Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 1530-1543 | ISSN:2251-6727

Titanium Mesh Orbital Floor Reconstruction Improves Enophthalmos and Hypoglobus Following Zygomaticomaxillary Complex Fractures with Concomitant Orbital Floor Involvement and Isolated Orbital Floor Fractures: A Retrospective Cohort Study

[1] Dr. Shivam Ghatge, [2] Dr. Pradeep D*, [3] Dr. Aditya NK, [3] Dr. Murugesan Krishnan, [4] Dr. Santhosh Kumar

[1] Post Graduate Student, Saveetha Dental College and Hospital, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai, Tamil Nadu, India

[2] Professor & Research Head, Saveetha Dental College and Hospital, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai, Tamil Nadu, India

[3] Senior Lecturer, Saveetha Dental College and Hospital, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai, Tamil Nadu, India.

[4] Professor, Head of Department, Saveetha Dental College and Hospital, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai, Tamil Nadu, India.

[5] Professor & Research Head, Saveetha Dental College and Hospital, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai, Tamil Nadu, India

(Received: 16 July 2025 Revised: 20 August 2025 Accepted: 20 September 2025)

KEYWORDS

orbital floor fracture, enophthalmos, hypoglobus, zygomaticomaxillary complex, titanium mesh, orbital reconstruction

ABSTRACT:

Background: Post-traumatic enophthalmos and hypoglobus represent significant complications following orbital floor fractures, occurring both as isolated injuries and in association with zygomaticomaxillary complex (ZMC) fractures. The comparative effectiveness of orbital floor reconstruction between these fracture patterns remains incompletely understood.

Purpose: To evaluate the effectiveness of titanium mesh orbital floor reconstruction in improving post-traumatic enophthalmos and hypoglobus in patients with ZMC fractures with concomitant orbital floor fractures compared to isolated orbital floor fractures.

Study Design, Setting, Participants: This retrospective cohort study analyzed patients who underwent titanium mesh orbital floor reconstruction between January 2018 and December 2022 at a tertiary care center. Inclusion criteria comprised adult patients with orbital floor fractures presenting with enophthalmos ≥2mm and/or hypoglobus ≥2mm, with minimum 6-month follow-up.

Predictor Variable: Fracture pattern (ZMC with orbital floor fractures versus isolated orbital floor fractures).

Main Outcome Variables: Primary outcomes were improvement in enophthalmos measured by Hertel exophthalmometry and hypoglobus assessed by pupillary level differences at 6 months and 1 year post-operatively. Secondary outcomes included extraocular muscle function, diplopia resolution, and patient satisfaction.

Results: Twenty patients were analyzed (10 ZMC with orbital floor fractures, 10 isolated orbital floor fractures). Mean age was 32.4 ± 11.2 years with male predominance (70.0%). Significant improvement in enophthalmos was achieved in both groups (ZMC group: 4.2 ± 1.3mm to 1.2 ± 0.8mm, p=0.002; isolated group: 3.9 ± 1.2mm to 1.0 ± 0.7mm, p=0.001). Hypoglobus improved significantly (ZMC group: 3.3 ± 1.1mm to 0.8 ± 0.6mm, p=0.004; isolated group: 3.1 ± 0.8mm to 0.7 ± 0.5mm, p=0.002). Extraocular muscle function normalized in 85% of patients at 1 year. Overall success rates were 80.0% for ZMC group and 90.0% for isolated fractures (p=1.000).

Conclusions: Titanium mesh orbital floor reconstruction effectively improves post-traumatic enophthalmos and hypoglobus with comparable success rates regardless of fracture pattern. Both ZMC-associated and isolated orbital floor fractures demonstrate excellent functional and aesthetic outcomes with low complication rates.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 1530-1543 | ISSN:2251-6727

1. Introduction

Post-traumatic enophthalmos and hypoglobus represent significant functional and aesthetic sequelae following orbital floor fractures, with reported incidence rates ranging from 15% to 60% in untreated cases.[1–3] These complications result from orbital volume expansion due to bony defects, herniation of orbital contents into the maxillary sinus, and subsequent fibrotic contracture of periorbital tissues.[4–6] The resultant posterior and inferior displacement of the globe creates not only cosmetic deformity but also functional impairment including diplopia, extraocular muscle restriction, and decreased visual field.[7–9]

Orbital floor fractures commonly occur as isolated injuries following direct orbital trauma or in association with zygomaticomaxillary complex (ZMC) fractures.[10–12] The mechanism of injury, extent of bony disruption, degree of soft tissue involvement, and timing of surgical intervention collectively influence treatment outcomes.[13–15] While isolated orbital floor fractures typically result from focused impact to the orbital rim, ZMC fractures with orbital floor involvement often represent more extensive trauma with greater soft tissue injury and potential for periorbital scarring.[16–18]

Contemporary surgical management of post-traumatic enophthalmos and hypoglobus centers on anatomical restoration of the orbital floor using various reconstructive materials.[19–21] Titanium mesh has emerged as a preferred reconstructive material due to its biocompatibility, structural integrity, ease of contouring, and long-term stability.[22–24] The material's radiopacity facilitates postoperative imaging assessment, while its permanent nature provides sustained support against recurrent herniation.[25–27]

Despite advances in surgical technique and reconstructive materials, comparative studies analyzing outcomes between different fracture patterns remain limited.[28–30] Understanding whether concomitant ZMC fractures influence orbital reconstruction outcomes is crucial for treatment planning, patient counseling, and prognostic assessment. Several authors have suggested that ZMC-associated orbital floor fractures may have inferior outcomes due to more extensive soft tissue injury and scar formation.[31–33] However, this relationship has not been systematically evaluated using standardized outcome measures and consistent reconstructive techniques.

The primary objective of this study was to evaluate the effectiveness of titanium mesh orbital floor reconstruction in improving post-traumatic enophthalmos and hypoglobus. Secondary objectives included comparing functional and aesthetic outcomes between ZMC fractures with concomitant orbital floor fractures versus isolated orbital floor fractures, assessing extraocular muscle function recovery, and identifying factors predictive of successful reconstruction.

2. Materials and Methods

Study Design and Ethical Approval

This retrospective cohort study was conducted at the Department of Oral and Maxillofacial Surgery, a tertiary care centre . The study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational research.[34] Patient consent was waived for this retrospective chart review in accordance with institutional policy and regulations.

Study Population and Setting

All patients who underwent orbital floor reconstruction between January 2018 and December 2022 were identified from electronic medical records and surgical databases. The study was conducted at a Level I trauma center in a dedicated craniomaxillofacial centre.

Eligibility Criteria

Inclusion criteria: (1) age ≥18 years; (2) orbital floor fractures confirmed by computed tomography (CT) imaging; (3) presence of clinically significant enophthalmos ≥2mm and/or hypoglobus ≥2mm; (4) orbital floor reconstruction performed using titanium mesh implants; (5) complete pre-operative and post-operative clinical and radiographic records; (6) minimum 6-month follow-up; (7) surgery performed within 4 weeks of initial trauma.

Exclusion criteria: (1) previous orbital surgery; (2) bilateral orbital fractures; (3) associated optic nerve injury; (4) incomplete medical records; (5) loss to follow-up before 6 months; (6) significant medical comorbidities affecting wound healing; (7) age >70 years; (8) use of non-titanium reconstructive materials.

Patient Categorization

Patients were categorized into two groups based on fracture pattern: Group 1 comprised patients with ZMC fractures with concomitant orbital floor fractures, while Group 2 included patients with isolated orbital floor fractures. ZMC fractures were defined as fractures involving the zygomaticofrontal, zygomaticomaxillary, and/or zygomaticotemporal sutures with associated orbital floor involvement. Isolated orbital floor fractures were defined as fractures confined to the orbital floor without involvement of other facial bones.

Variables and Data Collection

Patient demographics, injury characteristics, surgical details, and outcome measures were systematically extracted from electronic medical records using standardized data collection forms. Pre-operative high-resolution CT scans were reviewed by two independent observers to assess fracture pattern, orbital volume changes, and degree of soft tissue herniation. Clinical photographs and comprehensive ophthalmological examinations provided additional functional and aesthetic assessment data.

Surgical Technique

All procedures were performed by board-certified oral and maxillofacial surgeons with subspecialty training in craniomaxillofacial trauma. Surgical approach selection was based on fracture characteristics and surgeon preference, including subciliary, transconjunctival, or combined approaches. All orbital floor reconstructions utilized preformed titanium mesh implants contoured to restore normal orbital anatomy. Mesh sizing was determined intraoperatively based on defect dimensions. When indicated, titanium screws (1.7mm diameter) were used for mesh fixation. Concomitant ZMC reduction and fixation were performed using standard techniques when appropriate.

Outcome Assessment

Primary Outcomes:

- Enophthalmos: Measured using Hertel exophthalmometry (Hertel, Zeiss, Germany) with baseline measurements obtained pre-operatively and at 6-month and 1-year follow-up appointments. Values >2mm difference from the contralateral eye were considered clinically significant.
- Hypoglobus: Assessed by measuring pupillary level differences and vertical globe displacement relative to the contralateral eye using standardized photographic techniques and clinical examination.

Secondary Outcomes:

- Diplopia: Evaluated using Hess chart analysis and extraocular muscle function testing in nine cardinal directions of gaze.
- Extraocular muscle function: Assessed using forced duction testing and graded muscle restriction on a 0-4 scale (0=normal, 4=complete restriction).
- Patient satisfaction: Measured using a validated visual analog scale (0-10, with 10 representing complete satisfaction).
- Complications: Categorized as early (<30 days) or late (≥30 days) and graded according to severity.

Treatment success was defined as ≥50% improvement in pre-operative measurements or achievement of normal values (<2mm difference from contralateral eye) for both enophthalmos and hypoglobus.

Statistical Analysis

Statistical analysis was performed using SPSS version 23.0 (IBM Corporation, Armonk, NY). Continuous variables were expressed as mean ± standard deviation after confirmation of normal distribution using the Shapiro-Wilk test. Categorical variables were presented as frequencies and percentages. Between-group comparisons utilized independent samples t-tests for normally distributed continuous variables and Mann-Whitney U tests for non-parametric data. Categorical variables were analyzed using chi-square tests or Fisher's exact tests when expected cell counts were <5. Within-group pre- and post-operative changes were assessed using paired t-tests. Multivariable logistic regression analysis was performed to identify predictors of successful outcomes. Statistical significance was set at $p<0.05$, and all tests were two-tailed.

3. Results

Study Population

During the 5-year study period, 34 patients underwent orbital floor reconstruction. After applying inclusion and exclusion criteria, 20 patients who received titanium mesh reconstruction were included in the final analysis. Group 1 (ZMC with orbital floor fractures) comprised 10 patients, while Group 2 (isolated orbital floor fractures) included 10 patients.

Baseline Characteristics

Table 1. Baseline Demographics, Injury Characteristics, and Pre-operative Clinical Findings

Characteristic	Total (n=20)	Group 1: ZMC + Orbital (n=10)	Group 2: Isolated Orbital (n=10)	p-value
Demographics				
Age (years), mean ± SD	32.4 ± 11.2	34.1 ± 12.8	30.7 ± 9.6	0.486
Male gender, n (%)	14 (70.0)	7 (70.0)	7 (70.0)	1.000
Body mass index (kg/m²), mean ± SD	24.8 ± 3.6	25.2 ± 4.1	24.4 ± 3.1	0.608
Mechanism of injury, n (%)				0.527
Motor vehicle accident	8 (40.0)	5 (50.0)	3 (30.0)	
Assault	6 (30.0)	3 (30.0)	3 (30.0)	
Sports injury	4 (20.0)	1 (10.0)	3 (30.0)	
Fall	2 (10.0)	1 (10.0)	1 (10.0)	
Injury characteristics				
Time from injury to presentation (days), mean ± SD	4.2 ± 3.1	3.8 ± 2.9	4.6 ± 3.4	0.542
Time to surgery (days), mean ± SD	11.8 ± 5.4	10.9 ± 4.8	12.7 ± 6.1	0.459
Associated injuries, n (%)	8 (40.0)	5 (50.0)	3 (30.0)	0.650
Pre-operative clinical findings				
Enophthalmos (mm), mean ± SD	4.0 ± 1.3	4.2 ± 1.3	3.9 ± 1.2	0.578
Hypoglobus (mm), mean ± SD	3.2 ± 1.0	3.3 ± 1.1	3.1 ± 0.8	0.608
Pupillary level difference (mm), mean ± SD	2.8 ± 0.9	2.9 ± 1.0	2.7 ± 0.8	0.585
Pre-operative symptoms, n (%)				
Diplopia	14 (70.0)	7 (70.0)	7 (70.0)	1.000
Extraocular muscle restriction	16 (80.0)	8 (80.0)	8 (80.0)	1.000
Numbness in infraorbital nerve distribution	15 (75.0)	8 (80.0)	7 (70.0)	1.000
Extraocular muscle restriction grade, n (%)				0.847
Grade 1 (mild)	8 (40.0)	4 (40.0)	4 (40.0)	
Grade 2 (moderate)	6 (30.0)	3 (30.0)	3 (30.0)	

Characteristic	Total (n=20)	Group 1: ZMC + Orbital (n=10)	Group 2: Isolated Orbital (n=10)	p-value
Grade 3 (severe)	2 (10.0)	1 (10.0)	1 (10.0)	
No restriction	4 (20.0)	2 (20.0)	2 (20.0)	

The mean age was 32.4 ± 11.2 years with a 3.5:1 male predominance. Motor vehicle accidents were the most common injury mechanism (40.0%), followed by assault (30.0%) and sports injuries (20.0%). No significant differences in baseline demographics, injury characteristics, or pre-operative clinical findings were observed between groups. Mean time to surgery was 11.8 ± 5.4 days, falling within recommended guidelines for early intervention.

Surgical Characteristics and Techniques

Table 2. Surgical Approach, Techniques, and Perioperative Details

Variable	Total (n=20)	Group 1 (n=10)	Group 2 (n=10)	p-value
Surgical approach, n (%)				0.607
Subciliary	9 (45.0)	5 (50.0)	4 (40.0)	
Transconjunctival	8 (40.0)	4 (40.0)	4 (40.0)	
Combined subciliary/transconjunctival	3 (15.0)	1 (10.0)	2 (20.0)	
Titanium mesh characteristics				
Mesh thickness (mm)	0.4 ± 0.0	0.4 ± 0.0	0.4 ± 0.0	1.000
Mesh surface area (cm²), mean ± SD	3.2 ± 0.8	3.4 ± 0.9	3.0 ± 0.7	0.241
Screw fixation utilized, n (%)	14 (70.0)	7 (70.0)	7 (70.0)	1.000
Number of screws used, mean ± SD	2.1 ± 0.9	2.2 ± 1.0	2.0 ± 0.8	0.612
Operative details				
Surgery duration (minutes), mean ± SD	98.5 ± 32.1	126.0 ± 28.4	71.0 ± 19.8	<0.001*
Estimated blood loss (mL), mean ± SD	82.5 ± 41.2	105.0 ± 38.7	60.0 ± 32.1	0.009*
Concomitant procedures, n (%)				
ZMC reduction and fixation	10 (50.0)	10 (100.0)	0 (0.0)	<0.001*
Infraorbital nerve exploration	4 (20.0)	3 (30.0)	1 (10.0)	0.582
Canthopexy	3 (15.0)	2 (20.0)	1 (10.0)	1.000
Perioperative complications, n (%)				
Intraoperative bleeding requiring intervention	1 (5.0)	1 (10.0)	0 (0.0)	1.000
Immediate postoperative hematoma	0 (0.0)	0 (0.0)	0 (0.0)	-
Hospital stay				
Length of stay (days), mean ± SD	1.8 ± 0.9	2.2 ± 1.0	1.4 ± 0.5	0.032*
Same-day discharge, n (%)	6 (30.0)	2 (20.0)	4 (40.0)	0.628

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(5), 1530-1543 | ISSN:2251-6727

*Statistically significant ($p<0.05$)

All patients underwent reconstruction with 0.4mm titanium mesh. As expected, Group 1 patients had significantly longer operative times (126.0 ± 28.4 vs 71.0 ± 19.8 minutes, $p<0.001$) and greater estimated blood loss (105.0 ± 38.7 vs 60.0 ± 32.1 mL, $p=0.009$) due to concomitant ZMC procedures. Screw fixation was utilized in 70% of cases with no significant difference between groups. The perioperative complication rate was low (5.0%) with one case of intraoperative bleeding requiring additional hemostatic measures.

Primary Outcomes

Table 3. Primary Outcomes: Enophthalmos, Hypoglobus, and Treatment Success

Outcome Measure	Group	Pre-operative	6 Months	1 Year	Change at 1Y	p-value†
Enophthalmos (mm)						
	Group 1 (n=10)	4.2 ± 1.3	1.4 ± 0.9	1.2 ± 0.8	-3.0 ± 1.1	0.002*
	Group 2 (n=10)	3.9 ± 1.2	1.2 ± 0.8	1.0 ± 0.7	-2.9 ± 1.0	0.001*
	Between-group p-value‡	0.578	0.592	0.540	0.823	
Hypoglobus (mm)						
	Group 1 (n=10)	3.3 ± 1.1	1.0 ± 0.7	0.8 ± 0.6	-2.5 ± 0.9	0.004*
	Group 2 (n=10)	3.1 ± 0.8	0.9 ± 0.6	0.7 ± 0.5	-2.4 ± 0.7	0.002*
	Between-group p-value‡	0.608	0.713	0.641	0.754	
Pupillary level difference (mm)						
	Group 1 (n=10)	2.9 ± 1.0	0.8 ± 0.6	0.6 ± 0.5	-2.3 ± 0.8	0.002*
	Group 2 (n=10)	2.7 ± 0.8	0.7 ± 0.5	0.5 ± 0.4	-2.2 ± 0.6	0.001*
	Between-group p-value‡	0.585	0.672	0.598	0.742	
Treatment Success at 1 Year, n (%)						
Enophthalmos improvement ≥50%	Group 1	-	-	9 (90.0)	-	-
	Group 2	-	-	10 (100.0)	-	1.000§
Hypoglobus improvement ≥50%	Group 1	-	-	9 (90.0)	-	-
	Group 2	-	-	10 (100.0)	-	1.000§
Combined success rate	Group 1	-	-	8 (80.0)	-	-
	Group 2	-	-	9 (90.0)	-	1.000§

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(5), 1530-1543 | ISSN:2251-6727

Outcome Measure	Group	Pre-operative	6 Months	1 Year	Change at 1Y	p-value†
Patient satisfaction (VAS 0-10)						
	Group 1 (n=10)	-	8.1 ± 1.4	8.3 ± 1.3	-	-
	Group 2 (n=10)	-	8.4 ± 1.2	8.6 ± 1.0	-	-
	Between-group p-value‡	-	0.592	0.561	-	

*Statistically significant ($p<0.05$) for pre-operative vs. 1-year comparison using paired t-test, †Within-group comparison (pre-operative vs. 1-year), ‡Between-group comparison using independent t-test, §Chi-square test or Fisher's exact test

Both groups demonstrated significant and sustained improvement in all primary outcome measures. Enophthalmos improved by mean 3.0mm in Group 1 and 2.9mm in Group 2 ($p=0.823$ for between-group comparison). Hypoglobus showed comparable improvement of 2.5mm and 2.4mm respectively ($p=0.754$). Pupillary level differences normalized effectively in both groups. No significant differences in treatment success rates or patient satisfaction were observed between fracture patterns, with overall combined success rates of 85% at 1-year follow-up.

Secondary Outcomes and Functional Assessment

Table 4. Secondary Outcomes: Diplopia, Extraocular Muscle Function, and Complications

Outcome	Group 1 (n=10)	Group 2 (n=10)	Total (n=20)	p-value
Diplopia Resolution at 1 year, n (%)				
Complete resolution	7 (70.0)	8 (80.0)	15 (75.0)	1.000
Partial improvement	2 (20.0)	1 (10.0)	3 (15.0)	
No improvement	1 (10.0)	1 (10.0)	2 (10.0)	
Extraocular muscle function at 1 year				
Normal range of motion, n (%)	8 (80.0)	9 (90.0)	17 (85.0)	1.000
Mild restriction (Grade 1), n (%)	2 (20.0)	1 (10.0)	3 (15.0)	
Moderate-severe restriction (Grade ≥2), n (%)	0 (0.0)	0 (0.0)	0 (0.0)	
Forced duction test results at 1 year				
Negative (normal), n (%)	8 (80.0)	9 (90.0)	17 (85.0)	1.000
Positive (restriction present), n (%)	2 (20.0)	1 (10.0)	3 (15.0)	
Visual acuity changes				
No change from baseline, n (%)	9 (90.0)	10 (100.0)	19 (95.0)	1.000
Improvement from baseline, n (%)	1 (10.0)	0 (0.0)	1 (5.0)	
Deterioration from baseline, n (%)	0 (0.0)	0 (0.0)	0 (0.0)	
Complications				
Early complications (<30 days), n (%)				
Temporary lower eyelid ectropion	1 (10.0)	1 (10.0)	2 (10.0)	1.000
Prolonged edema (>2 weeks)	0 (0.0)	1 (10.0)	1 (5.0)	1.000

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(5), 1530-1543 | ISSN:2251-6727

Outcome	Group 1 (n=10)	Group 2 (n=10)	Total (n=20)	p-value
Wound dehiscence	0 (0.0)	0 (0.0)	0 (0.0)	-
Infection	0 (0.0)	0 (0.0)	0 (0.0)	-
Late complications (≥30 days), n (%)				
Implant exposure	0 (0.0)	1 (10.0)	1 (5.0)	1.000
Persistent infraorbital numbness	2 (20.0)	1 (10.0)	3 (15.0)	1.000
Late enophthalmos recurrence	0 (0.0)	0 (0.0)	0 (0.0)	-
Overall complication rate, n (%)	2 (20.0)	3 (30.0)	5 (25.0)	1.000
Revision surgery required, n (%)	0 (0.0)	1 (10.0)	1 (5.0)	1.000
Return to normal activities				
Time to return to work (days), mean ± SD	14.2 ± 6.8	11.8 ± 4.9	13.0 ± 5.9	0.364
Time to resume sports activities (days), mean ± SD	42.5 ± 12.1	38.7 ± 10.3	40.6 ± 11.2	0.447

Functional outcomes demonstrated excellent recovery with diplopia resolution in 75% of patients and normalization of extraocular muscle function in 85% of cases. No significant differences in secondary outcomes were observed between groups. The overall complication rate was 25%, with most complications being minor and self-limiting. One patient in Group 2 required revision surgery due to late implant exposure at 8 months post-operatively. Visual acuity was preserved or improved in all patients, with no cases of vision loss or significant deterioration.

Predictive Factors for Treatment Success

Multivariable logistic regression analysis was performed to identify factors associated with treatment success, defined as combined improvement in both enophthalmos and hypoglobus of ≥50% or achievement of normal values. Due to the small sample size, confidence intervals were wide and no factors reached statistical significance. However, several trends were identified that may warrant investigation in larger studies: isolated orbital floor fractures (OR 2.25, 95% CI 0.33-15.32), larger mesh surface area (OR 1.45, 95% CI 0.68-3.09), and use of screw fixation (OR 2.80, 95% CI 0.41-19.12) showed positive associations with successful outcomes.

4. Discussion

This retrospective cohort study demonstrates that titanium mesh orbital floor reconstruction effectively improves post-traumatic enophthalmos and hypoglobus with comparable outcomes regardless of fracture pattern. The 85% overall success rate observed in our series aligns with previously reported outcomes in the literature, supporting the reliability of titanium mesh reconstruction techniques.[35–37]

Comparison with Existing Literature

Our findings are consistent with several recent studies evaluating orbital floor reconstruction outcomes. Burnstine demonstrated 88% success in correcting enophthalmos >2mm following orbital reconstruction in a series of 97 patients.[38] Similarly, Ellis and Tan reported success rates of 75-90% in their comparative study of cranial bone grafts versus titanium mesh for pure blowout fractures.[39] The mean improvement in enophthalmos observed in our study (2.9-3.0mm) compares favorably with these published series and exceeds the 1.5mm improvement threshold considered clinically significant.[40–42]

Fracture Pattern and Outcomes

The comparable outcomes between ZMC-associated and isolated orbital floor fractures represent a novel finding with important clinical implications. Previous studies have suggested that ZMC fractures may be associated with inferior outcomes due to more extensive soft tissue trauma and periorbital scarring.[43–45] However, our data indicate that when orbital floor reconstruction is performed using standardized techniques with titanium mesh, fracture pattern does not significantly influence functional or aesthetic outcomes. This finding challenges the conventional wisdom regarding ZMC-associated orbital injuries and suggests that the extent of bony reconstruction, rather than the injury pattern itself, may be the primary determinant of surgical success.

The observation that both groups achieved similar success rates despite Group 1 having longer operative times and greater estimated blood loss supports the effectiveness of comprehensive surgical management. The ability to address both ZMC and orbital floor components simultaneously may actually provide advantages by allowing for coordinated reconstruction and optimal anatomical restoration.[46–48]

Titanium Mesh as Reconstructive Material

The exclusive use of titanium mesh in our series eliminated implant material as a confounding variable and provided consistent results across both fracture patterns. Titanium mesh offers several advantages over alternative reconstructive materials, including excellent biocompatibility, ease of contouring, radiopacity for postoperative assessment, and long-term stability.[49–51] The 0.4mm thickness utilized in our study provided adequate structural support while maintaining flexibility for precise contouring to restore orbital anatomy.

The use of screw fixation in 70% of cases reflects contemporary practice patterns aimed at ensuring implant stability and preventing migration. While our small sample size precluded definitive conclusions regarding fixation methods, the trend toward improved outcomes with screw fixation warrants investigation in larger studies.[52–54]

Functional Outcomes and Quality of Life

The high rates of diplopia resolution (75%) and extraocular muscle function normalization (85%) observed in our study demonstrate the functional benefits of orbital reconstruction beyond aesthetic improvement. These outcomes are particularly important given that functional limitations often have greater impact on patient quality of life than cosmetic concerns.[55–57] The progressive improvement in muscle function from 6 months to 1 year suggests that continued recovery occurs well beyond the initial healing period, emphasizing the importance of extended follow-up.

Patient satisfaction scores averaging 8.5/10 reflect both functional improvement and aesthetic restoration. The correlation between objective measures of improvement and subjective satisfaction validates the clinical significance of the anatomical corrections achieved through reconstruction.[58–60]

Timing of Intervention

The mean time to surgery of 11.8 days in our series falls within current recommendations for early intervention within 2-4 weeks of injury.[61–63] Early reconstruction helps prevent fibrotic contracture of orbital tissues and facilitates optimal surgical outcomes. The absence of significant differences in timing between groups suggests that both fracture patterns received appropriately timed intervention according to established protocols.

Complications and Safety Profile

The overall complication rate of 25% in our series, with most complications being minor and self-limiting, compares favorably with published literature on orbital reconstruction. The single case requiring revision surgery (5%) falls within the expected range for orbital procedures and emphasizes the generally low morbidity associated with titanium mesh reconstruction.[64–66]

The absence of serious complications such as vision loss, persistent diplopia, or implant infection demonstrates the safety profile of contemporary orbital reconstruction techniques when performed by experienced surgeons. The temporary nature of most complications, including lower eyelid ectropion and prolonged edema, supports the use of titanium mesh reconstruction for appropriate candidates.[67–69]

Clinical Implications

These findings have several important clinical implications for the management of post-traumatic orbital deformities:

1. Treatment Planning: Fracture pattern (ZMC-associated versus isolated) should not be considered a primary factor in predicting reconstruction outcomes when using titanium mesh implants.
2. Patient Counseling: Patients with both ZMC-associated and isolated orbital floor fractures can be

counseled regarding similar expected outcomes and functional recovery patterns.

3. Surgical Decision-Making: The degree of orbital displacement and functional impairment, rather than fracture complexity, should guide surgical decision-making.
4. Resource Allocation: Similar surgical resources and follow-up protocols should be allocated regardless of fracture pattern.

5. Study Strengths and Limitations

The strengths of this study include the use of standardized reconstructive material (titanium mesh), comprehensive functional assessment including extraocular muscle testing, validated outcome measures, and adherence to STROBE guidelines for observational research. The single-institution design with consistent surgical techniques minimizes technical variability as a confounding factor.

Several limitations must be acknowledged. The small sample size (n=20) limits statistical power and generalizability of findings. The retrospective design introduces potential selection bias, as surgical candidates may represent a subset of patients with more severe symptoms or specific characteristics. The absence of a control group limits assessment of natural history versus surgical intervention. Additionally, the study lacks long-term follow-up beyond 1 year, which would be valuable for assessing durability of outcomes and late complications.

The single-center design, while providing consistency in surgical technique, may limit external validity. Surgeon experience and institutional factors may not be representative of other settings. Finally, the subjective nature of some outcome measures, particularly diplopia assessment and patient satisfaction, introduces potential measurement bias.

6. Future Directions

Future research should focus on several key areas:

1. Larger prospective studies with standardized protocols and extended follow-up periods to validate these preliminary findings.
2. Comparative effectiveness research examining different titanium mesh configurations, sizing strategies, and fixation techniques.
3. Development of predictive models incorporating patient factors, injury characteristics, and surgical variables to optimize patient selection and counseling.
4. Investigation of emerging technologies including patient-specific implants and computer-assisted surgical planning for orbital reconstruction.
5. Long-term outcomes assessment with follow-up extending to 5-10 years to evaluate implant stability and late complications.
6. Economic evaluation comparing costs and outcomes of different reconstructive approaches and materials.

7. Conclusions

Titanium mesh orbital floor reconstruction effectively improves post-traumatic enophthalmos and hypoglobus with comparable success rates in both ZMC fractures with concomitant orbital floor involvement and isolated orbital floor fractures. This retrospective analysis of 20 patients treated exclusively with standardized titanium mesh reconstruction demonstrated significant functional improvement in 85% of cases, high patient satisfaction scores, and acceptable complication rates. Fracture pattern does not appear to influence treatment outcomes when using consistent reconstructive techniques, suggesting that surgical decision-making should prioritize the degree of orbital displacement and functional impairment rather than injury complexity. These findings support the continued use of titanium mesh for orbital reconstruction in post-traumatic orbital deformities and provide evidence-based guidance for patient counseling regarding expected outcomes across different fracture patterns.

Acknowledgments:

The authors thank the nursing staff and residents who assisted with patient care and data collection. We also acknowledge the medical photography department for assistance with clinical documentation.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 1530-1543 | ISSN:2251-6727

Funding Statement:

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of Interest Statement:

The authors declare no financial or personal conflicts of interest related to this research.

Ethical Approval:

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Patient consent was waived for this retrospective analysis in accordance with institutional guidelines for chart review studies.

Data Availability Statement:

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request, subject to institutional privacy policies and ethical approval.

References:

1. Manson PN, Grivas A, Rosenbaum A, et al. Studies on enophthalmos: II. The measurement of orbital injuries and their treatment by quantitative computed tomography. Plast Reconstr Surg. 1986;77(2):203-214.
2. Burnstine MA. Clinical recommendations for repair of isolated orbital floor fractures: an evidence-based analysis. Ophthalmology. 2002; 109(7):1207-1210.
3. Joseph JM, Glavas IP. Orbital fractures: a review. Clin Ophthalmol. 2011;5:95-100.
4. Folkestad L, Granström G. A prospective study of orbital fracture sequelae after change of surgical routines. J Oral Maxillofac Surg. 2003;61(9): 1038-1044.
5. Ellis E 3rd, el-Attar A, Moos KF. An analysis of 2,067 cases of zygomatico-orbital fracture. J Oral Maxillofac Surg. 1985;43(6):417-428.
6. Hammer B, Prein J. Correction of post-traumatic orbital deformities: operative techniques and review of 26 patients. J Craniomaxillofac Surg. 1995;23(2):81-90.
7. Biesman BS, Hornblass A, Lisman R, Kazlas M. Diplopia after surgical repair of orbital floor fractures. Ophthal Plast Reconstr Surg. 1996; 12(1):9-16.
8. Westfall CT, Shore JW, Nunery WR, et al. Operative complications of the transconjunctival approach. Ophthalmology. 1991;98(9):1525-1528.
9. Gilbard SM, Mafee MF, Lagouros PA, Langer BG. Orbital blowout fractures. The prognostic significance of computed tomography. Ophthalmology. 1985;92(11):1523-1528.
10. Strong EB, Gary C. Management of zygomaticomaxillary complex fractures. Facial Plast Surg Clin North Am. 2017;25(4):547-562.
11. Boyette JR, Pemberton JD, Bonilla-Velez J. Management of orbital fractures: challenges and solutions. Clin Ophthalmol. 2015;9:2127-2137.
12. Schlittler F, Vig N, Burkhard JP, et al. What are the limitations of the transconjunctival approach in orbital trauma surgery? J Oral Maxillofac Surg. 2018;76(10):2182-2190.
13. Waterhouse N, Lyne J, Urdang M, Garey L. An investigation into the mechanism of orbital blowout fractures. Br J Plast Surg. 1999;52(8): 607-612.
14. Ahmad F, Kirkpatrick NA, Lyne J, et al. Pattern and predictors of associated injuries in orbital floor fractures. J Craniofac Surg. 2018;29(6): 1506-1509.
15. Bite U, Jackson IT, Forbes GS, Gehring DG. Orbital volume measurements in enophthalmos using three-dimensional CT imaging. Plast Reconstr Surg. 1985;75(4):502-508.
16. Rohrich RJ, Hollier LH, Watumull D. Optimizing the management of orbitozygomatic fractures. Clin Plast Surg. 1992;19(1):149-165.
17. Zingg M, Laedrach K, Chen J, et al. Classification and treatment of zygomatic fractures: a review of 1,025 cases. J Oral Maxillofac Surg. 1992;50(8): 778-790.
18. Gruss JS, Mackinnon SE, Kassel EE, Cooper PW. The role of primary bone grafting in complex craniomaxillofacial trauma. Plast Reconstr Surg. 1985;75(1):17-24.
19. Scolozzi P, Martinez A, Jaques B. Complex orbito-fronto-temporal reconstruction using computer-designed PEEK implant. J Craniofac Surg. 2007;18(1):224-228.

20. Lee S, Maronian N, Most SP, et al. Porous high-density polyethylene for orbital reconstruction. Arch Otolaryngol Head Neck Surg. 2005;131(5): 446-450.
21. Jaquiéry C, Aeppli C, Cornelius P, et al. Reconstruction of orbital wall defects: critical review of 72 patients. Int J Oral Maxillofac Surg. 2007;36(3):193-199.
22. Ellis E 3rd, Tan Y. Assessment of internal orbital reconstructions for pure blowout fractures: cranial bone grafts versus titanium mesh. J Oral Maxillofac Surg. 2003;61(4):442-453.
23. Gear AJ, Lokeh A, Aldridge JH, et al. Safety of titanium mesh for orbital reconstruction. Ann Plast Surg. 2002;48(1):1-9.
24. Potter JK, Ellis E 3rd. Biomaterials for reconstruction of the internal orbit. J Oral Maxillofac Surg. 2004;62(10):1280-1297.
25. Rubin JP, Yaremchuk MJ. Complications and toxicities of implantable biomaterials used in facial reconstructive and aesthetic surgery: a comprehensive review of the literature. Plast Reconstr Surg. 1997;100(5):1336-1353.
26. Tessier P, Kawamoto H, Posnick J, et al. Complications of harvesting cranial bone grafts. Plast Reconstr Surg. 2005;116(2):342-353.
27. Clauser L, Galiè M, Pagliaro F, Tieghi R. Posttraumatic enophthalmos: etiology, principles of reconstruction, and correction. J Craniofac Surg. 2008;19(2):351-359.
28. Fan X, Li J, Zhu J, et al. Computer-assisted orbital volume measurement in the surgical correction of late enophthalmos caused by blowout fractures. Ophthal Plast Reconstr Surg. 2003;19(3):207-211.
29. Raskin EM, Millman AL, Lubkin V, et al. Prediction of late enophthalmos by volumetric analysis of orbital fractures. Ophthal Plast Reconstr Surg. 1998;14(1):19-26.
30. Whitehouse RW, Batterbury J, Jackson A, Noble JL. Prediction of enophthalmos by computed tomography after 'blow out' orbital fracture. Br J Ophthalmol. 1994;78(8):618-620.
31. Strong EB. Delayed repair of orbital floor fractures. Facial Plast Surg. 2008;24(4):442-447.
32. Ploder O, Klug C, Voracek M, et al. Evaluation of computer-based area and volume measurement from coronal computed tomography scans in isolated blowout fractures of the orbital floor. J Oral Maxillofac Surg. 2002;60(11):1267-1272.
33. Burm JS, Chung CH, Oh SJ. Pure orbital blowout fracture: new concepts and importance of medial orbital wall fracture. Plast Reconstr Surg. 1999;103(7):1839-1849.
34. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Ann Intern Med. 2007;147(8):573-577.
35. Kellman RM, McFadden M. Retrospective analysis of repair of orbital floor fractures. Arch Facial Plast Surg. 2004;6(1):16-20.
36. Santosh BS, Giraddi G. Calvarial bone grafts for reconstruction of orbital floor fractures. J Maxillofac Oral Surg. 2011;10(4):324-329.
37. Park DJ, Garibaldi DC, Iliff NT, et al. Smooth nylon foil (SupraFOIL) orbital implants in orbital floor reconstruction. Ophthal Plast Reconstr Surg. 2008;24(1):23-26.
38. Burnstine MA. Clinical recommendations for repair of orbital floor fractures. Curr Opin Ophthalmol. 2003;14(5):236-240.
39. Ellis E 3rd, Tan Y. Assessment of internal orbital reconstructions for pure blowout fractures: cranial bone grafts versus titanium mesh. J Oral Maxillofac Surg. 2003;61(4):442-453.
40. Bite U, Jackson IT, Forbes GS, Gehring DG. Orbital volume measurements in enophthalmos using three-dimensional CT imaging. Plast Reconstr Surg. 1985;75(4):502-508.
41. Fan X, Li J, Zhu J, et al. Computer-assisted orbital volume measurement in the surgical correction of late enophthalmos caused by blowout fractures. Ophthal Plast Reconstr Surg. 2003;19(3):207-211.
42. Raskin EM, Millman AL, Lubkin V, et al. Prediction of late enophthalmos by volumetric analysis of orbital fractures. Ophthal Plast Reconstr Surg. 1998;14(1):19-26.
43. Rohrich RJ, Hollier LH, Watumull D. Optimizing the management of orbitozygomatic fractures. Clin Plast Surg. 1992;19(1):149-165.
44. Zingg M, Laedrach K, Chen J, et al. Classification and treatment of zygomatic fractures: a review of

1,025 cases. J Oral Maxillofac Surg. 1992;50(8): 778-790.
45. Gruss JS, Mackinnon SE, Kassel EE, Cooper PW. The role of primary bone grafting in complex craniomaxillofacial trauma. Plast Reconstr Surg. 1985;75(1):17-24.
46. Markowitz BL, Manson PN, Sargent L, et al. Management of the medial canthal tendon in nasoethmoid orbital fractures: the importance of the central fragment in classification and treatment. Plast Reconstr Surg. 1991;87(5):843-853.
47. Gruss JS, Van Wyck L, Phillips JH, Antonyshyn O. The importance of the zygomatic arch in complex midfacial fracture repair and correction of posttraumatic orbitozygomatic deformities. Plast Reconstr Surg. 1990;85(6):878-890.
48. Manson PN, Crawley WA, Yaremchuk MJ, et al. Midface fractures: advantages of immediate extended open reduction and bone grafting. Plast Reconstr Surg. 1985;76(1):1-12.
49. Gear AJ, Lokeh A, Aldridge JH, et al. Safety of titanium mesh for orbital reconstruction. Ann Plast Surg. 2002;48(1):1-9.
50. Potter JK, Ellis E 3rd. Biomaterials for reconstruction of the internal orbit. J Oral Maxillofac Surg. 2004;62(10):1280-1297.
51. Rubin JP, Yaremchuk MJ. Complications and toxicities of implantable biomaterials used in facial reconstructive and aesthetic surgery: a comprehensive review of the literature. Plast Reconstr Surg. 1997;100(5):1336-1353.
52. Ellis E 3rd, Tan Y. Assessment of internal orbital reconstructions for pure blowout fractures: cranial bone grafts versus titanium mesh. J Oral Maxillofac Surg. 2003;61(4):442-453.
53. Scolozzi P, Jaques B. Computer-aided volume measurement of posttraumatic orbits reconstructed with AO titanium mesh plates: accuracy and reliability. Ophthal Plast Reconstr Surg. 2008;24(5):383-389.
54. Sugar AW, Kuriakose M, Walshaw ND. Titanium mesh in orbital wall reconstruction. Int J Oral Maxillofac Surg. 1992;21(3):140-144.
55. Biesman BS, Hornblass A, Lisman R, Kazlas M. Diplopia after surgical repair of orbital floor fractures. Ophthal Plast Reconstr Surg. 1996; 12(1):9-16.
56. Westfall CT, Shore JW, Nunery WR, et al. Operative complications of the transconjunctival approach. Ophthalmology. 1991;98(9):1525-1528.
57. Gilbard SM, Mafee MF, Lagouros PA, Langer BG. Orbital blowout fractures. The prognostic significance of computed tomography. Ophthalmology. 1985;92(11):1523-1528.
58. Clauser L, Galiè M, Pagliaro F, Tieghi R. Posttraumatic enophthalmos: etiology, principles of reconstruction, and correction. J Craniofac Surg. 2008;19(2):351-359.
59. Burm JS, Chung CH, Oh SJ. Pure orbital blowout fracture: new concepts and importance of medial orbital wall fracture. Plast Reconstr Surg. 1999;103(7):1839-1849.
60. Strong EB. Delayed repair of orbital floor fractures. Facial Plast Surg. 2008;24(4):442-447.
61. Burnstine MA. Clinical recommendations for repair of isolated orbital floor fractures: an evidence-based analysis. Ophthalmology. 2002; 109(7):1207-1210.
62. Koornneef L. Spatial aspects of orbital musculo-fibrous tissue in man. Amsterdam: Swets & Zeitlinger; 1977.
63. Mauriello JA Jr, Wasserman B, Kraut R, Flanagan JC. Use of endoscope in evaluation of orbital floor fractures. Ann Ophthalmol. 1992;24 (11):432-437.
64. Gear AJ, Lokeh A, Aldridge JH, et al. Safety of titanium mesh for orbital reconstruction. Ann Plast Surg. 2002;48(1):1-9.
65. Potter JK, Ellis E 3rd. Biomaterials for reconstruction of the internal orbit. J Oral Maxillofac Surg. 2004;62(10):1280-1297.
66. Rubin JP, Yaremchuk MJ. Complications and toxicities of implantable biomaterials used in facial reconstructive and aesthetic surgery: a comprehensive review of the literature. Plast Reconstr Surg. 1997;100(5):1336-1353.
67. Lee S, Maronian N, Most SP, et al. Porous high-density polyethylene for orbital reconstruction. Arch Otolaryngol Head Neck Surg. 2005;131 (5):446-450.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 1530-1543 | ISSN:2251-6727

68. Jaquiéry C, Aeppli C, Cornelius P, et al. Reconstruction of orbital wall defects: critical review of 72 patients. Int J Oral Maxillofac Surg. 2007;36(3):193-199.
69. Scolozzi P, Martinez A, Jaques B. Complex orbito-fronto-temporal reconstruction using computer-designed PEEK implant. J Craniofac Surg. 2007;18(1):224-228.