Reconstruction of Orbital Floor Fractures Using Porous Polyethylene with Embedded Titanium Mesh

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Abstract

Purpose: To evaluate safety and efficacy of porous polyethylene with embedded titanium mesh in the reconstruction of fractured orbital floors.

Methods: Interventional case series study of twenty patients who underwent orbital floor reconstructions using 1.0-mm thick porous polyethylene with embedded titanium mesh for the repair of orbital floor fractures. A transconjunctival approach was used in 16 patients, subciliary incision in 3 cases and subtarasal approach in one case. Patients were followed-up for ocular projection, diplopia, and any complications.

Results: All twenty patients had improved diplopia and/or enophthalmos relative to their preoperative condition. Diplopia resolved in 11 patients (78.57%) and improved in the remaining 3 patients of 14 patients with pre-operative significant diplopia. Enophthalmos was corrected to within 2mm of the opposite eye in seven out of nine cases (77.77%) and improved in the remaining two cases. There was no postoperative diplopia worse than before surgery. Also there was no volume over-correction resulting in proptosis. No major complication with potential loss of vision, implant infection, or migration was noted over 6 months of follow-up. Complications included lower lid ectropion in one case, infraorbital hypoesthesia in another patient, lower lid retraction in two cases and palpable screw in two cases.

Conclusion: Porous polyethylene with embedded titanium mesh is safe and highly effective in the reconstruction of orbital floor in cases of orbital floor fractures that provided intraoperative rigid fixation and stable structural support over 6 months postoperative follow-up period.

Key Words: Orbital floor fracture – Porous polyethylene – Titanium mesh – Porous polyethylene with embedded titanium mesh.

Introduction

THE orbital floor is also the roof of the maxillary sinus and is mainly composed from the orbital plate of maxilla with contributions from the orbital plate of zygomatic bone and the orbital process of palatine [1]. It is relatively thin and is further weakened by the passage of the infraorbital canal hosting the infraorbital neurovascular bundle making it liable for even trivial trauma [2]. The floor is the most often affected orbital wall by trauma and is the most common mid-facial fracture site next to nasal bone. Fractures of the orbital floor commonly affects young and middle age population groups with interpersonal violence and motor vehicle accidents as the most common causative trauma [3,4]. Orbital floor fracture results in disruption of bony orbital floor continuity permitting bone fragments and orbital contents to herniate beyond the original bony orbit into the maxillary antrum leading to enophthalmos, infraorbital paresthesia and hypoglobus. Soft tissue entrapment at the fracture site may result in restricted ocular motility and diplopia [5,6].

Orbital floor exploration and reconstruction is generally indicated in orbital floor fractures with enophthalmos more than 2mm compared to the opposite side, radiographic evidence of extra ocular muscle entrapment, and/or diplopia in the primary or reading positions lasting more than one week to ten days. Oculocardiac reflex caused by extra ocular muscle entrapment is an urgent indication for surgical exploration [7,8]. The goals of reconstruction in cases of orbital floor fractures are to free the incarcerated extra ocular muscle, to reduce the herniated orbital contents and to span the orbital floor defect with an implant [9]. A multitude of autologous and alloplastic materials have been used as orbital floor implants. Autologous implants which are mainly autologous bone and cartilage of varying origin, have the advantages of being readily available and have less incidence of infec-
The ideal alloplastic implant material should be biocompatible, nonreactive, non-carcinogenic, easily kept in position and provide good structural support \[14,15\]. Alloplastic implant material may be resorbable or non resorbable. Non resorbable are either integrating or non integrating. Integrating implant materials allow fibrovascular tissue ingrowth through the implant with decreased risk of migration and infection \[16-18\]. Titanium mesh and porous polyethylene sheets are commonly used integrating implants in the reconstruction of orbital floor fractures. Titanium mesh is highly biocompatible material used for bony facial reconstruction \[17\]. It is malleable and therefore easily adapts to the shape of the orbital defect. Because of the mesh structure connective tissue can grow around and through the implant providing more stability, allowing integration with bones and decreasing the risk of migration. However, the property of high compatibility may be a disadvantage when removal of the implant is indicated for any reason \[18\]. It may also result in orbital adherence syndrome, in which the induced connective tissue growth results in adherence between the titanium implant and orbital soft tissues resulting in progressive restriction of ocular motility after surgical reconstruction and lower eyelid retraction \[19,20\]. Titanium mesh may also has sharp points at its edges and at the bent borders that may result in injury to orbital contents during the surgery or even years later \[21\]. Porous polyethylene is another alloplastic implant material that is widely used for orbital floor reconstruction. It is porous, biocompatible and durable material which is available in sheets of different thicknesses \[22\]. Porosity of porous polyethylene implants allows for fibrovascular tissue ingrowth that provides stability and decreases risk of infection \[23\]. However, compared to titanium mesh, it is not as easy to shape, and is not seen on postoperative scans being radiolucent. Also, the same support provided by Medpor can be provided with much thinner titanium mesh \[24\].

Porous polyethylene with embedded titanium mesh (Medpor Titan® Stryker, Kalamazoo, Michigan, U.S.A.), is a relatively new composite material formed of a thin titanium mesh embedded in a sheet of porous polyethylene. It is designed to combine the advantages and avoid the disadvantages of both titanium mesh and porous polyethylene sheets \[24\]. The aim of this work is to assess the efficacy and safety of the use of porous polyethylene with embedded titanium mesh in the reconstruction of orbital floor fractures.

**Patients and Methods**

This is a prospective interventional, case-series study carried out in the Research Institute of Ophthalmology Giza, Egypt from 2013 to 2015. Patients of any age and both sex presenting with orbital floor fractures within one month of the causative trauma, with enophthalmos more than 2mm compared to the opposite side, diplopia in primary position and/or down gaze persistent after one week and/or radiographic evidence of entrapment of extra ocular muscle in the fracture site were included. Patients with complex facial fractures with marked bone displacements as in orbital floor fractures associated with Le Fort type II or III fractures were excluded.

**Surgical procedure:**

Transconjunctival approach was used in 15 cases and transconjunctival approach combined with transcaruncular approach in another case. Subciliary approach was used in 3 cases and sub-tarsal approach in one case. In the cases who underwent the transconjunctival approach, the incision was performed 3mm inferior to the lower border of the tarsus using a needle tipped electrocautery and dissection anterior to the orbital septum was then continued in the preseptal plane until the inferior orbital margin was reached. Lateral canthotomy and cantholysis were performed in eight cases out of the 16 cases who underwent the transconjunctival approach to provide better exposure of the orbital floor. When the subciliary approach was employed, incision 2mm inferior and parallel to the ciliary line was performed through the skin and orbicularis occuli muscle using the surgical scalpel blade No. 15. Dissection was then performed anterior to the tarsus and the orbital septum to the inferior orbital rim.

The periosteum was then exposed and incised outside the orbital rim, and dissection continued in the sub-periosteal space until the borders of the fracture site are reached. Orbital tissues incarcerated in the fracture site were gently freed, and herniated orbital contents in the maxillary antrum were then reduced into the orbital cavity using hand over hand technique taking care not to cause any more trauma to the muscles and other tissues.
After full reduction of the herniated orbital contents, the orbital floor defect dimensions were identified and measured. The defect was then spanned with a fashioned sheet of porous polyethylene with embedded titanium mesh of the MTB version with a solid, barrier surface on one side and a porous surface on the other side. The implant was contoured and bent to smoothly adapt to the curves of the orbital floor with the rough porous surface of the implant facing the bony orbital floor and the smooth non-porous surface facing the orbital contents Fig. (1). Titanium micro screws were used to fix the porous polyethylene sheet in six cases when stability of the implant was questionable at the end of the surgery either due to a large defect or insufficient rim. The periosteum was then closed using vicryl 6/0 sutures. Conjunctival incisions were left sutureless in the transconjunctival approach and the lateral canthal tendons sutured to the periosteum behind the lateral orbital rim using 5-0 polypropylene sutures in cases who underwent adjunctive lateral cantholysis. Skin incisions were closed using continuous 6/0 polypropylene sutures in the cases who underwent the transcutaneous approach.

Postoperative care:
Postoperatively, the patients were prescribed topical combination of tobramycin 0.3% and dexamethasone 0.1% (Tobradex®) six times daily, oral Amoxicillin/cavulanic acid in a dose of 90 mg/kg/day for children and 2g/day for adults divided into two doses, and oral metronidazole in a dose of 7.5mg/kg/day for children and 1g/day for adults divided into two doses. Patients were examined one day, one week, three months, and six months after surgery.

Statistical analysis:
Statistical analysis was done by IBM SPSS v20.0 statistical software (IBM Corporation, New York, USA). Descriptive statistics were calculated and the data summarized as mean ± standard deviation (±SD), median and range, or frequencies (number of cases) and percentages when appropriate. For assessing the association between categorical data, Chi square ($\chi^2$) test was be performed. Fisher’s exact test was used instead when the expected frequency is less than 5. The results were considered statistically significant with a p-value <0.05.

Results
A total of 20 patients with unilateral orbital floor fractures were included of which 18 (90%) were males and 2 were females (10%). The ages of the patients ranged between 9 and 52 years with a mean of 24 years ±12.54. Eight patients had right orbital floor fractures (40%), while the left side was affected in the remaining 12 cases (60%), no cases had bilateral fractures. Assaults accounted for 10 cases (50%) and represented the most common causative trauma for orbital floor fractures in our series followed by Motor Vehicle Accidents (MVA) which caused fractures in 6 cases (30%). Other causes were occupational (10%), falls (5%) and sports (5%) injuries. Associated injuries are shown in Table (1).

Table (1): Injuries associated with orbital floor fractures in this study.

<table>
<thead>
<tr>
<th>Associations</th>
<th>Frequency</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>ZMC fracture</td>
<td>2</td>
<td>10.0</td>
</tr>
<tr>
<td>Roof + medial wall + ZMC fracture</td>
<td>1</td>
<td>5.0</td>
</tr>
<tr>
<td>ZMC + roof fractures</td>
<td>1</td>
<td>5.0</td>
</tr>
<tr>
<td>Ptosis + roof fracture</td>
<td>1</td>
<td>5.0</td>
</tr>
<tr>
<td>Mandibular fracture</td>
<td>1</td>
<td>5.0</td>
</tr>
<tr>
<td>Iridodialysis</td>
<td>1</td>
<td>5.0</td>
</tr>
<tr>
<td>Choroidal rupture</td>
<td>1</td>
<td>5.0</td>
</tr>
<tr>
<td>Commotio retinae</td>
<td>1</td>
<td>5.0</td>
</tr>
<tr>
<td>None</td>
<td>11</td>
<td>55.0</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>100.0</td>
</tr>
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</table>

ZMC: Zygomatic Maxillary Complex fracture.

The indications for surgery in our series were diplopia in the primary position lasting more than seven to ten days after the injury and radiographic evidence of entrapment based on CT scan images (in 11 cases, 55%), enophthalmos more than 2mm relative to the opposite side (in 6 cases, 30%) and combination of both diplopia and enophthalmos (in 3 cases, 15%). Surgery was performed between 9 and 25 days from the time of injury (mean of 15.56±4.39). Resolution of diplopia was achieved in 8 patients out of 11 cases who had diplopia as the main indication of surgery. Three patients...
continued to have diplopia at 6 month postoperative follow-up, however less than the pre-operative diplopia. No case had diplopia worsened or induced by surgery (Table 2 & Fig. 2).

Enophthalmos was corrected in seven cases out of nine who had preoperative enophthalmos, to within 2mm compared to the opposite side at 3rd and 6th post-operative months; the remaining two cases had improvement despite suboptimal correction of their enophthalmos. No case had post-operative volume overcorrection (proptosis) of either those operated for diplopia or enophthalmos (Table 3 & Fig. 3).

Table (2): Diplopia outcome.

<table>
<thead>
<tr>
<th>Indication for surgery</th>
<th>Resolution</th>
<th>Residual</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diploma</td>
<td>11 (78.57%)</td>
<td>3 (21.43%)</td>
<td>14</td>
</tr>
</tbody>
</table>

Table (3): Enophthalmos outcome.

<table>
<thead>
<tr>
<th>Indication for surgery</th>
<th>Resolution</th>
<th>Residual</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enophthalmos</td>
<td>7 (77.77%)</td>
<td>2 (22.23%)</td>
<td>9</td>
</tr>
</tbody>
</table>

Of the three cases who continued to have residual diplopia after surgery, one case had tight inferior rectus muscle confirmed by reoperation after 6 months of follow-up. The second case was a 32 year old male who had left orbital roof fracture and left ptosis in addition to orbital floor fracture secondary to severe occupational blunt injury with a ruptured pressure pot. The diplopia improved after surgery however residual diplopia persisted at 3 and 6 month postoperative visits. Ptosis also showed partial improvement over the 6 months follow-up period. Postoperative CT showed that implant in the correct position and forced duction test showed no restriction. The postulated explanation for persistence of both diplopia and ptosis was weakness of the superior rectus/levator complex due to either direct injury or injury of their nerve supply at the time of trauma. The three cases underwent squint surgery later on. Two cases had residual postoperative enophthalmos more than 2mm compared to the opposite side. One case was a 12 year old male patient who had associated ZMC, medial wall and roof fractures. However enophthalmos improved from 8mm preoperatively to 4mm compared to the opposite side postoperatively and will be discussed later.

Post-operative complications:

No loss of visual acuity was noted in any patient in this series. No implant infection or migration was reported during the follow up period. Postoperative complications are shown in Table (4).
Discussion

Although there is no complete consensus on the best management guidelines of orbital floor fractures [8], it is generally accepted that repair of orbital floor fractures should be performed in patients with enophthalmos greater than 2mm compared to the opposite side, diplopia that persists beyond 7 to 10 days, radiographic evidence of entrapment of orbital contents and entrapment that causes an oculocardiac reflex. Orbital floor reconstruction is ideally performed within 1-3 weeks of injury to allow the edema to resolve and not beyond to prevent ischemic contracture and scarring of herniated muscle/s [7,8].

Titanium mesh and porous polyethylene sheets have been widely investigated for their utility in reconstruction of orbital floor fractures. The high biocompatibility of titanium mesh induces fibrogenic activity that may predispose to orbital adherence syndrome. Kersey et al., reported reoperation of ten patients with orbital adherence syndrome who underwent previous orbital floor reconstruction using titanium mesh. The ten patients complained of diplopia and three of them had also lower lid retraction. The pertinent intraoperative finding was the presence of a dense meshwork of fibrotic tissue that was adherent to and growing through the titanium implants and extending to include some of the orbital contents [19]. Lee et al., reported another ten cases with orbital adherence syndrome 9 of them presented with limited ocular motility and six of them had lower lid retraction. During the subsequent surgical repair of these patients, an intense fibrotic adherence was also noted between the titanium mesh and the orbital and periorbital tissues [20].

Porous polyethylene is a high-density, non-resorbable, flexible implant available in a variety of thicknesses and has a proven biocompatibility with adequate pore size to allow for fibrovascular ingrowth and stabilization of implant positioning [22,23]. However, compared to titanium mesh, it is not as easy to shape, and is not seen on postoperative scans being radiolucent. Also, the same support provided by Medpor can be provided with much thinner titanium mesh [24].

Table (4): Post operative complications.

<table>
<thead>
<tr>
<th>Complications</th>
<th>Number of cases and %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palpable micro screw</td>
<td>2 (10%)</td>
</tr>
<tr>
<td>Lower lid retraction</td>
<td>2 (10%)</td>
</tr>
<tr>
<td>Infraorbital hypoesthesia</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Lower lid ectropion</td>
<td>1 (5%)</td>
</tr>
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</table>

Porous polyethylene with embedded titanium mesh is a composite material formed of a thin titanium mesh embedded in a sheet of porous polyethylene that aims at combining the advantages and avoiding the disadvantages of both titanium mesh and porous polyethylene sheets Fig. (4). It is available in three forms; the first is the Medpor Titan Medpor (MTM) implant which is porous, high-density polyethylene with titanium mesh embedded in it, potentially providing the advantages of fibrovascular integration of the patient’s host tissue through both surfaces of the sheet. The second is the Medpor Titan Barrier (MTB) which has a porous surface to allow integration and a non porous barrier surface to prevent adherence and facilitate insertion of the implant. The third form is the double barrier (BTB) implant which is composed of titanium mesh embedded within solid polyethylene.

In this study, 20 patients with orbital floor fractures underwent orbital floor reconstructions using 1.0-mm porous polyethylene with embedded titanium mesh of the MTB type. The diplopia resolved in 11 patients (78.57%) and partially improved in the remaining 3 patients of 14 patients with pre-operative significant diplopia. Enophthalmos was corrected to within 2mm of the opposite eye in 7 of 9 cases (77.77%) and partially improved in the remaining two cases. There was no postoperative diplopia worse than before surgery. Also there was no volume overcorrection resulting in proptosis.

In this study we used the MTB form in the 20 cases. Garibaldi et al., studied 106 patients who received sheets of porous polyethylene with embedded titanium mesh for orbital wall reconstruction. The complications they reported were retrobulbar hemorrhage in one case that resolved without sequelae, a vertical overcorrection that required removal of the implant, a transient oculomotor disturbance, and infraorbital hyperesthesia caused by screw near the infraorbital canal that necessitated removal of the screw [24]. Tabrizi et al., evaluated orbital floor reconstruction in 101 patients using different materials of whom 42 patients received Porous polyethylene with embedded titanium mesh as an implant material. Three patients of the 42 patients who received porous polyethylene with embedded titanium mesh implant had post-operative residual enophthalmos, one patient had overcorrection and 3 patients developed infection of the implant [25].

In this study, 20 patients with orbital floor fractures underwent orbital floor reconstructions using 1.0-mm porous polyethylene with embedded titanium mesh of the MTB type. The diplopia resolved in 11 patients (78.57%) and partially improved in the remaining 3 patients of 14 patients with pre-operative significant diplopia. Enophthalmos was corrected to within 2mm of the opposite eye in 7 of 9 cases (77.77%) and partially improved in the remaining two cases. There was no postoperative diplopia worse than before surgery. Also there was no volume overcorrection resulting in proptosis.

We used malleable retractors to reduce the orbital contents and to provide a smooth surface
to facilitate insertion of the implant and prevent posterior dragging of orbital soft tissues Fig. (1). Also the soft orbital surface of the implant made the implantation easier compared to other implant materials like titanium mesh or porous polyethylene. We also performed forced duction test after implant insertion to confirm the absence of posterior dragging of orbital soft tissues.

Alloplastic orbital floor implant related complications are considered rare. They include implant infection, cyst formation, migration, and injury to vital orbital [3,26-28]. In this study, no major complication with potential loss of vision, implant infection, or migration was noted over 6 months of follow-up. Complications included lower lid ectropion in one case, lower lid retraction in 2 cases, palpable screw in 2 cases and infraorbital hypoesthesia in one patient. The radio-opacity of the implant was of benefit in the reassessment of the cases with under correction of either ocular motility or enophthalmos. In the three cases that had residual diplopia, postoperative CT scans showed that the implant is in proper place with no residual or recurrent soft tissue herniation and entrapment. Of the two patients who had residual enophthalmos, postoperative CT scan showed improperly placed implant with downward sloping medial border Fig. (5). This resulted from insufficient support medially caused by the associated fracture of the medial orbital wall involving the inferomedial strut. Such cases are particularly difficult with higher rates of reoperations and may require specially preshaped porous polyethylene with embedded titanium mesh implant that has titanium extensions for fixation to the orbital rim [29]. Other described management options for combined orbital floor and medial wall fractures involving the inferomedial strut include the use of two separate implants with fixation of each of them to the corresponding orbital rim [30] and the wraparound technique of a large nylon foil implant around the floor and medial wall of the orbit spanning the bony defect [31]. The patient and his legal guardians were counseled about these options but they refused further intervention. The radio-opacity of the implant was also helpful here to explain the cause of under correction of enophthalmos. In this series only one patient had re-exploration because of significant up gaze limitation and positive forced duction test. The exploration showed tight inferior rectus without significant adhesion between the implant and orbital contents.

Fig. (4): A- Saggital and B- Coronal CT scans of reconstructed orbital floor fractures using porous polyethylene with embedded titanium mesh. The radio-opacity of the implant enables postoperative assessment of its position and orientation.

Fig. (5): A- Preoperative coronal CT scan of the orbits showing fractures of the four orbital walls with the inferomedial strut. B- Postoperative coronal section of the same patient showing downward sloping of the implant explaining the suboptimal correction of enophthalmos.
The limitations of the current study are the limited number of cases and the different surgical approaches used for orbital floor reconstruction. Although further studies on larger number of cases may be required to confirm the results, porous polyethylene with embedded titanium mesh appears to be a safe and efficient implant material for the reconstruction of orbital floor fractures.

References


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