www.surgicalneurologyint.com

Surgical Neurology International

Editor-in-Chief: Nancy E. Epstein, MD, Professor of Clinical Neurosurgery, School of Medicine, State U. of NY at Stony Brook.

SNI: Trauma

Editor
Naveed Ashraf, M.S., M.B.B.S.
University of Health Sciences; Lahore, Pakistan

ScientificScholar® Knowledge is power
Publisher of Scientific Journals

SNI® Open Access

Review Article

Penetrating orbital trauma: Comprehensive review and meta-analysis of bullet injuries

Injam Ibrahim Sulaiman[1], Ahmed Shakir Ali Al-Wassiti[2], Mohammed Bani Saad[3], Mohammed Tareq Mutar[2], Rokaya H. Abdalridha[4], Sajjad G. Al-Badri[2], Toka Elboraay[5], Mustafa Ismail[6]

[1]Department of Surgery, Hawler Medical University, College of Medicine, Erbil, [2]Department of Surgery, University of Baghdad, College of Medicine, [3]Department of Surgery, Iraqi Medical Association, Baghdad, [4]Department of Surgery, Babylon University, College of Medicine, Babylon, Iraq, [5]Faculty of Medicine, Zagazig University, Sharqia Governorate, Egypt, [6]Department of Surgery, Baghdad Teaching Hospital, Baghdad, Iraq.

E-mail: *Injam Ibrahim Sulaiman - anjam.rowandizy@hmu.edu.krd; Ahmed Shakir Ali Al-Wassiti - ahmed.alwassiti@comed.uobaghdad.edu.iq; Mohammed Bani Saad - mohammedbanisaad@gmail.com; Mohammed Tareq Mutar - mohammed.tareq1600c@comed.uobaghdad.edu.iq; Rokaya H. Abdalridha - rokayahassan101@gmail.com; Sajjad G. Al-Badri - Sajjad.ghanim57@gmail.com; Toka Elboraay - Tokaelboraay20@gmail.com; Mustafa Ismail - mustafalorance2233@gmail.com

***Corresponding author:**
Injam Ibrahim Sulaiman, Department of Surgery, Hawler Medical University, College of Medicine, Erbil, Iraq.

anjam.rowandizy@hmu.edu.krd

Received: 30 July 2024
Accepted: 31 October 2024
Published: 20 December 2024

DOI
10.25259/SNI_632_2024

Quick Response Code:

ABSTRACT

Background: Orbital bullet injuries resulting from high-velocity trauma pose significant clinical challenges due to the potential for severe ocular and systemic complications. This meta-analysis consolidates the existing body of knowledge on direct orbital bullet injuries with respect to clinical outcomes, management strategies, and long-term effects.

Methods: The literature search was conducted by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses, using databases such as PubMed and Scopus. Seventeen articles were reviewed, out of which six studies met the inclusion criteria. Extracted data included details on study design, sample size, patient demographics, projectile type, clinical presentation, imaging modalities used in establishing the diagnosis, surgical interventions performed, duration of follow-up, and the outcomes achieved. Data synthesis was done using fixed and random effects models; heterogeneity testing was assessed using the I^2 statistic.

Results: A total of 688 patients with orbital bullet injuries were analyzed. The average age years ranged from 7 to 58, with a predilection for the male gender, about 70%. These injuries caused marked visual impairment, which included optic nerve injuries, legal blindness, cornea injuries, hyphema, orbital fractures, vitreous hemorrhage, lid lacerations, cataracts, and retinal injuries. Optic nerve injuries exhibited substantial variability ($I^2 = 100\%$, $H^2 = 1.254 \times 10^8$). Legal blindness was common ($I^2 = 100\%$, $H^2 = 1.628 \times 10^7$), with high rates reported in conflict zones. Corneal injuries and hyphema were also prevalent, with significant heterogeneity observed ($I^2 = 100\%$, $H^2 = 8.183 \times 10^6$ for corneal injuries and $I^2 = 99.861\%$, $H^2 = 721.638$ for hyphema). Only orbital fractures, vitreous hemorrhage, lid lacerations, cataracts, and retinal injuries showed very high heterogeneity with varying clinical presentation. Early surgical intervention and advanced imaging techniques played a very vital role in the management of these injuries and those which improved the prognosis of outcome.

Conclusion: Orbital bullet injuries remain a great clinical challenge and are very variable in nature. This huge variability of injury patterns and outcomes enjoins that treatment must be individualized, with very early intervention, evolved imaging modalities, and thorough surgical management for the best possible improvement in the patient's outcomes and prevention of long-term sequelae. Further studies should be done to come up with unified guidelines regarding the evaluation and treatment of such complex injuries.

Keywords: Bullet injury, Meta-analysis, Ocular trauma, Orbital trauma, Surgical management, Visual outcomes

This is an open-access article distributed under the terms of the Creative Commons Attribution-Non Commercial-Share Alike 4.0 License, which allows others to remix, transform, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.
©2024 Published by Scientific Scholar on behalf of Surgical Neurology International

INTRODUCTION

Orbital bullet injuries are a type of high-velocity trauma that creates the most challenging clinical situations because it is associated with a very poor prognosis in ocular and systemic complications. In an overall sense, such injuries would depend on factors such as projectile velocity, entry point, and relation to vital orbital structures. For example, Pacio *et al.*[18] reported a toy gun injury that led to monocular blindness in a 9 year old child. Similarly, marking cartridge from military training incidents led to complete vision loss in some cases and accounted for the need to some cosmetic interventions.[6]

Nonlethal missiles, rubber, and plastic bullets utilized during riot control also considerably cause orbital trauma. According to some studies, these projectiles range from lid lacerations to globe ruptures and, even further on, orbital fractures in conflict zones.[16] The high incidence of serious injuries necessitates a re-evaluation of their use in civilian settings. In Switzerland, plastic bullet shotguns have caused severe ocular damage, including traumatic cataracts and retinal detachment.[20]

Management of these injuries often requires prompt surgical intervention, especially in cases involving intraorbital foreign bodies. The decision to remove or observe these foreign bodies depends on their size, location, and associated risks.[5] Despite advances in surgical techniques, the prognosis for severe orbital bullet injuries remains guarded, emphasizing the need for early intervention and comprehensive management.

We aim to consolidate existing knowledge on direct orbital bullet injuries, evaluating clinical outcomes, management strategies, and long-term effects. By synthesizing data from various studies, we aim to provide a clearer understanding of best practices and areas for further research in managing these complex injuries.

METHODS

Literature search

A comprehensive literature search was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines[17] using databases such as PubMed and Scopus to identify studies on orbital bullet injuries using the combination of the Boolean operators “OR” and “AND” and search keywords: “bullet injuries,” “ocular trauma,” “intraorbital,” and “orbit.” Reference lists of the identified 179 articles, articles were uploaded to Rayyan, and duplicates were deleted. The articles were then screened and the included articles number was reduced to 17. The selection process is summarized in Figure 1.

Inclusion and exclusion criteria

Inclusion and exclusion criteria were established to select the relevant studies. Studies were included if they reported cases of direct orbital bullet injuries, provided detailed clinical outcomes, management strategies, and long-term follow-up, included human subjects, and were published in peer-reviewed journals. Conversely, studies were excluded if they involved deceased and nonhuman subjects, lacked detailed clinical data or outcomes, or were review articles, commentaries, or editorials without original data.

Data extraction

Data extraction was conducted independently by two reviewers using a standardized form. The extracted information encompassed study design, sample size, patient demographics (including age and sex), type of projectile and its velocity, clinical presentation, imaging modalities used, surgical interventions and management strategies, follow-up duration, and outcomes, as well as complications and long-term consequences.

Quality assessment and bias assessment

The quality of the included studies was assessed using the Oxford Centre For Evidence-Based Medicine guidelines.[12] Discrepancies in quality assessment were resolved through discussion. The risk of bias was assessed by two authors using the Joanna Briggs Institute checklists for case reports and case series.[14] The bias assessment of the included studies came low. Supplementary File 1 demonstrates the assessment of the risk of bias.

Data synthesis and statistical analysis

Data were synthesized narratively and quantitatively. A meta-analysis was performed using fixed and random effects models to pool outcomes across studies. Heterogeneity was assessed using the I^2 statistic. Subgroup analyses were conducted based on the type of projectile and surgical intervention.

RESULTS

We included 6 articles in this meta-analysis out of 17. The analyses included assessing the prevalence and severity of optic nerve injuries, legal blindness, corneal injuries, hyphema, orbital fractures, vitreous hemorrhage, lid lacerations, cataracts, and retinal injuries. The results are illustrated in Table 1.[1-11,13,15,16,18-20]

Demographics and clinical presentation

The additional data incorporated from the second file included a total of 693 patients. The average age varied across studies, with specific age ranges from 7 to 58 years. The gender distribution showed a predominance of male patients (85.425%), reflecting a higher incidence of orbital bullet injuries in males. The types of projectiles causing injuries

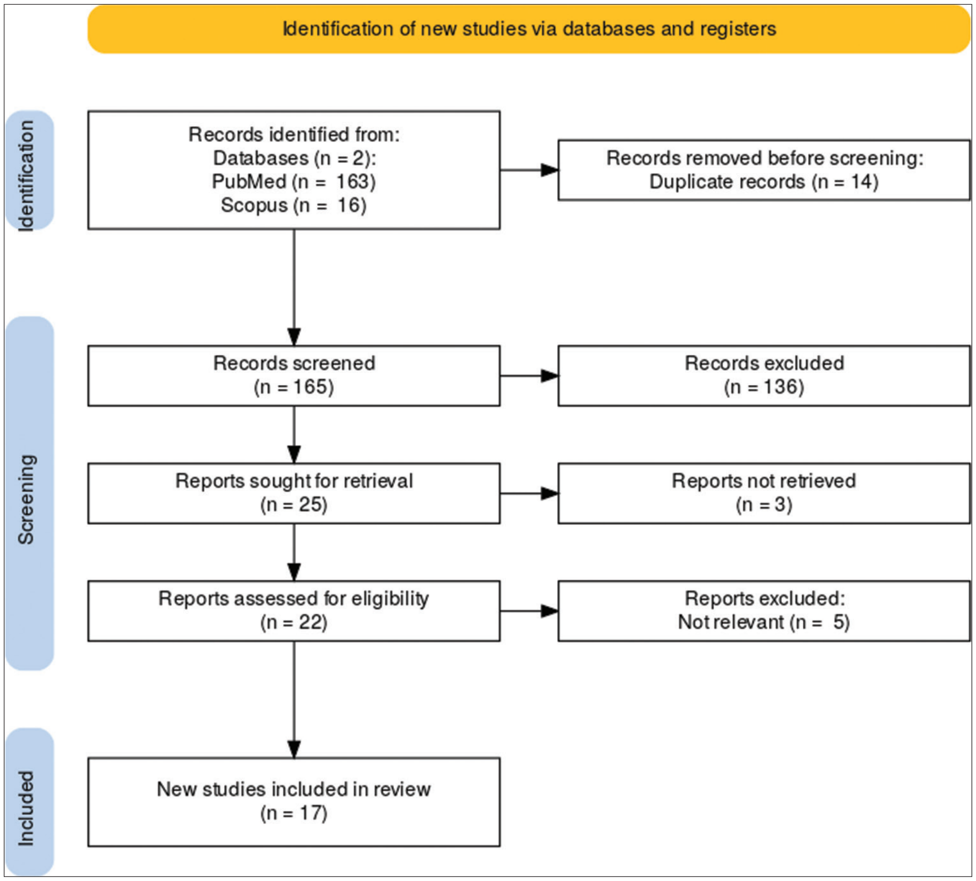

Figure 1: PRISMA flow diagram for the included articles.

included lead alloy pistol bullets, rubber bullets, plastic bullets, airsoft gun pellets, and metallic shrapnel fragments. These details are well illustrated in Table 2.

Clinical presentations

The clinical presentation of injuries included a range of ocular and orbital complications. The most common injuries were hyphema, vitreous hemorrhage, orbital fractures, and optic nerve injuries. For example, Bullock *et al.*[1] reported frequent hyphema, vitreous hemorrhage, and orbital fractures, while Lavy and Abu Asleh[16] found high incidences of lid lacerations, ruptured globes, and retinal damage. Each clinical presentation, along with its statistical data, is listed next, and these statistical data and percentages are illustrated in Tables 3 and 4. The relevant forest plots are illustrated in Figure 2. Figure 3 illustrates how bullets can damage the orbit.

Optic nerve injuries

The meta-analysis of optic nerve injuries included data from multiple studies. The omnibus test of model coefficients was not statistically significant ($Q = 3.397$, $df = 1$, $P = 0.065$), indicating no significant overall effect. However, the residual heterogeneity was significant (Q = 1.79 × 10^7, $df = 3$, $P < 0.001$), suggesting substantial variability among the included studies. The estimate for the intercept was 7.110 with a standard error of 3.858 ($z = 1.843$, $P = 0.065$). The I^2 value was 100%, indicating high heterogeneity, and the H^2 value was 1.254×10^8. The forest plot for optic nerve injuries showed wide confidence intervals for most studies, highlighting the variability in reported outcomes, particularly in studies by Bullock *et al.*,[1] Detorakis *et al.*,[5] and Jaouni and O'Shea.[13]

Legal blindness

The meta-analysis for legal blindness demonstrated a significant omnibus test of model coefficients ($Q = 7.167$, $df = 1$, $P = 0.007$). The residual heterogeneity was also significant ($Q = 1.421 \times 10^8$, $df = 3$, $P < 0.001$), reflecting high variability. The estimate for the intercept was 17.513 with a standard error of 6.542 ($z = 2.677$, $P = 0.007$). The I^2 value was 100%, indicating complete heterogeneity and the H^2 value was 1.628×10^7. The forest plot for legal blindness

Table 1: Comprehensive overview of direct orbital bullet injuries.

*Study Reference (Author, Year)	Sample size	Study design	Side of injury	Pupils	Surgical intervention	Clinical presentation	Imaging modality used	Finding on imaging	Initial management	Type of surgery	Complication and long term consequences	Visual outcome
Detorakis 1990[5]	1	Case report	Left	Relative affer- ent pupillary defect (RapD) grade 2	-	-	CT	Metallic object along the orbital floor.	-	-	-	Vitreal hemorrhage.
Bullock 1997[1]	17	A Clinical, epidemiologic, and experimental study	-	An afferent pupillary defect	-	Hyphema, vitreous hemorrhage, orbital fractures, optic atrophy, corneal edema, iridodialyses, orbital fractures	CT	Fracture of left orbital floor.	-	-	-	Legal blindness
Howick J, 1997[12]	567 Intifada eye injuries	Prospective study	Bilateral	-	-	-	-	-	-	Enucleated and open sinus surgery undertaken to remove the projectille.	-	143 (25.2%) lost perception of light and 72 (12.6%) had vision less than or equal to 6/60. Eighty-six eyes (15.1%) required enucleation. In total 43.1% of the series had severe ocular injuries.
Endo 2001[7]	1	Case report	Right	-	-	-	Ultrasound biomicroscopy (UBM)	-	-	-	-	Corneal abrasion and edema, hyphema, and commotio retinae
Pacio 2002[18]	1	Case report	-	-	-	-	-	-	-	-	-	-
Lavy 2003[16]	42	Case series	-	-	Primary surgeries and secondary surgeries.	54% had lacerations, 40% hyphaema, 38% ruptured globe, 33% orbital fracture, 26% retinal damage, and 21% retained rubber bullet	-	-	-	Primary surgeries include evisceration with orbital implant, bullet removal, and laceration repair (12 cases), laceration repair only (7 cases), globe repair only (4 cases), and foreign body removal (1 case). Secondary surgeries include orbit reconstruction (4 cases), craniotomy (2 cases), revision of orbital implant (1 case), retinal detachment repair (1 case), and tarsorrhaphy (1 case).	--	23 had lid or skin lacerations, 17 hyphaema, 16 ruptured globe, 14 orbital fracture, 11 retinal damage, 9 retained rubber bullet, 8 Vitreous haemorrhage 2 Iridodialysis , 1 Optic nerve transection
Sutter 2004[20]	5	Case series	-	-	2 patients	-	-	-	-	Six surgical interventions in one patient, and Retinal laser coagulation in one.	-	Traumatic cataract (1), iris sphincter rupture (2), traumatic glaucoma (1), corneal erosion (1), vitreous hemorrhage (2), iridodialysis (1), cyclodialysis (1), hyphema (1), ocular hypotony (1), optic disc edema and macular scar (1), angle recession (1), retinal edema (1), retinal hemorrhage (1), peripheral retinal tears (1), anterior chamber cells and flare (1).
Gonul 2005[9]	35	Retrospective study	30 Unilateral, 5 Bilateral	-	All(35)	-	Plain radiography and computed tomography (CT), magnetic resonance imaging (MRI) study	-	-	Craniotomy for brain debris and in cases of penetrating injuries separating the sinus from the intradural space by a frontal craniotomy.	CSF leak, cranial-sinus communication in 2 patients and acute posttraumatic epilepsy in 2 patients.	Proptosis 14 Pulsating exophthalmos 5. Motility disturbance 18 Corneal abrasion 28 Lid laceration 12 Rhinorrhea 2 Commotio retinae 19 Lid edema18 Lens disruption 8 Vitreous hemorrhage 26 Endophthalmitis 2 Retinal detachment 12
Feichtinger 2007[8]	1	Case report	Left	-	-	-	CT	Several pellets spread; no critical damage.	Mild restriction in abduction and adduction.	A high-resolution endoscope originally designed for endo-scopic sinus surgery.	No complications	-
Deyle 2011[4]	1	Case report	Left	Left pupil sluggish reaction.	-	Severe hemorrhage, ptosis, pain on movement, optic neuropathy, Orbital fracture, foreign body dislodgement Infections, orbital/ cerebral abscess.	CT	-	-	-	Infections and orbital or cerebral abscess	-
Clarós 2016[3]	1	Case report	Left	Left pupil reactive mydriasis; normal consensual reflex.	-	-	-	-	Conservative.	-	Chorioretinitis sclopetaria	-
Henry 2018[10]	1	Case report	Left	-	-	-	-	-	-	-	Retinal dialysis	New floaters, no flashes, vision stable.
Riyadh 2018[19]	16	3-year interventional study	Two patients injured bilaterally (12.5%), four on the left (25%), and ten on the right (62.5%).	-	For cases without soft tissue or orbital rim loss, the treatment involved aggressive debridement, reduction, rigid fixation and reconstruction. For cases with soft tissue or orbital rim loss involved aggressive debridement, daily irrigation with normal saline, and packing the defect with iodoform gauze until clean then reduction, rigid fixation and reconstruction.	-	Computerized tomography (CT)	Decreased visual acuity	Immediately evacuated from the frontlines to our emergency unit after advanced trauma life support (ATLS)	-	Infection 1 (5.6%) Wound dehiscence 1 (5.6%) Enophthalmos 2 (11.1%) Flap failure 1 (5.6%) Graft failure 0 Nerve sensibility disturbances 5 (27.8%), Vision (unfavorable outcome) 13 (72.2%) Complicated scar 0, Oronasal fistula 1 (5.6%), Mortality 2 (12.5% of 16 patients)	Enophthalmos 2 (11.1%), Nerve sensibility disturbances 5 (27.8%), Vision (unfavorable outcome) 13 (72.2%)
Cho 2019[2]	1	Case report	Right	-	-	-	-	-	-	-	-	-
Kim 2021[15]	1	Case report	Left	Reactive to light	-	Reduced vision in left eye: photophobia, floaters, photopsia. Right eye: normal. Left eye vision: 20/50.	CT	Fractures in left orbit: inferior and medial walls. Hemorrhage in left maxillary sinus. No open globe signs.	-	-	-	Reduced vision in left eye: photophobia, floaters, photopsia. Right eye: normal. Left eye vision: 20/50 with near card. IOP: 14 mmHg (Tono-Pen). Pupil: round, reactive to light. Direct photophobia present, no consensual photophobia. Inferior gaze restriction on left side.
Donegan 2022[6]	1	Case report	Right globe	Relative afferent pupillary defect	-	-	CT	Plastic dome and metal sabot visible transversely in deflated right globe.	Enucleation and open sinus surgery performed to remove projectile.	-	Pruritis	-
Hou YT 2022[11]	1	Case report	Left	Pupil: 6 mm, nonresponsive to light, positive reverse relative afferent pupillary defect.	Endoscopic transnasal removal assisted by surgical navigation system.	-	CT	Bullet in left orbit.	-	-	Traumatic optic neuropathy.	Superomedial left upper eyelid: ecchymosis, complete ptosis, hemorrhagic chemosis, and left exotropia in primary gaze.

Table 2: Infographic data.

Category	Details
Case reports	11
Case series	6
Total number of cases studied	688
Sex	
Males	588 (85.425%)
Females	100 (14.575%)
Age	
Mean	23.46 years
Range	7-58 years
Mentioned geographical distribution	USA: 5 studies, 21 cases Switzerland: 2 studies, 6 cases Greece: 1 study 1, case Gaza: 1 study, 567 cases Japan: 1 study, 1 case Israel: 1 study, 42 cases Turkey: 1 study, 35 cases Austria: 1 study, 1 case Cameroon: 1 study, 1 case Iraq: 1 study, 16 cases Taiwan: 1 study, 1 case
Bullet types	Studies involve various types of bullets including lead alloy pistol bullets, rifle bullets, rubber bullets, airsoft gun bullets, metal shrapnel fragments, and nerf foam bullets.

indicated that while some studies reported high rates of blindness, others showed lower incidences, contributing to the overall heterogeneity, particularly in studies by Bullock *et al.*,[1] Jaouni and O'Shea,[13] and Lavy and Abu Asleh.[16]

Corneal injuries

For corneal injuries, the omnibus test of model coefficients was highly significant (Q = 7.175 × 10^6, df = 1, $P < 0.001$). The test of residual heterogeneity also showed significant results (Q = 8.183 × 10^6, df = 2, $P < 0.001$). The estimate for the intercept was 17.504 with a standard error of 0.007 (z = 2678.651, $P < 0.001$), indicating a strong effect size. The I^2 value was 100%, showing high heterogeneity, and the H^2 value was 8.183 × 10^6. The forest plot for corneal injuries illustrated that nearly all studies reported significant injury rates, although with varying effect sizes, including studies by Endo *et al.*,[7] Sutter,[20] and Feichtinger *et al.*[8]

Hyphema

The hyphema meta-analysis revealed a significant omnibus test of model coefficients (Q = 13595.339, df = 1, $P < 0.001$) and significant residual heterogeneity (Q = 721.638, df = 1, $P < 0.001$). The intercept estimate was 40.826 with a standard error of 0.350 (z = 116.599, $P < 0.001$). The I^2 value of 99.861% indicated substantial heterogeneity, and the H^2 value was 721.638. The forest plot showed consistently high rates of hyphema across studies, with relatively narrow confidence intervals, particularly in studies by Bullock *et al.*,[1] Lavy and Abu Asleh,[16] and Sutter.[20]

Orbital fractures

The analysis of orbital fractures indicated a significant omnibus test of model coefficients (Q = 493.655, df = 1, $P < 0.001$) with significant residual heterogeneity (Q = 186492.005, df = 2, $P < 0.001$). The intercept estimate was 36.167 with a standard error of 1.628 (z = 22.218, $P < 0.001$). The I^2 value of 99.998% showed high heterogeneity, and the H^2 value was 46445.653. The forest plot for orbital fractures highlighted the varying severity and frequency of fractures reported in different studies, including those by Bullock *et al.*,[1] Detorakis *et al.*,[5] Lavy and Abu Asleh,[16] and Sutter.[20]

Vitreous hemorrhage

The vitreous hemorrhage analysis showed a significant omnibus test of model coefficients (Q = 14.124, df = 1, $P < 0.001$) and significant residual heterogeneity (Q = 6.600 × 10^6, df = 3, $P < 0.001$). The intercept estimate was 44.216 with a standard error of 11.765 (z = 3.758, $P < 0.001$). The I^2 value was 100%, indicating high heterogeneity, and the H^2 value was 2.481 × 10^6. The forest plot depicted wide confidence intervals for vitreous hemorrhage rates, suggesting varied reporting among studies, including those by Bullock *et al.*[1] Detorakis *et al.*,[5] and Jaouni and O'Shea.[13]

Lid lacerations

For lid lacerations, the omnibus test of model coefficients was highly significant (Q = 2.301 × 10^7, df = 1, $P < 0.001$), and the test of residual heterogeneity also showed significant results (Q = 9.766 × 10^6, df = 2, $P < 0.001$). The intercept estimate was 24.878 with a standard error of 0.005 (z = 4797.296, $P < 0.001$). The I^2 value was 100%, showing high heterogeneity, and the H^2 value was 9.766 × 10^6. The forest plot for lid lacerations showed consistent findings across studies, with high effect sizes reported, including those by Lavy and Abu Asleh,[16] Sutter,[20] and Riyadh *et al.*[19]

Cataracts

The cataract meta-analysis demonstrated a significant omnibus test of model coefficients (Q = 233.659, df = 1, $P < 0.001$) with significant residual heterogeneity (Q = 4772.779, df = 1, $P < 0.001$). The intercept estimate was 21.400 with a standard error of 1.400 (z = 15.286, $P < 0.001$). The I^2 value was 99.979%, indicating substantial heterogeneity, and the H^2 value was 4772.779. The forest plot indicated variable

Table 3: Statistical information related to each clinical presentation of direct orbital injuries.

Injury Type	Q	df	p (Omnibus)	Coefficients (Intercept)	Standard error	z	p (Intercept)	Residual heterogeneity estimates (τ^2)	Residual heterogeneity estimates (τ)	Residual heterogeneity estimates (I^2 %)	Residual heterogeneity estimates (H^2)
Optic nerve	3.397	1	0.065	7.11	3.858	1.843	0.065	59.523	7.715	100.0	$1.254\times10^{+8}$
Legal blindness	7.167	1	0.007	17.513	6.542	2.677	0.007	171.178	13.084	100.0	$1.628\times10^{+7}$
Corneal injury	7175000.0	1	< 0.001	17.504	0.007	2678.651	< 0.001	0.245	0.495	99.861	721.638
Hyphema	13595.339	1	< 0.001	40.826	0.35	116.599	< 0.001	7.949	2.819	99.998	46445.653
Orbital fracture	493.655	1	< 0.001	36.167	1.628	22.218	< 0.001	7.949	2.819	99.998	46445.653
Vitreous hemorrhage	14.124	1	< 0.001	44.216	11.765	3.758	< 0.001	553.676	23.53	100.0	$2.481\times10^{+6}$
Lid laceration	$2.301\times10^{+7}$	1	< 0.001	24.878	0.005	4797.296	< 0.001	0.245	0.495	99.861	721.638
Cataract	233.659	1	< 0.001	21.4	1.4	15.286	< 0.001	3.919	1.98	99.979	4772.779
Retinal injury	$2.337\times10^{+7}$	1	< 0.001	22.013	0.005	4834.295	< 0.001	3.919	1.98	99.979	4772.779

Q is a statistical value for testing the heterogeneity. df: Degree of freedom

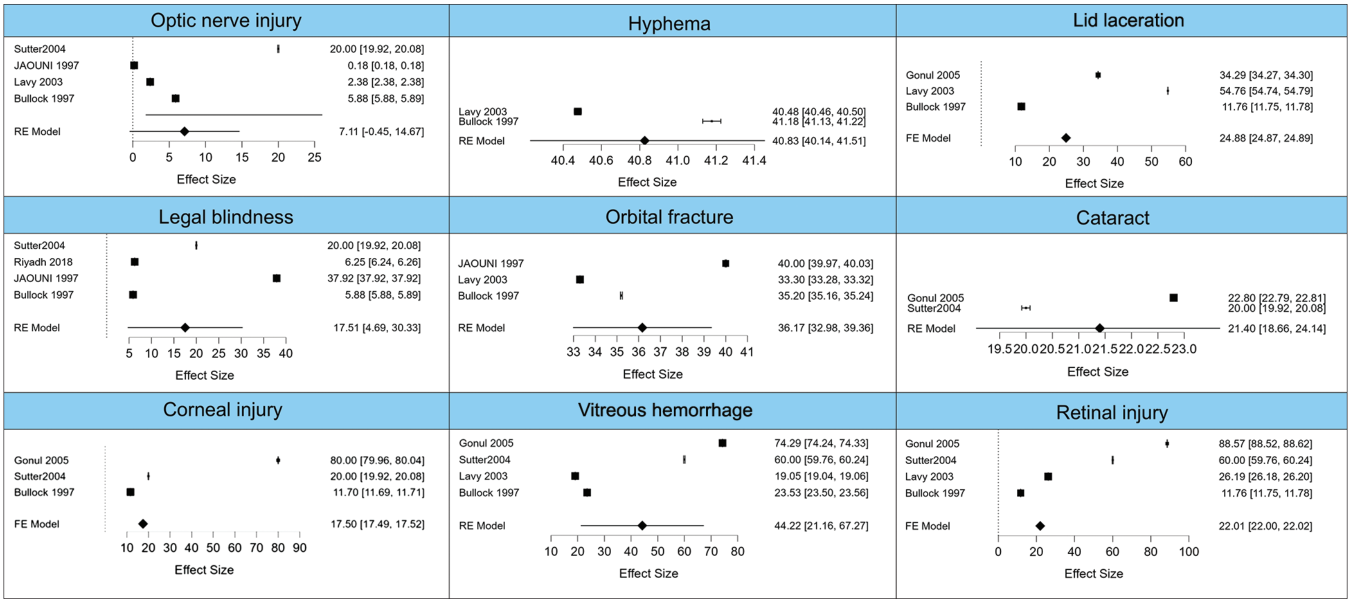

Figure 2: Forest plots for the clinical presentations of direct orbital injuries.

Figure 3: Illustration of bullet injuries to the orbit.

Table 4: An overview of each clinical presentation.

Clinical Presentation	Percentage (%) *	Number of Cases
Vitreous Hemorrhage	5.34	37
Orbital Fracture	4.62	32
Corneal Abrasion	4.18	29
Retinal Detachment	3.32	23
Hyphema	2.60	18
Visual Impairment	1.88	13
Retained Bullet	1.30	9
Pupillary Defect	0.43	3
Optic Neuropathy	0.14	1
Infections	0.14	1
Traumatic Glaucoma	0.14	1
Other Conditions	6.20	43

*The total sum of the percentages for clinical presentations is less than 100% because not all studies report every possible condition. Some conditions might be underreported or not present in certain studies.

Table 5: Joanna Briggs Institute Checklist for case reports assessment.

Joanna Briggs Institute Checklist for case reports – Criteria

1. Were patient's demographic characteristics clearly described?
2. Was the patient's history clearly described and presented as a timeline?
3. Was the current clinical condition of the patient on presentation clearly described?
4. Were diagnostic tests or assessment methods and the results clearly described?
5. Was the intervention (s) or treatment procedure (s) clearly described?
6. Was the postintervention clinical condition clearly described?
7. Were adverse events (harms) or unanticipated events identified and described?
8. Does the case report provide takeaway lessons?

Responses Options: Yes, No, Unclear, Not Applicable (NA)

Quality Rating: Poor 0 – 2; Fair 3 – 5; Good 6 – 8

but generally high rates of cataracts reported in the studies, including those by Sutter[20] and Bullock *et al.*[1]

Retinal injuries

The analysis for retinal injuries showed a highly significant omnibus test of model coefficients (Q = 2.337 × 10^7, df = 1, P < 0.001) and significant residual heterogeneity (Q = 9.660 × 10^6, df = 3, P < 0.001). The intercept estimate was 22.013 with a standard error of 0.005 (z = 4834.295, P < 0.001). The I^2 value was 100%, showing high heterogeneity, and the H^2 value was 9.660 × 10^6. The forest plot for retinal injuries demonstrated wide confidence intervals and varied effect sizes across studies, including those by Bullock *et al*.,[1] Lavy and Abu Asleh,[16] and Sutter.[20]

Visual acuity and clinical outcomes

Visual acuity outcomes varied significantly among the patients. For instance, Bullock *et al*. reported[1] that the average visual acuity was 20/30, whereas, in Lavy and Abu Asleh's study,[16] some visual acuities were as good as 6/6 and as poor as no perception of light. In more serious injuries, the cases of Jaouni and O'Shea[13] and Riyadh *et al.*[19] show that a significant number of patients, 43.1% and 72.2% at respective percentages, suffer profound loss of vision, including legal blindness and complete loss of perception of light.

Imaging modalities

Imaging modalities such as computed tomography (CT) and ultrasound biomicroscopy were in frequent use for ascertaining the extent of the injuries and planning surgical intervention. CT was especially helpful in picking up fractures and foreign bodies within the orbit. For example, orbital floor fractures and foreign bodies were shown in CT imaging by Bullock *et al*. study.[1]

Management strategies and surgical techniques

Most of the management strategies included surgical interventions. Detorakis *et al*.[5] described a case that had metallic foreign bodies along the floor of the orbit and was managed surgically. In severe cases, open sinus surgery with enucleation was required for removing projectiles, just like in the studies by Jaouni and O'Shea[13] and Donegan *et al*.[6]

The surgical interventions varied according to the extent and nature of the injury. The most common surgeries undertaken were evisceration with orbital implant, removal of bullet, and laceration repair, according to Lavy and Abu Asleh.[16] A few secondary surgeries, such as orbital reconstruction and retinal detachment repair were also carried out in those with complicated injuries.

Complications and long-term outcomes

Such complications were common and included infections, wound dehiscence, enophthalmos, and flap failure. Other long-term consequences included serious visual impairment in some patients, with partial or complete recovery achieved by others. For instance, Riyadh *et al.*[19] stumbled upon a report that stated 72.2% of patients have a poor outcome in terms of their vision-less than counting fingers at 1 m.

These results underline that orbital bullet injuries are a formidable clinical challenge with a very wide range of outcomes. Hence, the importance of early intervention, proper surgical management, and state-of-the-art imaging techniques in improving prognosis and reducing long-term morbidity cannot be overemphasized. The variability in injury types and outcomes underlines the individualization of treatment plans and further research into the optimization of management strategies. The overall bias assessment for the study was determined to be good, indicating a low risk of systematic errors that could impact the validity of the findings [Tables 5 and 6].

DISCUSSION

These meta-analysis results underline the comprehensive and diversified effect of orbital bullet injuries. The findings also reflected a significant heterogeneity across different types of injury, reflecting that a huge number of factors, such as projectile type, velocity, and initial medicamentous interventions applied, influence the injuries. Although most of the results ranged from damage to the optic nerve and retinal injuries, high variability in the outcome indicates that treatment should be individualized. Such results underline the fact that orbital bullet injuries can be very complicated and require advanced imaging techniques, surgical interventions, and follow-up care if an improvement in patient outcome is wished to be attained.

Effects of orbital bullet impact on the optic nerve are also highly variable, with significant residual heterogeneity

Table 6: Joanna Briggs Institute Checklist for case series assessment.

Study	1	2	3	4	5	6	7	8	Rating
Detorakis *et al*., 1990	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	7- Good
Endo *et al*., 2001	Yes	Yes	Yes	Yes	No	Yes	No	Yes	6- Good
Pacio, 2002	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8- Good
Feichtinger *et al*., 2007	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8- Good
Deyle *et al*., 2011	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8- Good
Clarós *et al*., 2017	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8- Good
Henry *et al*., 2019	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8- Good
Cho *et al*., 2019	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	7- Good
Kim *et al*., 2021	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8- Good
Donegan *et al*., 2022	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8- Good
Hou *et al*., 2022	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8- Good

(I^2 = 100%, $H^2 = 1.254 \times 10^8$). Such kinds of injury are really related to high-velocity missile injuries that usually result in very serious consequences, including optic neuropathy and blindness. Bullock *et al.*,[1] Detorakis *et al.*,[5] and Jaouni and O'Shea[13] cited severe optic nerve damage due to being shot by high-velocity missiles; our findings validate these results. From looking at the forest plot, one observes what seems like wide confidence intervals, which may arise from variability in the severity of injury and clinical outcomes across studies. This variability could be a result of individual differences in projectile type, entry point, and immediate management of the injury. These are factors suggesting that an individualized approach to treatment may be required to optimize patient outcomes with optic nerve injuries.

Legal blindness, I^2 = 100%, $H^2 = 1.628 \times 10^7$ – the heterogeneity here is very large – implies very severe vision loss due to orbital-bullet-induced causes. Bullock *et al.*,[1] Jaouni and O'Shea,[13] and Lavy and Abu Asleh[16] quote rates of blindness that are remarkably high, particularly in areas of conflict where rubber bullets have been commonly used. This result does indeed suggest a fair amount of heterogeneity regarding the type of projectile or missile, its velocity at the time of impact, and even the quality of medical intervention. For instance, rubber bullets, supposedly nonlethal, are said to yield extensive ocular trauma, leading to blindness. Drawing from this is the imperative of severe restrictions on their use and an increase in protections afforded against such munitions among persons in conflict zones.

Corneal injuries were highly prevalent with significant heterogeneity (I^2 = 100%, $H^2 = 8.183 \times 10^6$). Endo *et al.*,[7] Sutter,[20] Feichtinger *et al.*[8] variously reported abrasions to severe corneal edema and scarring with high heterogeneity basic differences in projectile types and immediate management of injuries, therefore resulting in variable outcomes. Prompt surgical intervention and protective measures are important factors in managing such injuries. For example, Endo *et al.*[7] emphasized the importance of early medical treatment so as to prevent sequelae such as corneal scarring, which can cause irreversible visual loss.

Hyphema was another common injury with high heterogeneity (I^2 = 99.861%, H^2 = 721.638). Bullock *et al.*,[1] Lavy and Abu Asleh,[16] Sutter[20] all show a high hyphema rate. This mirrors the vulnerability of the anterior chamber to blunt trauma. There is significant heterogeneity that calls for early intervention and careful monitoring to avoid serious complications such as glaucoma and permanent loss of vision. Hyphema can lead to increased intraocular pressure, thereby causing more damage in the eye if it is not managed in time. Thus, very early detection and timely intervention are the keys to preventing adverse outcomes.

Orbital fractures indicated significant results (I^2 = 99.998%, H^2 = 46445.653). Bullock *et al.*,[1] Detorakis *et al.*,[5] Lavy and Abu Asleh,[16] and Sutter[20] documented various types of orbital fractures resulting from high-velocity impacts. The forest plot highlighted the diverse clinical presentations, ranging from minor fractures to complex fractures involving the orbital floor and walls. Surgical reconstruction and the use of advanced imaging techniques are critical in managing these injuries and restoring functionality. The variability in fracture patterns suggests that individualized surgical approaches are necessary to address the unique anatomical disruptions caused by different projectiles.

Vitreous hemorrhage showed significant heterogeneity (I^2 = 100%, $H^2 = 2.481 \times 10^6$). The reports by Bullock *et al.*,[1], Detorakis *et al.*,[5], and Jaouni and O'Shea[13] described varying degrees of vitreous hemorrhage with significant visual disablement. Again, variable outcomes resulted from differences in projectile type, impact velocity, and timely medical intervention. A surgical approach to vitreous hemorrhage requires early intervention for the preservation of vision. For instance, it could be performed to evacuate the hemorrhage and prevent retinal detachment where vitrectomy would have to be undertaken, reflecting specialized surgical knowledge in handling such cases.

Lid lacerations were highly prevalent with significant heterogeneity (I^2 = 100%, $H^2 = 9.766 \times 10^6$). Studies by Lavy and Abu Asleh,[16] Sutter,[20] and Riyadh *et al.*[19] demonstrated quite clearly the frequent occurrence of lid lacerations in orbital bullet injuries. More importantly, the large effect sizes across studies point out that these are common injuries often needing meticulous surgical repair to avoid attendant functional and cosmetic complications. Such variability in techniques, including microsurgical methods in management, underlines further the need for specialized training in oculoplastic surgery if optimal outcomes are to be achieved.

The cataract meta-analysis demonstrated substantial heterogeneity (I^2 = 99.979%, H^2 = 4772.779). According to Sutter[20] and Bullock *et al.*,[1], there were high rates of traumatic cataracts, reflecting severe blunt trauma to the lens. This again underlines that significant variation exists and that factors such as the projectile itself and quality of care influence the development and management of traumatic cataracts. Early surgical intervention may usually be necessary with phacoemulsification to restore vision. Furthermore, postoperative care with anti-inflammatory medications is required to prevent secondary complications.

Retinal injuries showed significant results with high heterogeneity (I^2 = 100%, $H^2 = 9.660 \times 10^6$). Bullock *et al.*,[1], Lavy and Abu Asleh [16], and Sutter[20] documented rather a diversity of injuries to the retina, ranging from simple tears of the retina to serious detachment. The variability in outcomes makes notice of early identification and intervention necessary for preventing permanent vision loss. Advanced imaging techniques, such as optical coherence tomography, and timely surgical repair through scleral buckling or vitrectomy are critical to the management of retinal injuries.

The gross heterogeneity seen across all types of injury does not suggest that individual patient factors, projectile characteristics, and medical interventions play no role. The findings underscore the need for comprehensive management that includes prompt surgical intervention, advanced imaging techniques, and long-term follow-up to optimize clinical outcomes. For example, high-resolution CT and magnetic resonance imaging aid in the correct diagnosis and planning of surgical intervention, hence improving prognosis in patients with complex orbital injuries.

The present meta-analysis has several limitations. The included studies were of different designs, and sample size and quality differed considerably, as reflected by the significant heterogeneity. Moreover, differences in outcome reporting – in combination with the diversity of applied imaging and surgical techniques – might have had a conceivable influence on the measured outcomes. Future studies should seek standard reporting and exhaust maximum effort to include larger sample sizes for more robust data. In addition, multicenter studies may help generalize the findings to different populations and healthcare settings.

CONCLUSION

The meta-analysis underscores the orbital bullet injuries heterogeneity and seriousness, hereby needing tailored clinical approaches for case management. Therefore, variable outcomes arise because of differences in effective early interventions, advanced imaging modalities, and surgical interventions, which are comprehensive for optimal recovery of the patient and prevention of long-term complications. Future studies should seek to standardize protocols regarding the assessment and management of orbital bullet injuries so that better patient care and outcomes can be attained.

Ethical approval

Institutional Review Board approval is not required.

Declaration of patient consent

Patient's consent not required as there are no patients in this study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

REFERENCES

1. Bullock JD, Ballal DR, Johnson DA, Bullock RJ. Ocular and orbital trauma from water balloon slingshots. A clinical, epidemiologic, and experimental study. Ophthalmology 1997;104:878-87.
2. Cho SM, Cho D, Read-Fuller A, Vrcek I. Orbitozygomatic approach for bullet retrieval from the temporal fossa. Proc (Bayl Univ Med Cent) 2019;32:435-7.
3. Clarós P, Fokouo JV, Clarós A. Intraorbital foreign body: A rifle bullet removed 20 years after the accident. Eur Ann Otorhinolaryngol Head Neck Dis 2017;134:63-65.
4. Deyle S, Exadaktylos AK, Kneubuehl BP, Buck U, Thali MJ, Voisard MX. Collateral damage--penetrating head injury and orbital injury: A case report. Am J Forensic Med Pathol 2011;32:215-8.
5. Detorakis ET, Symvoulakis EK, Drakonaki E, Halkia E, Tsilimbaris MK. Unexpected finding in ocular surface trauma: A large intraorbital foreign body (bullet). Acta Medica (Hradec Kralove) 2012;55:100-3.
6. Donegan PJ, Niear MA, Law JC, Barahimi B. Military marking round injury to the globe. J Emerg Trauma Shock 2022; 15:108-10.
7. Endo S, Ishida N, Yamaguchi T. Tear in the trabecular meshwork caused by an airsoft gun. Am J Ophthalmol 2001;131:656-7.
8. Feichtinger M, Zemann W, Kärcher H. Removal of a pellet from the left orbital cavity by image-guided endoscopic navigation. Int J Oral Maxillofac Surg 2007;36:358-61.
9. Gönül E, Erdoğan E, Taşar M, Yetişer S, Akay KM, Düz B, *et al*. Penetrating orbitocranial gunshot injuries. Surg Neurol 2005;63:24-30, discussion 31.
10. Henry T, Palakkamanil M, Rubin U, Tennant M. Traumatic retinal dialysis resulting from Nerf foam bullet. Can J Ophthalmol 2019;54:e100-2.
11. Hou YT, Wei YH, Liao CK, Lin CF. Personalized multidisciplinary approach of orbital apex foreign body: A case report and literature review. Taiwan J Ophthalmol 2022; 12:374-7.
12. Howick J, Chalmers I, Glasziou P, Greenhalgh T, Heneghan C, Liberati A, *et al*. Explanation of the 2011 Oxford centre for evidence-based medicine (OCEBM) levels of evidence (Background Document). Oxford Centre for Evidence-Based Medicine; 2011. Available from: https://www.cebm.ox.ac.uk/resources/levels-of-evidence/ocebm-levels-of-evidence [Last acceessed on 2024 Jul 24].
13. Jaouni ZM, O'Shea JG. Surgical management of ophthalmic trauma due to the Palestinian intifada. Eye (Lond) 1997;11 (Pt 3): 392-7.
14. Joanna Briggs Institute. Checklist for case reports; 2020.

Available from: https://jbi.global/critical-appraisal-tools [Last acceessed on 2024 Jul 24]
15. Kim HJ, Ali S, Kelly LD. Ocular foam round injury: A case report and literature review. Am J Ophthalmol Case Rep 2021;23:101149.
16. Lavy T, Asleh SA. Ocular rubber bullet injuries. Eye (Lond) 2003;17:821-4.
17. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al*. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ 2021;372:n71.
18. Pacio J. Monocular blindness caused by a BB embolus: A case report. Pediatrics 2002;110:776-8.
19. Riyadh S, Abdulrazaq SS, Zirjawi AM. Surgical management of the recent orbital war injury. J Craniofac Surg 2018;29:1123-6.
20. Sutter FK. Ocular injuries caused by plastic bullet shotguns in Switzerland. Injury 2004;35:963-7.

How to cite this article: Sulaiman II, Al-Wassiti AS, Bani Saad M, Mutar MT, Abdalridha RH, Al-Badri SG, *et al*. Penetrating orbital trauma: Comprehensive review and meta-analysis of bullet injuries. Surg Neurol Int. 2024;15:465. doi: 10.25259/SNI_632_2024

Disclaimer

The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Journal or its management. The information contained in this article should not be considered to be medical advice; patients should consult their own physicians for advice as to their specific medical needs.