



(REVIEW ARTICLE)



ORBITAL FLOOR RECONSTRUCTION: A COMPREHENSIVE REVIEW OF SURGICAL APPROACHES AND RECONSTRUCTIVE MATERIALS

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International Journal of Science and Research Archive, 2026, 21(01), 206–213

Publication history: Received on 30 August 2026; revised on 06 October 2026; accepted on 08 October 2026

Article DOI: <https://doi.org/10.30574/ijrsra.2026.21.1.1869>

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ABSTRACT

Orbital floor fractures are common components of midfacial trauma and may produce diplopia, enophthalmos, ocular motility disturbance, infraorbital sensory change, and aesthetic deformity when orbital volume and wall anatomy are not adequately restored. Orbital floor reconstruction therefore requires integration of clinical findings, computed tomography, fracture morphology, timing of intervention, surgical access, and implant selection. This narrative review synthesizes the principal concepts contained in a comprehensive dissertation on orbital floor reconstruction, including orbital anatomy and biomechanics, fracture classification and mechanisms, clinical and radiological assessment, indications and timing of repair, surgical approaches, reconstructive biomaterials, postoperative care, complications, and recent digital advances. The review emphasizes that clinical examination remains central to treatment planning, while computed tomography defines defect morphology, herniation, associated wall involvement, and the three-dimensional reconstructive target. Transconjunctival, transcutaneous, transantral, endoscopic, and combined approaches each have specific indications and morbidity profiles. Autogenous grafts, titanium, porous polyethylene, resorbable polymers, and customized implants remain important reconstructive options. Contemporary computer-assisted planning, patient-specific implants, navigation, and three-dimensional printing may improve geometric accuracy in selected complex, comminuted, delayed, or secondary reconstructions, although cost, workflow, technical expertise, and heterogeneous evidence remain relevant limitations. Successful reconstruction is therefore based on restoration of orbital boundaries and volume while preserving ocular function and minimizing surgical morbidity.

Keywords: Orbital floor fracture; Orbital reconstruction; Blowout fracture; Orbital implants; Titanium mesh; Patient-specific implant; Virtual surgical planning; Three-dimensional printing

1 INTRODUCTION

Orbital trauma represents a demanding area of maxillofacial surgery because injury may affect vision, ocular motility, orbital volume, facial sensation, and the appearance and position of the globe. Orbital wall fractures may occur in isolation or as components of zygomaticomaxillary complex, naso-orbito-ethmoid, or Le Fort injuries. The orbital floor is particularly vulnerable because of its thin bony architecture, the course of the infraorbital canal, and its characteristic

curvature from the anterior floor toward the posterior ledge. Inadequate restoration of orbital anatomy can result in persistent diplopia, enophthalmos, hypoglobus, vertical dystopia, sensory disturbance, and aesthetic deformity.[1-6]

The supplied dissertation emphasizes that orbital reconstruction should be approached with the same attention to anatomic detail used for repair of the orbital rims. Clinical indicators such as muscle entrapment or incarceration, persistent diplopia, infraorbital paraesthesia, oculocardiac symptoms, enophthalmos, hypoglobus, and selected radiographic findings have historically been used to guide operative treatment.[5,6] Computed tomography (CT) is central to diagnosis and planning because it demonstrates fracture configuration, herniation, posterior extension, and associated orbital-wall or facial fractures.[7]

The purpose of this narrative review is to provide a clinically oriented synthesis of orbital floor reconstruction, integrating the anatomy, mechanisms, assessment, indications, operative approaches, reconstructive materials, postoperative management, complications, and contemporary computer-assisted techniques described in the dissertation.

2 REVIEW METHODOLOGY

This manuscript is a narrative review derived primarily from the supplied dissertation, which contains a broad anatomical, clinical, surgical, biomaterial, and historical discussion of orbital floor reconstruction. The dissertation references were reorganized into Vancouver-style numerical citations and the material was condensed to meet the recommended length and structure for a review article. Contemporary literature already incorporated into the journal-oriented narrative review was retained where it directly addressed radiographic indications, patient-specific implants, digital planning, navigation, three-dimensional printing, and newer reconstructive materials. This was not designed as a systematic review; therefore, no claim of systematic database searching, formal risk-of-bias assessment, or meta-analysis is made in this manuscript.

3 ANATOMY AND BIOMECHANICAL CONSIDERATIONS

The orbit is a pyramidal cavity whose walls are formed by several bones and whose floor is composed predominantly of the orbital surface of the maxilla, with contributions from the zygomatic and palatine bones. The orbital floor is separated from the maxillary sinus by a thin bony partition and is traversed by the infraorbital canal and neurovascular bundle. The floor is relatively concave immediately posterior to the orbital rim and becomes more convex posteriorly, where the thicker posterior ledge provides important support for an orbital implant.[8,9]

The orbital anatomy described in the dissertation includes clinically important relationships with the inferior rectus and inferior oblique muscles, the infraorbital nerve, the inferior orbital fissure, and the medial orbital wall. The anterior ethmoidal canal, posterior ethmoidal canal, and optic canal require particular attention during deep medial orbital dissection. The dissertation notes that the anterior ethmoidal canal lies approximately 21 mm from the medial orbital edge, the posterior ethmoidal canal approximately 14 mm posterior to it, and the optic canal approximately 7 mm beyond the posterior ethmoidal canal.[8]

Successful reconstruction has two linked objectives: restoration of the bony boundary and restoration of orbital volume and three-dimensional contour. Enlargement of orbital volume can permit posterior displacement of the globe and contribute to enophthalmos or hypoglobus. An implant therefore must cover the defect, remain stable, preserve the intended orbital contour, and avoid entrapment or compression of orbital soft tissues.[1,8,10]

4 EPIDEMIOLOGY AND FRACTURE CLASSIFICATION

Orbital fractures are common facial injuries and occur frequently in association with road-traffic injuries, interpersonal violence, falls, sports injuries, and other blunt trauma. Isolated internal orbital fractures have been reported as a proportion of facial fractures, while the incidence is substantially higher when fractures of the zygomaticomaxillary complex and naso-orbito-ethmoid region are included.[11]

Orbital fractures may be broadly divided into pure and impure fractures. Impure fractures involve the orbital rim as well as the internal orbit and include zygomatico-orbital, naso-orbito-ethmoid, Le Fort-associated, and supraorbital-rim injuries. Pure fractures, commonly termed blowout fractures, involve the internal orbital walls without an associated rim fracture. The dissertation further describes three internal patterns: linear, blowout, and complex fractures.[11]

Linear fractures generally preserve periosteal attachments and may not produce substantial herniation. Blowout fractures commonly involve the floor and/or medial wall. Complex internal orbital fractures involve two or more walls

and may extend toward the posterior orbit, optic canal, or orbital apex. In impure fractures, restoration of the orbital rim and facial framework is performed before definitive internal orbital reconstruction.[11]

5 MECHANISMS OF ORBITAL FLOOR FRACTURE

Three principal mechanisms have historically been proposed for orbital blowout fractures: the hydraulic theory, the globe-to-wall contact theory, and the bone-conduction or buckling theory.[12-15]

The hydraulic theory proposes that a force applied to the globe causes posterior displacement and a rapid rise in intraorbital pressure, producing failure of the thin orbital floor and/or medial wall. The globe-to-wall theory proposes that posterior displacement causes the globe to contact and fracture the orbital wall. Bone-conduction theories emphasize transmission of force from the orbital rim, with transient deformation or buckling of the rim followed by fracture of the floor or medial wall.[12-15]

The mechanisms are not necessarily mutually exclusive. The resulting fracture pattern is influenced by the direction and magnitude of force, point of impact, orbital geometry, and characteristics of the surrounding facial skeleton.

5.1 Clinical and Radiological Assessment

Initial assessment must prioritize the globe and vision. Examination includes visual acuity, pupillary responses, ocular motility, diplopia, globe position, anterior segment and fundus assessment when indicated, infraorbital nerve function, and evidence of orbital compartment syndrome or retrobulbar haemorrhage. Severe visual impairment, an afferent pupillary abnormality, marked proptosis, a tense orbit, or other signs of acute orbital compromise warrant urgent ophthalmic and surgical evaluation.[16,17]

Infraorbital nerve injury is common because the nerve traverses the orbital floor in the infraorbital sulcus and canal. Sensory disturbance may involve the cheek, lateral nose, upper lip, and maxillary teeth and gingiva.[18] Globe displacement may manifest as enophthalmos or hypoglobus when orbital volume is increased. The dissertation notes that relatively small changes in orbital volume can produce clinically evident globe displacement.[4]

CT is central to diagnosis and operative planning. Coronal and sagittal reconstructions demonstrate defect location and extent, herniation of orbital contents, infraorbital canal involvement, posterior extension, associated medial-wall or rim injury, and the relationship of the fracture to the inferior rectus. Importantly, a CT scan without obvious muscle entrapment does not exclude clinically significant restriction; physical examination remains essential.[7,19]

5.2 Indications and Timing of Reconstruction

Management should be individualized according to symptoms, physical findings, fracture morphology, and the anticipated risk of delayed deformity. Common indications described in the literature include persistent or functionally significant diplopia attributable to the fracture, clinically significant enophthalmos or hypoglobus, proven muscle entrapment, oculocardiac symptoms associated with entrapment, and selected large or strategically located defects likely to alter orbital volume.[1,7,20]

Timing remains an area of clinical debate because some symptoms improve as oedema resolves, whereas prolonged soft-tissue displacement can be followed by fibrosis and scarring. A short period of observation may therefore be appropriate in selected patients with equivocal diplopia or minimal globe-position change when reliable follow-up is possible. Urgent or early treatment is appropriate when muscle entrapment produces functional compromise, severe oculocardiac symptoms, vision-threatening pathology, or another compelling clinical indication. Pediatric trapdoor fractures with entrapment require particular attention because significant muscle incarceration may occur despite limited external signs.[20,21]

Fracture size and orbital-volume change are useful risk modifiers, but the supplied contemporary review notes that published radiographic thresholds vary considerably. Clinical findings and the trajectory of ocular symptoms should therefore be interpreted together with CT findings rather than applying a single numerical threshold in isolation.[7]

6 PRINCIPLES OF ORBITAL FLOOR REPAIR

Successful reconstruction requires adequate exposure, identification of the fracture margins, release of herniated orbital contents, protection of the infraorbital nerve and extraocular muscles, accurate contouring or selection of the implant, stable positioning, and verification of globe mobility before closure.[1,8,22]

The reconstructive objective is not simply to cover the visible defect. The implant must recreate the three-dimensional boundaries of the orbit and restore appropriate orbital volume. Posterior support is particularly important because an implant that fails to engage stable posterior bone may migrate or fail to restore the intended orbital contour.[1,8]

In complex injuries, facial buttresses and the orbital rim should be restored before final internal orbital reconstruction. Intraoperative forced-duction testing can be used to identify mechanical restriction before closure and provides a functional check on the reconstruction.[22]

7 SURGICAL APPROACHES

Selection of surgical access should provide adequate visualization while minimizing morbidity to the eyelid, lacrimal system, infraorbital nerve, and orbital contents. The principal approaches described in the dissertation are transconjunctival, transcutaneous, transantral/endoscopic, and combined approaches. Choice depends on fracture location and size, associated rim or zygomatic injury, and the required field of exposure.

7.1 Transconjunctival Approach

The transconjunctival approach provides access to the orbital floor and infraorbital rim without an external skin incision. It may be performed through preseptal or retroseptal planes and can be extended with lateral canthotomy when broader exposure is required. Its principal aesthetic advantage is the absence of a visible cutaneous scar.[22-24]

Potential complications include conjunctival scarring, entropion, eyelid malposition, and canthal abnormalities when lateral canthotomy is added. Careful handling of the lower-lid retractors and appropriate closure are important.

7.2 Subciliary, Subtarsal, and Infraorbital Approaches

Transcutaneous approaches provide direct access to the infraorbital rim and floor. The subciliary approach offers broad exposure but has historically been associated with lower-eyelid retraction and ectropion. The subtarsal approach places the incision within or near a natural lower-eyelid crease and provides a balance between exposure and scar position. The infraorbital approach provides direct access but may produce a more conspicuous scar.[22,25]

Approach selection should therefore consider the required exposure as well as eyelid morbidity. Transcutaneous access remains useful when wider exposure or specific soft-tissue conditions make a cutaneous route appropriate.

7.3 Transantral and Endoscopic Approaches

Transantral techniques access the orbital floor through the maxillary sinus and may be performed endoscopically. They can provide a minimally invasive route for selected floor defects, particularly when access from the sinus side is advantageous. Limitations include restricted access to the anterior orbital rim and the technical requirements of endoscopic visualization and implant stabilization.[26-28]

7.4 Materials for Orbital Floor Reconstruction

Reconstructive materials can be divided into autogenous, allogeneic, xenogeneic, and alloplastic categories; alloplasts may be resorbable or nonresorbable. The ideal material should be biocompatible, stable, appropriately rigid or contourable, resistant to infection, compatible with surrounding tissues, and capable of maintaining orbital volume. No single material satisfies all desirable properties, so selection depends on defect size, location, wall involvement, soft-tissue condition, patient factors, surgeon experience, and available technology.[3,29-34]

Autogenous bone is biologically attractive because of its biocompatibility and potential for incorporation. Limitations include donor-site morbidity, additional operative time, limited quantity, and resorption. Cartilage may be useful for selected small defects but is less commonly used for extensive floor reconstruction.[29,33]

Nonresorbable alloplasts include titanium mesh, porous polyethylene, reinforced polyethylene, and other permanent materials. Titanium provides strength, radiopacity, and contourability, whereas porous polyethylene permits tissue ingrowth and is available in preformed configurations. Permanent materials can nevertheless be associated with infection, malposition, extrusion, or other late complications.[3,29,31]

Resorbable materials include polylactide, polyglycolide-derived materials, polyglactin, and polydioxanone. Their attraction is temporary support followed by degradation, potentially reducing long-term foreign-body burden. Limitations include variable mechanical strength, deformation, inflammatory responses during degradation, and uncertainty regarding whether support persists for the particular defect.[31,32]

8 PATIENT-SPECIFIC IMPLANTS AND DIGITAL RECONSTRUCTION

Digital technology has shifted orbital reconstruction from predominantly freehand contouring toward image-based planning and defect-specific reconstruction. Virtual surgical planning can be used to segment the injured orbit, mirror the contralateral orbit when appropriate, define target orbital volume and globe position, and design or select an implant. Intraoperative navigation can then translate the virtual plan into the operative field. The dissertation describes this workflow as a sequence of data acquisition, image manipulation, surgical transfer, and intraoperative or postoperative assessment.

Recent systematic reviews incorporated into the supplied narrative review have reported increasing evidence for customized orbital reconstruction. A 2022 systematic review evaluated customized orbital-wall products; a 2023 systematic review and meta-analysis examined patient-specific implants; and a 2024 systematic review and meta-analysis assessed technology-assisted planning, navigation, and customized implant designs.[35-37]

A 2026 systematic review included 23 studies and 1,222 subjects and reported improved measures of orbital-volume restoration, globe position, persistent diplopia, and revision in patient-specific groups compared with conventional reconstruction, while also noting higher initial cost. These findings should be interpreted in light of heterogeneity in study design, implant manufacturing, fracture complexity, and outcome assessment.[38]

Three-dimensional printed surgical guides provide another route for transferring virtual planning into reproducible intraoperative execution. A 2026 narrative review described potential improvements in implant positioning and restoration of orbital volume while emphasizing the need for standardized outcome and cost-effectiveness research.[39]

8.1 Postoperative Care

Postoperative management focuses on protection of the reconstruction, monitoring ocular function, control of oedema, and prevention of orbital and paranasal sinus complications. Serial examinations should assess visual acuity, pupillary function, ocular motility, globe position, and persistent or new diplopia. Head elevation and measures to limit swelling may be useful during the early postoperative period.[1,22]

Sinus precautions, particularly avoidance of forceful nose blowing and activities that markedly increase nasal pressure, are commonly recommended after orbital floor reconstruction. Antibiotics, corticosteroids, and nasal decongestants are used selectively according to institutional practice and patient-specific factors. Follow-up should be sufficiently long to identify delayed diplopia, enophthalmos, lower-eyelid malposition, infection, implant displacement, or other late complications.[1,22]

8.2 Complications

Complications may be ocular, orbital, eyelid-related, infectious, neurologic, or implant-related. Diplopia and ocular motility deficits may result from persistent muscle tethering, scar formation, implant malposition, or inaccurate restoration of the orbital walls. Enophthalmos may occur when orbital volume remains increased or when the implant fails to reproduce the appropriate three-dimensional contour. Lower-eyelid complications include retraction, ectropion, and entropion, with risk influenced by the surgical approach and tissue handling.[22,25,29]

Serious complications include retrobulbar haemorrhage, optic-nerve compromise, superior orbital fissure or orbital apex syndromes, carotid-cavernous fistula, infection, and misplaced or displaced hardware. Prevention depends on meticulous preoperative imaging, atraumatic dissection, protection of the globe and extraocular muscles, stable implant positioning, and appropriate postoperative surveillance.

8.3 Current Controversies and Future Directions

There is no universally accepted radiographic threshold that independently mandates orbital floor reconstruction. Fracture size and orbital-volume change should be interpreted together with clinical findings rather than used as isolated numerical triggers.[7]

No single reconstructive material is ideal for every defect. Material choice remains dependent on defect geometry, wall involvement, surgeon experience, patient factors, cost, and availability.[29-34] Future material research is focused on improved biocompatibility, mechanical behavior, controlled degradation, and defect-specific designs.

The increasing availability of patient-specific implants, virtual planning, navigation, and three-dimensional printing raises an important clinical question: when does additional geometric precision translate into clinically meaningful benefit? Current evidence suggests potential advantages in selected complex reconstructions, but heterogeneity and

resource requirements remain important considerations.[35-39] Future comparative studies should use standardized measures of orbital volume, globe position, diplopia, ocular motility, complications, operative time, cost, and revision rates.

Table 1: Practical comparison of commonly used orbital floor reconstruction materials

Material	Principal advantages	Important limitations	Typical role
Autogenous bone	Biocompatible; potential for incorporation; no permanent alloplastic implant	Donor-site morbidity; limited quantity; resorption	Selected defects where biologic grafting is desirable
Titanium mesh	High strength; radiopaque; contourable; widely available	Permanent implant; possible malposition or soft-tissue interaction	Large, irregular, or complex defects
Porous polyethylene	Tissue integration; preformed options; easy handling	Permanent material; infection or extrusion may occur	Selected isolated or combined defects
Resorbable polymers	Temporary support with subsequent degradation	Variable strength and degradation response	Selected defects with appropriate mechanical requirements
Patient-specific implants	Defect-specific contour; potential for accurate volume restoration	Cost; planning/manufacturing time; dependence on imaging and workflow	Complex, delayed, or secondary defects and selected primary reconstructions

9 CONCLUSION

Orbital floor reconstruction is an anatomy-driven and multidisciplinary procedure in which the principal objectives are restoration of orbital volume, support of orbital contents, preservation of ocular function, and prevention of delayed functional and aesthetic deformity. Clinical examination remains fundamental, while CT provides essential information regarding defect morphology, herniation, wall involvement, and operative planning.

Surgical approach and implant material should be selected according to fracture characteristics, associated injuries, patient factors, and the required degree of exposure. Titanium, porous polyethylene, autogenous grafts, and resorbable materials remain established options, while patient-specific implants, virtual surgical planning, navigation, and three-dimensional printing provide increasingly precise options for selected complex or secondary reconstructions. Further comparative research using standardized outcomes is required to clarify the clinical and economic role of advanced customized reconstruction.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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