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ORIGINAL RESEARCH

CLINICAL AND RADIOGRAPHIC EVALUATION OF THREE-DIMENSIONAL PRE-BENT ORBITAL PLATES IN MANAGEMENT OF ORBITAL FRACTURES. RANDOMIZED CONTROLLED TRIAL

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Abstract

Background: Orbital fractures are commonly seen in maxillofacial practice. Recently, three-dimensionally preformed orbital implants have been introduced to enhance the accuracy of reconstruction in complex defects of the orbital floor and medial wall. These implants are designed based on consistent orbital shapes and common fracture patterns, enabling reliable restoration of the orbital contour. This study aims to evaluate and compare, through clinical and radiographic assessments, the reconstructive outcomes achieved with standard preformed titanium orbital meshes versus three-dimensionally anatomical orbital plates in post-traumatic internal orbital defects.
Materials and Methods: This clinical study included eighteen randomly selected patients, nine in each group, who were amenable to internal orbital reconstruction. All patients enrolled in this study underwent clinical and radiographic examinations, including preoperative CT scans and immediate postoperative CT scans, and preoperative stereolithographic three-dimensional mirrored-printed orbital models for patients in the group treated with standard preformed implants. Additionally, surgical procedures were performed via transcutaneous or transorbital routes. All patients underwent radiographic follow-up one day postoperatively and had three clinical follow-up visits at one week, four weeks, and twelve weeks. Orbital volume, corneal projection, motility restriction, visual acuity, diplopia, and implant contour analysis were used as calipers to evaluate the accuracy of orbital reconstruction.
Results: Using 3D titanium orbital plates in reconstructive surgery for orbital wall fractures resulted in significantly more accurate restoration of orbital volume than conventional titanium mesh ($p = 0.04$). It also showed a stronger inverse correlation with Hertel exophthalmometry ($r = -0.60$, $p = 0.048$) and significantly reduced operative time ($p < 0.001$).
Conclusion: 3D titanium orbital plates provide a more accurate and straightforward method for repairing orbital floor and medial wall fractures, minimizing surgical time, enabling more precise anatomical reconstruction, and allowing for quicker surgeries.

Keywords: Orbital trauma, 3D orbital reconstruction, 3D anatomical orbital plate, virtual surgical planning.

INTRODUCTION

Orbital wall fractures are a frequent result of maxillofacial trauma, making up about 30–40% of such fractures[1]. The etiology varies geographically, with assaults, traffic accidents, sports injuries, and falls being the most common worldwide. Diplopia and enophthalmos are among the typical complications, and their optimal treatment continues to be a topic of ongoing discussion[2]. Orbital fractures most commonly affect the weakest parts of the orbit, particularly the medial wall and the orbital floor. Disruption of the orbital wall allows soft tissues to herniate into nearby sinuses, increasing orbital volume and causing enophthalmos and hypoglobus. Muscle entrapment may also occur, leading to restricted eye movement and diplopia, with possible involvement of neural, vascular, or lacrimal structures.[3]

Restoring the preinjury three-dimensional bony anatomy is crucial for achieving optimal cosmetic and functional recovery of the orbit. Therefore, selecting the appropriate reconstructive material is a vital part of the treatment. Titanium mesh implants are commonly used for repairing significant orbital defects because they offer reliable structural support, reduce postoperative displacement, and enable satisfactory results correction[4,5].

3D anatomical orbital plates represent a recent advancement in the development of preformed, ready-made orbital implants. Its relatively rigid posterior

segment is intended to re-establish the contour of the posterior orbital floor and to assist in maintaining proper globe position. Its S-shaped configuration reflects the natural curvature of the orbital floor and approximates the typical angulation of this region. A preformed posterior retrobulbar convexity is incorporated into the design, providing structural support in a critical load-bearing area of the orbit. This feature is considered essential for reconstructing the "key area" while maintaining globe projection and may help reduce the likelihood of postoperative enophthalmos.[5]

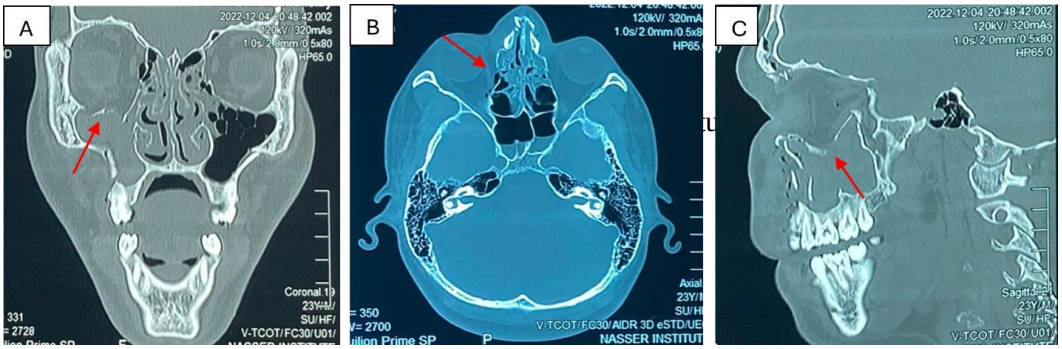
This study aimed to compare the reconstructive accuracy of two titanium orbital implant designs in cases of unilateral orbital wall fractures: a standard preformed titanium mesh adapted to virtually constructed, contralateral-mirrored 3D-printed models, and an anatomically pre-bent 3D plate, to identify a precise and clinically oriented approach for traumatic orbital reconstruction.

MATERIALS AND METHODS

Study design

Eighteen trauma patients with either pure or impure unilateral orbital fractures were included in this study from February 2022 to September 2024. The patients were selected from the Emergency and Outpatient Clinic of the Oral and Maxillofacial Surgery Department at Nasser Institute Hospital in Cairo, Egypt. After confirming eligibility, participants were randomly assigned to two groups using simple randomization. Allocation concealment was maintained by an independent staff member who prepared an opaque container holding an equal number of identical sealed slips labeled Group A or Group B. The container was reshuffled before each draw, and group assignment was determined immediately before the intervention by drawing a single slip for each participant. Surgeons and outcome assessors were blinded to the allocation process. The randomization procedure adhered to CONSORT guidelines. Due to the nature of the surgical intervention, the operating surgeons were aware of the implant type. However, postoperative radiographic measurements and clinical outcome assessments were performed by an independent evaluator who was blinded to the treatment allocation to minimize measurement bias. The inclusion and exclusion criteria are listed in Supplementary Table 1. Ethical approval was granted by the institutional ethics committee (approval number 454/2022). All procedures followed the Helsinki Declaration and its subsequent amendments, and written informed consent was obtained from all participants before enrollment.

Before enrollment, each patient underwent a comprehensive assessment comprising medical history, injury mechanism, post-trauma neurological status, prior facial skeletal surgeries, presenting complaints, fundus examination, and the interval between injury and indication for surgery. Preoperative evaluation involved high-resolution multislice computed tomography (CT). Axial, coronal, and sagittal images were obtained according to the standard CT protocol for orbital trauma.[6] CT data were exported in Digital Imaging and Communications in Medicine (DICOM) format and imported into surgical planning software (Mimics®, Materialise Medical NV, Leuven, Belgium; 2021) for image processing and analysis. Orbital fractures were evaluated to identify whether only the orbital floor was affected or if there were also medial and/or lateral orbital wall fractures. (Fig. 1)



Figur 1. Preoperative CT scan showing combined orbital floor and medial wall fractures on the right side in coronal (A), axial (B), and sagittal (C) views.

Soft-tissue entrapment through orbital fractures was evaluated using CT soft-tissue window settings with fat and muscle thresholding to determine the presence, morphology, and direction of muscle entrapment or incarceration, with particular focus on the inferior rectus, inferior oblique, and medial rectus muscles.

Surgery protocol

All surgeries were performed under general anesthesia following standard oral and maxillofacial surgery protocols.

The eyes were protected with ophthalmic ointment, and the contralateral eye was taped. Local infiltration of epinephrine ($1:10^4$) was administered at the planned incision sites for hemostasis. An intraoperative forced duction test was performed to assess extraocular muscle motility.

Orbital floor exposure was achieved through subciliary, subtarsal, or transconjunctival incisions. Combined medial wall and floor exposure was performed via a transconjunctival approach with retrocaruncular extension. The periosteum was incised and elevated, and subperiosteal dissection of the orbital floor and medial wall was performed posteriorly to identify fracture margins. Posterior dissection was limited to the orbital plate of the palatine bone for the floor, and to the posterior ethmoidal artery for the medial wall. The infraorbital neurovascular bundle was preserved, with careful release of adherent soft tissues when needed. Prolapsed or entrapped orbital contents were mobilized and repositioned into the orbital cavity. A stable posterior ledge was defined to support implant placement.

Orbital reconstruction was carried out using either anatomically preformed 3D titanium plate (Group A; Stryker Craniomaxillofacial, Kalamazoo, MI, USA) (Fig. 2) or standard preformed titanium mesh (Group B; Anton Hipp GmbH, Germany) (Fig. 3). In Group A, a side-specific 3D plate (Right/Left) was inserted by first positioning the medial wall component, then rotating and advancing it until the medial segment was posterior to the posterior lacrimal crest, with posterior support on the orbital plate of the palatine bone and anterior support on the inferior orbital rim. The implant did not require bending or contour modification, aside from minor adjustments to the fixation arms when needed. In Group B, the preformed titanium mesh was cut to size and preoperatively adapted to a virtually designed, contralateral, mirrored 3D-printed orbital model. It was then positioned to span the orbital defect, providing similar support anteriorly and posteriorly. Fixation was achieved with two 1.7-mm titanium monocortical screws inserted into the inferior orbital rim.

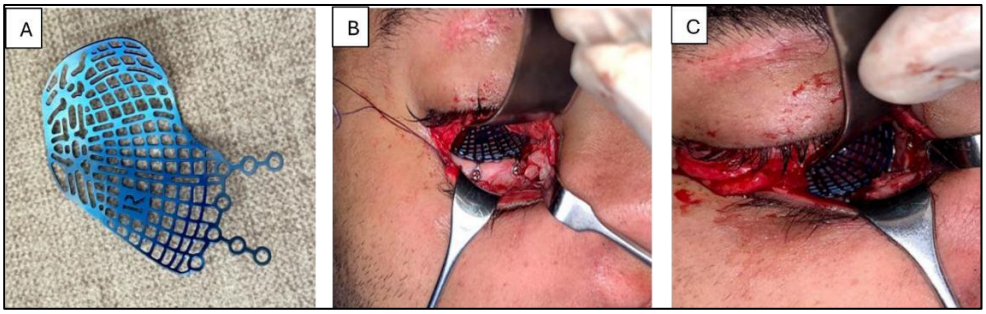
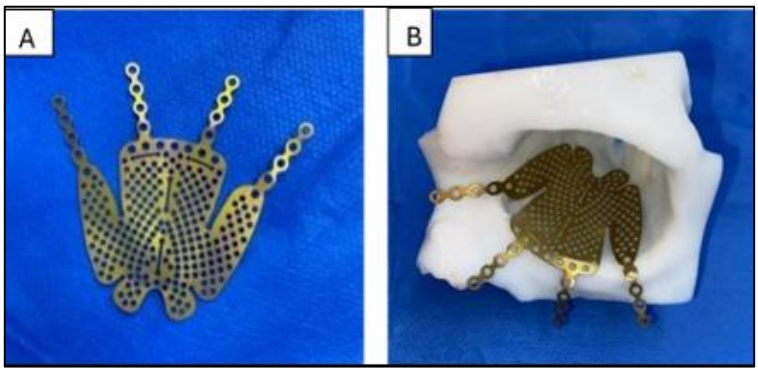


Figure 2. Right side Orbital reconstruction using an anatomically preformed 3D titanium plate (Group A). (A) Preformed anatomical orbital plate. (B) Plate positioned along the orbital floor. (C) Implant extending to support the medial orbital wall.



Figur.3 Orbital reconstruction of left side using standard preformed titanium mesh (Group B). (A) Preformed titanium mesh. (B) Preoperative adaptation of the mesh on a mirrored 3D-printed orbital model.

In all patients, a forced duction test was performed before wound closure to confirm the globe's free movement. Postoperative CT scans were analyzed using the same method previously described to evaluate implant positioning and reconstruction accuracy. The evaluation focused on complete defect coverage, stable bony support, and the extent to which the implants conformed to the reconstructed orbital walls for both types. (Fig. 4) Patients were monitored clinically at 1 week, 6 weeks, and 6 months post-surgery, with all complications documented. A

comparative analysis of pre- and postoperative orbital volume and corneal projection was performed, and changes in diplopia over time were evaluated to determine correction or improvement.

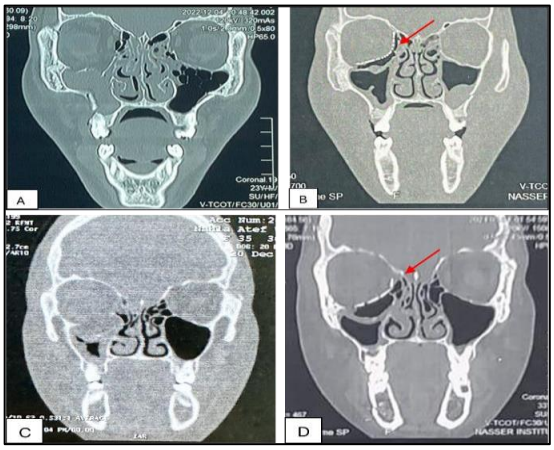


Figure 4. Coronal CT images demonstrating preoperative and postoperative reconstruction of orbital floor and medial wall fractures. The 3D anatomical plate shows better conformity to the medial orbital wall (A, B) compared with the preformed titanium mesh (C, D). Arrows indicate implant placement and anatomical adaptation.

Outcome measures

The primary outcomes were the evaluation of the interventional effects of both implant designs on orbital volume (ΔOV) and corneal projection (Hertel Exophthalmometry) in reconstructed orbits, assessed before and after surgery. Secondary outcomes included radiographic evaluation of the orbital implant's contour and positioning, clinical assessment of extraocular muscle movement and diplopia, intraoperative handling characteristics of each implant design, and operative time associated with implant manipulation. Orbital volume on the fractured side was calculated using surgical planning software (Mimics, Materialise Medical NV, Leuven, Belgium; version 2021). The bony orbital cavity was segmented on axial CT slices, with refinement on coronal and sagittal reconstructions. The anterior boundary was defined by the orbital rims, including the medial (anterior lacrimal crest) and lateral margins, while the posterior boundary matched the anterior edge of the optic canal. Herniated orbital contents were included in the preoperative volumetric measurements. Volumetric analysis was performed after creating a three-dimensional reconstruction of the segmented orbit using the cavity-filling tool[7]. The overall orbital volume was measured in mm^3. (Fig. 5).

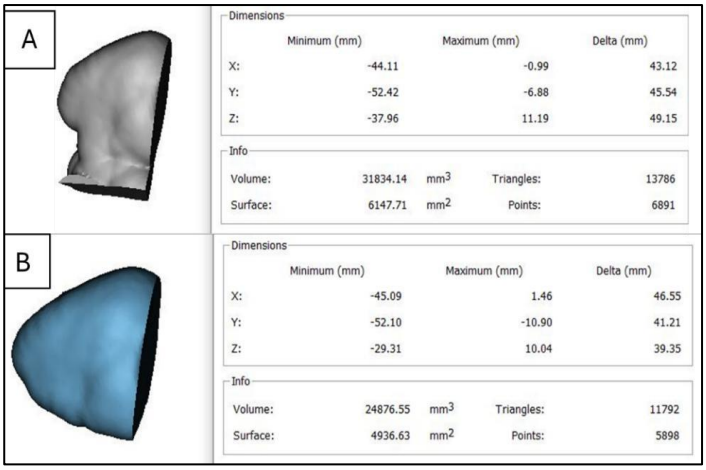


Figure 5. Three-dimensional CT-based orbital volume analysis. (A) Preoperative orbital defect. (B) Postoperative reconstruction demonstrating restoration of orbital volume.

Corneal projection was measured before and after surgery using CT-based Hertel Exophthalmometry on axial CT images. The axial slice showing the largest front-to-back globe diameter was chosen. A reference line was drawn from the front edge of the unaffected side's lateral orbital rim, perpendicular to the craniofacial midline. The linear

distance from the most anterior point of the corneal surface to this reference line indicated the globe position[8]. The inter-side difference was considered the degree of enophthalmos on the affected side (Fig. 6).

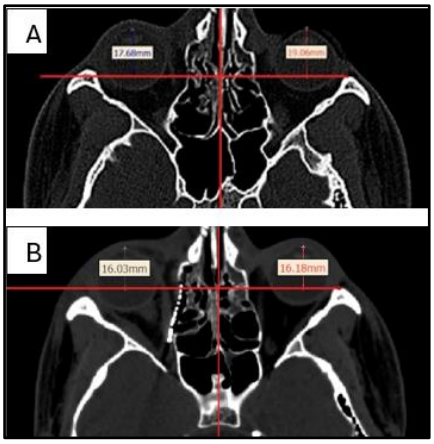


Figure.6 CT-based Hertel exophthalmometry measurements demonstrating improvement in globe projection following orbital reconstruction. (A) Preoperative measurement. (B) Postoperative measurement.

Diplopia was evaluated based on the subjective report of double vision in at least one direction of gaze, regardless of severity[9]. Pre-and postoperative external photographs of the nine cardinal gaze positions were taken in fully conscious patients. Ocular motility was considered normal when eye movements were unrestricted in all directions relative to the contralateral eye (Fig. 7).

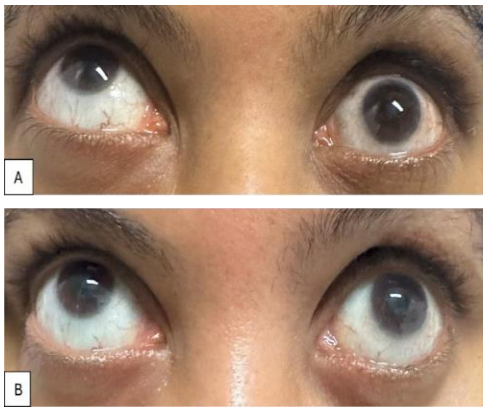


Figure.7 Clinical photographs of the cardinal gaze positions. (A) Preoperative limitation of upward gaze with associated enophthalmos. (B) Postoperative improvement in ocular motility and globe position.

Implant-related operative time was defined as the period from the completion of orbital bony exposure and dissection to the final fixation of the orbital implant in place. Time was recorded during surgery for each case and analyzed to assess the efficiency of each implant design.

Statistical analysis

Statistical analyses were performed using GraphPad Prism (GraphPad Software, San Diego, CA). Continuous variables are presented as median and interquartile range. Paired data were analyzed with the two-tailed Wilcoxon signed-rank test, while unpaired data were assessed using the two-tailed Wilcoxon rank-sum (Mann–Whitney U) test. The relationship between postoperative orbital volume and Hertel exophthalmometry was evaluated using a two-tailed Spearman rank correlation coefficient. Statistical significance was defined as a p-value less than 0.05. Because the study involved a limited number of predefined outcome variables, correction for multiple comparisons was not applied.

RESULTS

The study included eighteen patients (11 males, 61.1%; 7 females, 38.9%) with an average age of 28.9 years (range 19–60). The primary cause of injury was road traffic accidents (77.8%). Across all patients, the mean time from injury to surgery was 7 days. All had orbital floor fractures, with 55.6% involving the medial wall and 44.4% having isolated floor fractures. Concomitant facial fractures occurred in 61.1%, mainly zygomaticomaxillary complex fractures (50.0%). Preoperative assessments showed hypoglobus, enophthalmos, extraocular muscle entrapment, diplopia, and infraorbital nerve hypoesthesia in 38.9%, 50.0%, 44.4%, 50.0%, and 61.1% of cases, respectively.
Postoperative orbital volume was significantly reduced compared with the preoperative state in both reconstruction techniques. However, volume restoration achieved with the anatomical 3D plate was substantially different from that obtained with the conventional preformed titanium mesh (p = 0.04). In contrast, the difference between the preoperative and conventional implant groups did not reach statistical significance (*p* = 0.09). (Fig. 8)

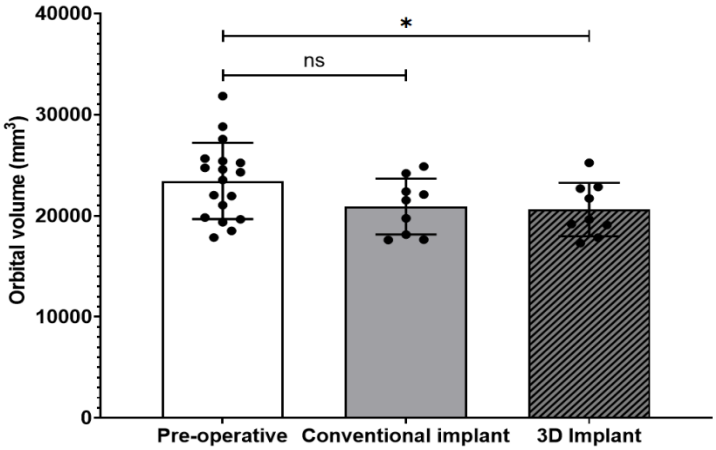


Figure. 8 Orbital volume measurements before reconstruction (n = 18) and after reconstruction using titanium mesh (Group B, n = 9) or anatomically preformed 3D plate (Group A, n = 9). *P < 0.05 indicates statistical significance for postoperative comparison between groups.

Assessment of globe position using Hertel Exophthalmometry revealed a significant postoperative improvement in both groups. Compared with the preoperative measurements, Hertel Exophthalmometry values increased significantly following reconstruction with the titanium mesh (*p* = 0.03) and the 3D anatomical plate (*p* = 0.04), indicating effective correction of enophthalmos. (Fig. 9)

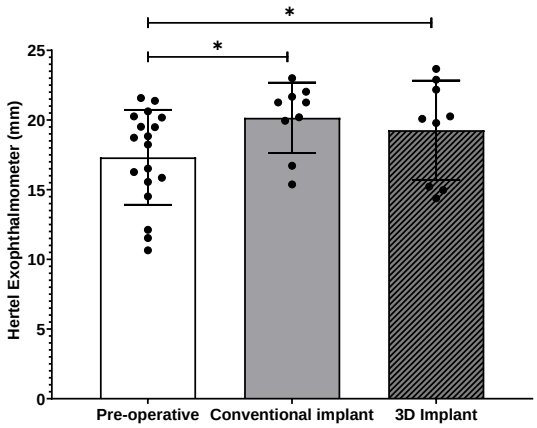


Figure. 9 Hertel exophthalmometry measurements before and after orbital reconstruction using titanium mesh (Group B) or anatomically preformed 3D plate (Group A). *P < 0.05 indicates statistical significance.

Correlation analysis showed an inverse relationship between postoperative orbital volume and Hertel Exophthalmometry. This association was moderate but not statistically significant in the titanium mesh group (Spearman r = −0.48, p = 0.13). In contrast, the 3D anatomical plate group exhibited a stronger, statistically significant inverse correlation (r = −0.60, p = 0.048), indicating more predictable globe projection with better volumetric restoration (Fig. 10).

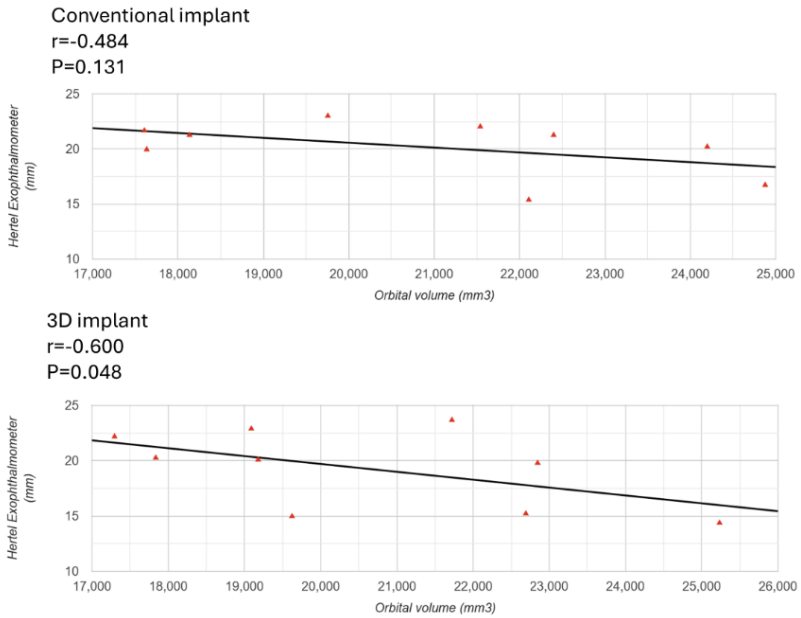


Figure.10 Scatter plots showing the correlation between postoperative orbital volume and Hertel exophthalmometry in the titanium mesh group and the anatomically preformed 3D plate group. A non-significant inverse correlation was observed in the titanium mesh group ($r = -0.48$, $p = 0.13$), whereas a significant inverse correlation was identified in the 3D plate group ($r = -0.60$, $p = 0.048$).

Operative time for implant adaptation and positioning was significantly shorter in the 3D anatomical plate group than in the titanium mesh group ($p < 0.001$), highlighting the procedural efficiency of the 3D anatomical plate design (Fig. 11).

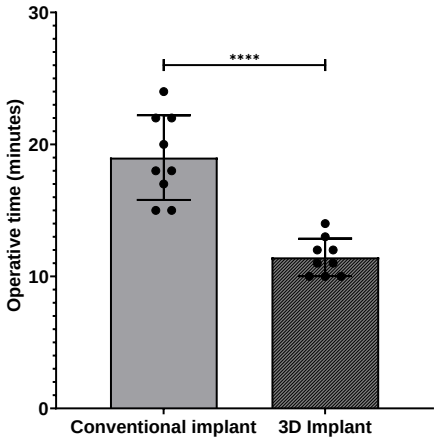


Figure. 11 Comparison of implant-related operative time between titanium mesh (Group B) and anatomically preformed 3D plate (Group A) reconstruction. ****P < 0.0001.

The ophthalmological assessment of extraocular motility and diplopia at 1 week, 6 weeks, and 6 months showed significant improvement over time in both groups, with no notable differences between groups ($p > 0.05$). In Group A, ocular motility restriction decreased from 4 patients (44.4%) at 1 week to 1 patient (11.1%) at 6 weeks, with complete resolution by 6 months (Friedman test, $p = 0.009$). A similar pattern was seen in Group B, declining from 5 patients (55.6%) to 2 (22.2%) and 1 (11.1%) across follow-ups (Friedman test, $p = 0.006$). Diplopia was present in all patients at 1 week. It improved significantly over time, with only one patient in group (B) experiencing it at 6 months, limited to extreme lateral gaze (Friedman test, $p < 0.001$). No significant differences between groups were observed ($p > 0.05$).

DISCUSSION

Orbital wall fractures are common in facial trauma and require adequate structural support because of their unique healing properties. Even isolated blowout fractures should not be overlooked, as the orbit is a complex three-dimensional structure. Accurate reconstruction is crucial to restore function and prevent complications such as diplopia, visual impairment, and enophthalmos.[10]

The present study primarily aimed to evaluate the clinical and radiographic accuracy of anatomically preformed 3D orbital plates compared with conventional preformed titanium mesh in orbital fracture reconstruction.

The choice of material for orbital reconstruction remains controversial, as no single option meets all anatomical and biomechanical needs. Therefore, material selection is usually tailored to the fracture pattern, defect size, surgeon experience, and the requirement for precise restoration of orbital volume and contour, rather than following the standard approach guideline.[11]

The development of titanium mesh implants for orbital reconstruction has advanced through multiple stages. Early methods relied on intraoperative trimming and manual shaping of flat meshes to match the orbital anatomy.[12,13] Subsequent advances introduced individually preformed meshes generated by computer-assisted stereolithography and placed using navigation guidance.[14,15] This approach developed into population-based preformed orbital plates derived from CT datasets of the general population, providing an average anatomical approximation and minimizing intraoperative manipulation.[16] Recently, the field has shifted toward patient-specific implants, which are digitally designed and custom-manufactured based on individualized three-dimensional orbital models, providing the highest level of anatomical accuracy. The inherent flexibility of titanium facilitates restoration of the native internal orbital contours, which is especially critical in complex fracture patterns involving multiple orbital area walls.[17]

Patient-specific implants offer high functional and aesthetic precision; however, when there is no pre-existing deformity or previous surgery, variation in orbital floor anatomy among individuals is minimal. Due to the higher cost, longer planning time, and logistical complexity of virtual design and stereolithographic fabrication, routinely using patient-specific implants in all cases is currently impractical.

Over the past decade, 3D pre-bent orbital plates have been developed to enable precise anatomical reconstruction of complex orbital floor and medial wall defects.[18,19] These implants leverage the relatively predictable contours and fracture patterns of the orbital floor and medial wall, eliminating the need to bend flat titanium meshes into complex shapes during surgery, while providing equal or better orbital volume restoration.[20]

In the current study, anatomically pre-bent 3D orbital plates were compared with standard preformed titanium meshes fitted to contralateral mirrored 3D-printed models. Both represent commonly used, commercially available implant options in modern oral and maxillofacial orbital reconstruction. This comparison reflects real-world clinical decision-making and provides a practical evaluation of implant performance in routine surgical practice.

In line with previous studies, the current study demonstrated that intraoperative bending of preformed titanium meshes on 3D-printed models can approximate orbital anatomy. However, 3D preformed orbital plates are industrially designed to replicate the native contours of the orbital floor and medial wall, including a built-in posterior infero-medial retrobulbar bulge, thereby enabling more consistent anatomical restoration of the “Hammer key area”.[21,22]

The present study demonstrated that both reconstruction techniques resulted in a reduction in orbital volume compared with the preoperative condition (ΔOV), consistent with previous studies.[7,21,23,24] However, the anatomical 3D plates achieved significantly better volume restoration than the conventional preformed titanium meshes ($p = 0.04$), whereas the latter did not differ significantly from preoperative values ($p = 0.09$). This improved volumetric correction was accompanied by better restoration of globe projection, as ascertained by Hertel Exophthalmometry measurements, with the 3D anatomical plate showing a stronger and statistically significant inverse correlation between orbital volume and globe projection ($r = -0.600$, $p = 0.048$), in contrast to the nonsignificant correlation observed with conventional implants ($r = -0.484$, $p = 0.131$).

Additionally, in line with previous studies, the use of the pre-bent three-dimensional implant was associated with a significantly shorter operative time than the conventional technique ($p < 0.001$), indicating improved intraoperative efficiency.[24] These findings suggest that anatomically preformed orbital plates may simplify intraoperative handling and improve surgical efficiency in orbital fracture reconstruction.

Regarding diplopia and extraocular motility, no significant differences between groups were observed ($p > 0.05$). The absence of intergroup differences suggests

that postoperative ocular motility and diplopia are primarily influenced by surgical technique—particularly adequate exposure, precise implant placement, and avoidance of soft-tissue impingement—rather than implant type, provided that early surgical repair is performed and no neurological deficits are present. In our series, residual diplopia limited to extreme upward gaze was observed in one patient and was not considered clinically significant; this likely reflected fracture severity or extraocular muscle ischemia or fibrosis, consistent with previous reports.[25,26] In the present study, diplopia assessment was based on clinical examination and patient-reported symptoms rather than a standardized scoring system. Future studies may benefit from incorporating validated scoring systems such as the Gorman diplopia score to improve reproducibility and inter-study comparison.

In accordance with previous studies, the choice of surgical approach in orbital reconstruction remains a critical factor influencing both exposure and postoperative outcomes.[27] In the present study, the surgical approach was selected according to fracture pattern, defect extent, and associated midfacial injuries to ensure adequate exposure and safe orbital manipulation. The most commonly used approach was the combined transconjunctival–retrocaruncular approach with lateral canthotomy (27.8%), followed by the transconjunctival approach with retrocaruncular extension (16.7%). Transcutaneous approaches were used less frequently, with subciliary and subtarsal incisions each accounting for 22.2%, whereas subtarsal with Lynch and transconjunctival with lateral canthotomy approaches were used in 5.6% of cases. No major approach-related complications, such as ectropion, entropion, or eyelid malposition, were observed.

The transconjunctival incision with retrocaruncular extension offered a highly aesthetic approach for combined orbital floor and medial wall fractures because the incisions are concealed; however, it requires a steeper learning curve compared with subciliary or subtarsal approaches. Although concerns have been raised regarding potential complications such as inferior oblique dysfunction, inferior canalicular obstruction, scarring, and postoperative diplopia, no technique-related complications were observed in our series, consistent with previous reports.[28,29] This approach provides excellent visualization within the limited operative field while minimizing tissue traction.

In line with previous literature[30], Several technical factors are critical to avoid complications during the placement of anatomically preformed 3D orbital plates. Due to their larger size, adequate exposure is often achieved by adding a retrocaruncular extension to the transconjunctival approach, allowing safe implant insertion while minimizing soft-tissue interference. Precise seating of the posterior plate margin on the orbital process of the palatine bone is essential to prevent displacement into the maxillary sinus. Lateral overextension onto the lateral orbital wall should be avoided to prevent medial orbital intrusion. In addition, the implant should be positioned medial to the posterior lacrimal crest to ensure stable reconstruction and avoid impingement on the lacrimal sac.

Our data aligned with a previous publication showing that anatomically preformed three-dimensional orbital plates better match the natural contours of the orbital floor and medial wall, providing improved intraoperative handling compared to traditional prefabricated plates.[31]

While conventional titanium meshes can be manually shaped during surgery to approximate orbital anatomy, their final contour may be inconsistent, particularly in fractures involving the medial orbital wall. Anatomically preformed 3D orbital plates are designed to replicate native orbital contours and may therefore provide more predictable restoration of orbital volume and symmetry while reducing operative time. In addition, these implants eliminate the need for extensive intraoperative contouring and avoid the time-consuming processes associated with virtual surgical planning and patient-specific implant fabrication in acute trauma settings.

The main limitation of this study is the relatively small sample size, reflecting the strict inclusion criteria and the clinical nature of the randomized surgical design. Although significant differences were observed in orbital volume restoration and operative time, the limited sample size may reduce the ability to detect differences in secondary outcomes such as diplopia or ocular motility. In addition, the six-month follow-up period may not fully capture long-term implant stability or delayed postoperative enophthalmos. Future multicenter studies with larger patient cohorts and longer follow-up periods are recommended to further validate these findings.

CONCLUSION

Orbital reconstruction is an art of anatomical precision. Accurate anatomical reconstruction is essential for restoring orbital function and aesthetics following orbital wall fractures. In this study, anatomically preformed 3D titanium plates demonstrated superior orbital volume restoration and improved globe projection compared with conventional preformed titanium mesh, while also reducing operative time. These findings suggest that anatomically preformed 3D orbital plates represent an efficient and reliable option for orbital fracture reconstruction.

Author contributions: All authors contributed to the study conception and design. Mohamed Abdelwahab handled material preparation, data collection, data analysis, and drafted the first version of the manuscript. Fahmy Mubarak, Mohamed Sholkamy, and Mohamed Saied critically revised the manuscript for important intellectual content. All authors read and approved the definitive version of the manuscript.

DECLARATION

Funding: The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Data availability: No datasets were generated or analyzed during the current study.

Ethical approval: Ethical approval was obtained from the institutional ethics committee (approval number 454/2022).

Clinical trial number: PACTR202511716966699.

Consent to participate: All procedures were conducted in compliance with the Helsinki Declaration and its subsequent amendments, and written informed consent was obtained from all participants prior to enrollment.

Consent for publication was obtained for every person's data included in the study.

Competing interests: The authors declare no competing interests.

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Supplementary Table 1: The study inclusion and exclusion criteria.

Inclusion criteria
▪ Adult cases of both genders (18-60 years old) indicated for ipsilateral primary internal orbital reconstruction. ▪ Either pure or impure orbital fractures. ▪ Fractures of the orbital floor and/or medial wall.
Exclusion criteria
▪ Patients with severe underlying systemic disease (American Society of Anesthesiologists III and IV) were excluded from this study. ▪ Patients with bilateral orbital fractures. ▪ Fracture of the orbital roof. ▪ Craniofacial malformations and Facial asymmetry. ▪ Injury to the globe that restricts surgical reconstruction (e.g., retinal detachment, globe rupture, or traumatic optic neuropathy).