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Article

Efficacy of Titanium Mesh in Correcting Orbital Volume and Enophthalmos in Impure Orbital Blow-Out Fractures

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ABSTRACT

Background: Orbital blow-out fractures, particularly those involving the zygomaticomaxillary complex, can result in significant functional and aesthetic complications such as enophthalmos due to increased orbital volume. While various materials are available for orbital floor reconstruction, titanium mesh offers promising biomechanical advantages; however, its clinical efficacy in impure orbital blow-out fractures remains underexplored. **Objective:** To evaluate the efficacy of titanium mesh in correcting orbital volume and enophthalmos in patients with impure orbital blow-out fractures using pre- and postoperative computed tomography (CT) measurements. **Methods:** This was a cross-sectional observational study conducted at the Oral and Maxillofacial Surgery Department, PMC Dental Institute, Faisalabad Medical University, from January to July 2021. A total of 75 patients aged 18–50 years with isolated impure orbital blow-out fractures and CT-confirmed enophthalmos were enrolled. Patients with pure orbital fractures, panfacial trauma, or contraindications to CT were excluded. All participants underwent open reduction and internal fixation of zygomaticomaxillary fractures with orbital floor reconstruction using 0.3 mm titanium mesh. Pre- and postoperative enophthalmos and orbital volume were assessed via CT imaging. Ethical approval was granted by the Institutional Review Board, and all procedures adhered to the Helsinki Declaration. Data was analyzed using SPSS v27 with paired t-tests and chi-square tests, considering $p \leq 0.05$ statistically significant. **Results:** The mean preoperative enophthalmos was 3.38 ± 0.48 mm, which reduced significantly to 0.73 ± 0.51 mm postoperatively ($p < 0.001$). Orbital volume discrepancies showed corresponding reduction, and clinical efficacy of titanium mesh was observed in 89.3% of cases. Minor complications occurred in 10.7% of patients, primarily related to mesh malposition or exposure. **Conclusion:** Titanium mesh is a clinically effective and reliable material for restoring orbital volume and correcting enophthalmos in impure orbital blow-out fractures. Its biocompatibility, ease of handling, and low complication rate make it a valuable reconstructive option in maxillofacial trauma surgery.

Keywords: Orbital Blowout Fractures, Titanium Mesh, Enophthalmos, Orbital Volume, Maxillofacial Surgery, Orbital Reconstruction, CT Imaging.

INTRODUCTION

Orbital fractures, particularly those involving the zygomaticomaxillary complex (ZMC), represent a common form of midfacial trauma due to the prominence of this anatomical structure. The increasing incidence of such fractures has been attributed to the rise in motor vehicle accidents, interpersonal violence, sports-related injuries, and industrial accidents (1). Among the complications associated with these fractures, enophthalmos—defined as the posterior displacement of the globe within the orbits is one of the most prevalent and aesthetically concerning outcomes. This condition is primarily caused by herniation of orbital contents into adjacent sinuses following disruption of the orbital floor (2). The reported incidence of isolated orbital fractures ranges from 4% to 16%, while fractures involving the ZMC account for 30% to 55% of all facial fractures (3). Orbital floor fractures are the most frequently observed, comprising nearly 48% of orbital fractures, followed by fractures of the medial wall, lateral wall, and roof (4).

Enophthalmos greater than 2 mm is generally considered clinically significant and aesthetically unacceptable (2). Accurate measurement is essential for diagnosis and treatment planning, with computed tomography (CT) considered the gold standard for assessing both orbital volume and globe position due to its ability to visualize hard and soft tissues simultaneously (6). The normal orbital volume is approximately 30 cm^3 ± 6, and a volumetric increase of about 2.25 cm^3 corresponds to a 2 mm increase in enophthalmos (5). Orbital floor reconstruction aims to restore this volume and globe position, thereby correcting both functional and cosmetic deficits. Several materials have been employed for this purpose, including autogenous bone grafts, allogeneic tissues, and alloplastic implants such as porous polyethylene, hydroxyapatite, and titanium mesh (5). Among these, titanium mesh has gained popularity due to its favorable mechanical properties, including biocompatibility, malleability, strength, and ease of intraoperative contouring, while eliminating the donor site morbidity associated with autogenous grafts (5).

Despite its widespread use, the literature on the clinical efficacy and complication rates associated with titanium mesh remains limited. While some studies have reported success rates ranging from 75% to 93%, with low rates of postoperative complications (9), others have highlighted potential issues such as implant exposure, infection, and late enophthalmos (7). Additionally, there is ongoing debate regarding the ideal timing of surgical intervention and the optimal reconstruction material, particularly for impure orbital blow-out fractures, which are complex injuries involving both the orbital floor and ZMC region (25). Considering this variability, there is a need for further clinical evidence to evaluate the effectiveness of titanium mesh specifically in cases of impure orbital blow-out fractures.

This study was therefore designed to address the knowledge gap concerning the efficacy of titanium mesh in restoring orbital volume and correcting enophthalmos in patients with impure orbital blow-out fractures. By quantitatively comparing preoperative and postoperative CT measurements of enophthalmos and orbital volume, the study aimed to assess whether titanium mesh provides a reliable and effective reconstructive option in such cases.

MATERIAL AND METHODS

This was a cross-sectional observational study conducted at the Department of Oral and Maxillofacial Surgery, PMC Dental Institute, Faisalabad Medical University, Faisalabad, Pakistan, between January 7, 2021, and July 30, 2021. A total of seventy-five patients were enrolled using a non-probability consecutive sampling technique. The inclusion criteria consisted of patients aged between 18 and 50 years presenting with isolated impure orbital blow-out fractures involving the orbital floor and zygomaticomaxillary complex (ZMC) and exhibiting enophthalmos on clinical and radiological assessment. Patients with pure orbital floor fractures, fractures extending to the frontal bone or orbital roof, pan-facial trauma, or those with contraindications to computed tomography (CT) scanning were excluded. Written informed consent was obtained from all participants after the study protocol was approved by the Institutional Review Board of Faisalabad Medical University, and the study was conducted in full accordance with the ethical principles outlined in the Declaration of Helsinki.

All patients underwent comprehensive clinical evaluation and preoperative imaging, including orbital CT scans in axial and coronal planes. The primary outcomes of the study were the correction of enophthalmos and restoration of orbital volume, both assessed using CT imaging. Enophthalmos was measured in millimeters using CT-based biometric analysis, with values compared preoperatively and postoperatively. Orbital volume was estimated by comparing the affected orbit with the contralateral normal side using volumetric analysis on CT. Secondary outcomes included assessment of surgical complications such as implant exposure, infection, or malposition. Open reduction and internal fixation (ORIF) of associated ZMC fractures were performed using a 2-0 titanium plating system. Reconstruction of the orbital floor defect was done using a pre-contoured 0.3 mm titanium mesh, fixed with 1.5 mm screws. Patients were recalled after one week for postoperative CT assessment to evaluate changes in enophthalmos and orbital volume. Any complications observed during the postoperative period were documented and managed accordingly.

The study ensured confidentiality of participant data through anonymization and secure record-keeping. All identifying information was removed from data sets prior to analysis. Data analysis was performed using SPSS version 27. Descriptive statistics including means and standard deviations were calculated for continuous variables such as age, enophthalmos, and orbital volume. Frequencies and percentages were computed for categorical variables such as gender and complication rates. A paired sample t-test was used to compare preoperative and postoperative measures of enophthalmos and orbital volume. Chi-square tests were applied to assess associations between categorical variables. A p-value of ≤ 0.05 was considered statistically significant. Missing data were managed through listwise deletion, and confounding variables such as the time between trauma and surgical intervention were analyzed as covariates during sensitivity analysis to account for their potential effect on outcome variability.

RESULTS

A total of 75 patients with impure orbital blow-out fractures involving the zygomaticomaxillary complex were included in the analysis. The mean age was 27.55 ± 4.32 years, ranging from 20 to 37 years. Most patients were male (n = 69, 92.0%), while females accounted for a smaller proportion (n = 6, 8.0%). The interval between trauma and surgical intervention ranged from 5 to 21 days, with a mean of 9.84 ± 3.78 days. These findings suggest a young, predominantly male demographic, consistent with high-risk exposure in road traffic accidents and physical trauma. Clinical efficacy, defined as postoperative enophthalmos <2 mm, was achieved in 67 out of 75 patients (89.3%). This high success rate demonstrates the reliability of titanium mesh in orbital floor reconstruction for impure blow-out fractures. Among the eight patients who did not meet efficacy criteria, two experienced

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Table 1 Patient Demographics and Injury-to-Surgery Interval

Variable	N	Minimum	Maximum	Mean ± SD
Age (years)	75	20	37	27.55 ± 4.32
Time Between Fracture and Surgery (days)	75	5	21	9.84 ± 3.78

delayed enophthalmos recurrence and six had complications including mesh malposition and partial exposure, likely due to poor bone support or improper intraoperative placement. CT-based measurements of enophthalmos revealed a significant postoperative improvement. Preoperatively, the mean enophthalmos was 3.38 ± 0.48 mm, with values ranging from 2.0 to 4.2 mm. Postoperative measurements demonstrated a marked reduction to 0.73 ± 0.51 mm (range: 0.3 to 3.0 mm). The paired sample t-test revealed this reduction to be statistically significant ($t = 38.72$, $p < 0.001$), confirming the effectiveness of titanium mesh in restoring orbital volume and globe positioning. Subgroup analysis by time to surgery (≤10 days vs >10 days) showed that early intervention (≤10 days) was associated with slightly better reduction in enophthalmos (mean postoperative 0.66 ± 0.42 mm) compared to delayed surgery (>10 days, mean 0.88 ± 0.58 mm), though the difference was not statistically significant ($p = 0.07$).

Table 2 Comparison of Preoperative and Postoperative Enophthalmos (CT-based)

Enophthalmos (mm)	N	Minimum	Maximum	Mean ± SD	p-value
Preoperative	75	2.0	4.2	3.38 ± 0.48	
Postoperative	75	0.3	3.0	0.73 ± 0.51	< 0.001**

Note: *Paired sample t-test applied; *p < 0.001 is considered statistically significant.

This trend suggests that earlier reconstruction may be associated with better outcomes, warranting further prospective investigation.

DISCUSSION

The findings of this study demonstrate that titanium mesh is a highly effective material for orbital floor reconstruction in cases of impure orbital blow-out fractures, with significant correction of enophthalmos and restoration of orbital volume observed postoperatively. The postoperative reduction in enophthalmos from a mean of 3.377 mm to 0.725 mm highlights the mesh's ability to restore the anatomic position of the globe, a key objective in orbital fracture management. These results align with prior studies that have reported efficacy rates ranging between 75% and 93% for titanium mesh reconstruction in similar clinical scenarios (9). In our cohort, 89.3% of patients showed substantial improvement, reaffirming titanium's clinical utility in midface trauma involving the orbit.

Comparatively, the results support earlier findings by Ebrahimi et al., who emphasized a strong correlation between orbital volume restoration and correction of enophthalmos in zygomaticomaxillary fractures, particularly when using rigid implants such as titanium (6). Similarly, Grob et al. and Hidalgo et al. reported reliable outcomes with titanium mesh in reducing post-traumatic enophthalmos and ensuring structural support to the orbital floor (9,13). Our study contributes further evidence by providing volumetric analysis on CT scans, reinforcing that even subtle volume discrepancies can lead to clinically significant enophthalmos, and that restoration through titanium mesh is both precise and predictable. Unlike autogenous grafts, which present challenges in terms of shape adaptation and donor site morbidity, titanium mesh offers intraoperative malleability and long-term structural integrity without resorption, making it superior in both function and patient comfort (5,12).

Despite these promising outcomes, the study's complication rate of approximately 10.7%—including mesh exposure and improper placement in eight patients—warrants discussion. These events were managed either conservatively or through mesh removal, suggesting that while titanium mesh is effective, surgical expertise and careful intraoperative placement are critical to minimizing adverse outcomes. These findings are consistent with previous literature that identifies improper placement and soft tissue impingement as potential sources of postoperative complications (7,19). Moreover, the risk of late enophthalmos, as seen in two of our patients, underlines the need for longer follow-up durations to monitor delayed volume changes or implant migration.

One of the theoretical advantages of titanium mesh is its excellent biocompatibility and capacity for osseointegration, which reduces the likelihood of chronic infection or implant rejection (28). Its radiopacity also facilitates postoperative assessment and long-term monitoring. However, its rigidity and sharp edges may pose a risk of soft tissue irritation or injury during placement, particularly in less experienced hands (30). The transcutaneous surgical approach used in this study allowed for better exposure and control during mesh placement, potentially reducing the risk of such complications.

From a clinical perspective, the study confirms that titanium mesh not only addresses the structural needs of orbital floor defects but also contributes to improved aesthetic and functional outcomes, which are critical to patient quality of life. The minimal postoperative complication rate, combined with a high success rate in terms of enophthalmos correction, supports its continued use in reconstructive protocols for impure orbital fractures. However, this study's findings must be interpreted within the context of certain limitations. The relatively small sample size and single-center design may restrict the generalizability of the results. Additionally, the short postoperative follow-up period (one week) limits the ability to evaluate long-term outcomes such as implant stability and late enophthalmos. The absence of a comparative control group using alternative materials like Medpor or autografts also limits the ability to definitively conclude superiority.

Future research should consider multicenter randomized controlled trials with larger sample sizes and longer follow-up periods to validate the current findings and explore the long-term stability of titanium mesh implants. Comparative studies involving other reconstructive materials would also provide valuable insight into optimal material selection based on defect size, patient-specific anatomy, and cost-effectiveness. Moreover, advancements in patient-specific implant technology and intraoperative navigation may further enhance the precision and outcomes of orbital floor reconstruction. Nonetheless, this study contributes meaningful data to the growing body of literature supporting titanium mesh as a reliable, effective, and safe option for the surgical management of impure orbital blow-out fractures.

CONCLUSIONS

This study concludes that titanium mesh is a highly effective and reliable material for correcting orbital volume and enophthalmos in patients with impure orbital blow-out fractures, achieving a high success rate with minimal complications. The significant postoperative reduction in enophthalmos and restoration of orbital volume underscores its clinical value in orbital floor reconstruction, aligning with the study objective and title. Given its biocompatibility, ease of contouring, and structural stability, titanium mesh offers a promising solution for improving both functional and aesthetic outcomes in midfacial trauma. These findings support its continued use in surgical practice and highlight the need for future research involving larger, multicenter trials to further validate its long-term efficacy and compare outcomes with alternative reconstructive materials.

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