male, although the difference in mean age between the two groups fell just short of statistical significance. Corresponding with gunshot injury as the predominant mechanism of trauma, patients in the primary eye removal group had more grave injuries, as indicated by several measures: they had a significantly longer hospital stay, and significantly more had facial fractures and intracranial injury.

Studies from the war in Iraq noted that gunshots produce particularly damaging effects on the eye relative to other mechanisms of trauma [7]. As Thach et al. note, a ballistic injury can shred the ocular and adnexal tissue in a pattern distinct from blunt trauma, which typically has a single rupture site [8]. In a study of gun trauma at an urban, Level I trauma centre in the U.S., Chopra et al. reported that 44% (8/18) of patients that survived gunshot wounds to the head suffered long-term visual damage, and 87.5% (7/8) of patients required enucleation or evisceration

Table 2. Mechanism of injury and associated morbidity by eye removal type ($n = 39$).

Variable	Primary ($n = 19$)	Secondary ($n = 20$)	<i>p</i> -value
Mechanism, <i>N</i> (%)			
BB gun	0 (0.0%)	1 (5.0%)	
Firework injury	0 (0.0%)	1 (5.0%)	
Gunshot wound	16 (84.2%)	4 (20.0%)	
Knife	1 (5.3%)	0 (0.0%)	
Auto	1 (5.3%)	1 (5.0%)	
Blast injury to face	1 (5.3%)	0 (0.0%)	
Blunt trauma/ assault	0 (0.0%)	7 (35.0%)	
Fall	0 (0.0%)	3 (15.0%)	
Paintball	0 (0.0%)	3 (15.0%)	
Mechanism Gunshot wound, <i>N</i> (%)			<0.0001
Gunshot wound	16 (84.2%)	4 (20.0%)	
Other	3 (15.8%)	16 (80.0%)	
Facial fractures, <i>N</i> (%)			0.006
N	1 (5.3%)	9 (45.0%)	
Y	18 (94.7%)	11 (55.0%)	
Intracranial injury, <i>N</i> (%)			<0.0001
N	3 (15.8%)	18 (90.0%)	
Y	16 (84.2%)	2 (10.0%)	
Consent self, <i>N</i> (%)			<0.0001
Other	14 (73.7%)	1 (5.0%)	
Self	5 (26.3%)	19 (95.0%)	
Days admitted			0.0002
Median (range)	17.0 (6.0, 42.0)	4.0 (1.0, 46.0)	
Discharged Home, <i>N</i> (%)			0.012
Home	9 (47.4%)	17 (85.0%)	
Other	10 (52.6%)	3 (15.0%)	

[17]. Terminal ballistics, which is the study of projectile behaviour in living tissue, has found that some civilian bullets can inflict even greater local tissue damage than military bullets [18]. As a bullet enters the body, it tears, compresses and destroys tissue, creating a permanent wound cavity, while shock waves also create a temporary wound cavity. Because adult bone is inelastic, it is prone to fracture from direct or indirect pressure from the bullet. In our series of patients, we observed that the facial fractures from gunshots often resulted in complex, comminuted fragments, compared to fractures from blunt trauma.

The procedure of choice for primary eye removal in our study was evisceration with silicone sphere implant as soon as the patient was medically stable for surgery; this was done in 68.4% of patients. Due to the serious nature of injuries in this group, there was frequently a delay to surgery; the median time to surgery was 6.0 days. We observed that the delay to surgery had the benefit of reducing the amount of conjunctival chemosis and soft tissue oedema, which was treated in the acute period with a suture tarsorrhaphy or pressure patch placed at the bedside. Even with this delay to surgery, most patients (73.7%), in this group were unable to consent themselves to surgery, which speaks to the protracted recovery process from their injuries. While it may be reasonable to delay eye removal surgery until a patient can consent themselves for it, it is not always clear in these cases when the patient will recover mental status, and eye removal

surgery is often just one of multiple reconstructive surgeries that the multi-disciplinary trauma team has planned.

We preferred evisceration to enucleation, which is consistent with a recommendation by Zheng and Wu [6]. Our rationale was that evisceration was less traumatic to the orbit, preserved as much remaining tissue as possible, and was technically easier in the setting of a swollen, acutely inflamed orbit. There were no cases of postoperative infection, implant extrusion or sympathetic ophthalmia. There was one case of socket contracture in each group; our overall success in avoiding long-term complications was similar in each group. Only 10.5% vs. 25.0% of patients in the primary and secondary eye removal group, respectively, wore prostheses at the time of last follow up, which may have been due to some patients being lost to follow up, or inability to get a prosthesis due to socioeconomic factors.

This study is limited by its retrospective nature and by a relatively small sample size and setting, as all three institutions were Level I trauma centres in a major U.S. city. Patients were not randomised into the primary or secondary eye removal groups, therefore, inherent differences in patient selection between the two groups could have biased or confounded the results. We used a consistent approach to primary eye removal, and did not vary this approach to compare outcomes. Further research can be done using alternative strategies, such as delaying primary eye removal surgery for up to two weeks; placing an implant secondarily; placing an implant other than a silicone sphere; and enucleating rather than eviscerating the eye contents.

This study demonstrates two key points about patients who undergo primary eye removal: their distinctive characteristics, including demographics and associated morbidity, and the safe outcomes that can be achieved in primary eye removal with this surgical approach.

Summary

What was known before

- Primary eye removal after open globe injury is sometimes necessary, but the patient characteristics and outcomes have not been extensively studied.

What this study adds

- Patients who underwent primary eye removal were more likely to have gunshot wounds and greater associated morbidity compared to patients who underwent secondary eye removal; surgery was safe, with a low complication and infection rate.

DATA AVAILABILITY

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

REFERENCES

1. McGwin G Jr, Xie A, Owsley C. Rate of eye injury in the United States. *Arch Ophthalmol.* 2005;123:970–6.
2. Mir TA, Canner JK, Zafar S, Srikumaran D, Friedman DS, Woret FA. Characteristics of open globe injuries in the United States from 2006 to 2014. *JAMA Ophthalmol.* 2020;138:268–75.
3. Burstein ES, Lazzaro DR. Traumatic ruptured globe eye injuries in a large urban center. *Clin Ophthalmol.* 2013;7:485–8.
4. Savar A, Andreoli MT, Kloek CE, Andreoli CM. Enucleation for open globe injury. *Am J Ophthalmol.* 2009;147:595–600.e1.

5. 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.
6. Zheng C, Wu AY. Enucleation versus evisceration in ocular trauma: a retrospective review and study of current literature. *Orbit*. 2013;32:356–61.
7. Colyer MH, Chun DW, Bower KS, Dick JS, Weichel ED. Perforating globe injuries during operation Iraqi Freedom. *Ophthalmology*. 2008;115:2087–93.
8. Thach AB, Johnson AJ, Carroll RB, Huchun A, Ainbinder DJ, Stutzman RD, et al. Severe eye injuries in the war in Iraq, 2003–2005. *Ophthalmology*. 2008;115:377–82.
9. 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.
10. Holmes CJ, McLaughlin A, Farooq T, Awad J, Murray A, Scott R. Outcomes of ocular evisceration and enucleation in the British Armed Forces from Iraq and Afghanistan. *Eye (Lond)*. 2019;33:1748–55.
11. Chu DS, Foster CS. Sympathetic ophthalmia. *Int Ophthalmol Clin*. 2002;42:179–85.
12. Kuhn F, Morris R, Witherspoon CD, Mann L. Epidemiology of blinding trauma in the United States Eye Injury Registry. *Ophthalmic Epidemiol*. 2006;13:209–16.
13. Négrel AD, Thylefors B. The global impact of eye injuries. *Ophthalmic Epidemiol*. 1998;5:143–69.
14. Baker-Schena L. Ocular trauma and guns: the need for data. *Eyenet Mag*. 2021;25:31–2.
15. Chen A, McGwin G Jr, Justin GA, Woreta FA. The United States eye injury registry: past and future directions. *Ophthalmology*. 2021;128:647–8.
16. Miller SC, Flitsos MJ, Justin GA, Yonekawa Y, Chen A. International Globe And Adnexal Trauma Epidemiology Study et al. Global current practice patterns for the management of open globe injuries. *Am J Ophthalmol*. 2021;S0002-9394:00407–4.
17. Chopra N, Gervasio KA, Kalosza B, Wu AY. Gun trauma and ophthalmic outcomes. *Eye (Lond)*. 2018;32:687–92.
18. Erickson BP, Feng PW, Ko MJ, Modi YS, Johnson TE. Gun-related eye injuries: A primer. *Surv Ophthalmol*. 2020;65:67–78.

ACKNOWLEDGEMENTS

Accepted for oral presentation at the 52nd Annual Fall Scientific Symposium of the American Society of Ophthalmic Plastic and Reconstructive Surgeons, November 11–12, 2021.

AUTHOR CONTRIBUTIONS

MK, MAP and HS: conceptualisation, methodology, writing, supervision. EJ, LG and ZS: data collection, writing. DY and XL: data analysis. MK, MAP and HS had full access to the data at their respective institutions, and take responsibility for the integrity of the data.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

Correspondence and requests for materials should be addressed to Mark Krakauer.

Reprints and permission information is available at <http://www.nature.com/reprints>

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.