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Original Article

Evaluation of the effect of Medpor implantation on extraocular muscle function, eye movement disturbance and diplopia in patients with orbital wall fracture

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Abstract: Objective: To evaluate the impact of Medpor implantation on extraocular muscle function, eye movement disorders, and diplopia in patients with orbital wall fracture. Methods: A retrospective study was conducted on 98 patients (98 eyes) who underwent Medpor implantation surgery at Bethune International Peace Hospital from January 2019 to December 2022. The degree of eyeball enophthalmos and total fracture area in patients before and after surgery, as well as orbital volume were measured. The relationship between enophthalmos severity and total fracture area was analyzed. Changes in extraocular muscle function, eye movement, and diplopia were assessed before and after surgery. Results: Before operation, enophthalmos severity was correlated with the total fracture area ($r = 0.323$, $P = 0.001$). After surgery, there was no significant correlation ($r = -0.053$, $P = 0.630$). Compared with preoperative measurements, both orbital volume and the volume difference improved significantly after surgery (both $P < 0.05$). Among the patients who received surgery within 3 weeks, the cure rates for rectus muscle restriction and extraocular muscle paralysis were 94.12% and 100.00%, respectively, higher than those in patients who underwent surgery after 3 weeks (67.27% and 65.62%) ($P < 0.05$). In comparison of preoperative conditions, notable improvements were observed in both ocular motility disorders and diplopia after operation (both $P < 0.05$). The total improvement rates in ocular motility disorders at 1, 3 and 6 months of follow-up were 84.69%, 90.82%, 96.94%, respectively, while these rates in diplopia were 89.79%, 91.84% and 95.92%, respectively. Abnormal maxillofacial sensations also improved significantly at 1-, 3-, and 6-month post-surgery (all $P < 0.05$). Conclusions: Medpor implantation effectively restores extraocular muscle function in patients with orbital wall fractures, significantly alleviating diplopia, eye movement disorders, and maxillofacial abnormalities.

Keywords: Orbital wall fracture, orbital prosthesis, extraocular muscle function, diplopia, eye movement disorder, medpor implantation

Introduction

Orbital wall fracture mainly refers to trauma caused by external force impacting the eye area, resulting in multiple fractures around the orbit due to the impact force [1]. Based on fracture characteristics, orbital wall fractures can be roughly categorized as blow-out fracture, complex orbital wall fracture, and complicated orbital wall fracture [2, 3]. A blow-out fracture typically involves an intact orbit rim accompanied by increased intraorbital pressure and soft tissue entrapment at the fracture site, causing restricted eye movement, diplopia, and enophthalmos [4, 5]. Epidemiological data indicate that common causes of orbital wall fractures include traffic accidents (43.5%), physical altercations (27.3%) and falls (13.3%) [6]. A joint study by four hospitals in China and Japan analyzed 470 patients treated for orbital wall fractures, revealing that inner wall fractures (61%) were more frequent than lower wall fractures (48%) [7]. The structural defect from these fractures alters the orbital diameter and intraorbital pressure, leading to enophthalmos, exophthalmos, eyeball displacement, changes in orbital volume, and disruption in the balance of orbital contents. These changes can result in compli-

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cations affecting eye function, such as diplopia, restricted ocular motility, as well as visible pathological features affecting eye appearance [8, 9].

Currently, treatment options for orbital wall fracture mainly include conservative management and surgical treatment. Surgical repair is typically required for patients with eye movement disorders, diplopia and other visual impairments as well as those with aesthetic concerns due to eyeball invagination, to restore visual function and correct orbital deformity [10, 11]. Effective orbital wall repair often necessitates the use of supportive materials. Due to the relatively high cost of absorbable materials, non-absorbable materials remain the most widely used for repairing blow-out fractures. Linear high-density polyethylene biomaterials (Medpor), known for their stability, plasticity and biocompatibility, are a particularly popular choice given their affordability compared to absorbable alternatives [12]. Therefore, they are also a common choice for surgical repair of orbital wall fractures.

In assessing patient recovery, symptom improvement serves as the primary indicator, with orbital CT results used as a key reference. The correlation between orbital CT results and symptom recovery was analyzed. Routine comparisons showed that orbital CT scans could intuitively reveal the restoration of orbital wall morphology, changes in extraocular muscle function, and alignment of eye position [13]. The orbital CT imaging can directly determine the extent of bone fractures, allowing for appropriate surgical plans. While CT results provide insights into the structural recovery of the orbital wall and changes in eyeball protrusion, they do not directly reflect improvements in symptoms like diplopia and strabismus. Thus, imaging-based morphological repair primarily serves as a reference for evaluating surgical outcomes, with symptom recovery being an important indicator of the surgical effect [14]. This study explores the impact of Medpor implants on orbital wall fracture repair, specifically on extraocular muscle function, eye movement disorders, and diplopia, to provide theoretical guidance for clinical orbital wall fracture repair surgery.

Materials and methods

Participant information

This study was approved by the Ethics Committee of Bethune International Peace Hospital. It retrospectively included 98 patients (98 eyes) who underwent Medpor implantation at Bethune International Peace Hospital between January 2019 and December 2022.

Inclusion criteria: (1) Confirmed orbital wall fractures by CT examination; (2) Documented history of eye trauma within the past month; (3) Presence of significant diplopia and eye movement disorders; (4) Minimum follow-up period of 6 months after Medpor implantation; (5) Complete clinical data.

Exclusion criteria: (1) Patients with ciliary detachment, eye rupture, retinal detachment, or similar conditions; (2) Advanced age or systemic disease preventing surgical tolerance; (3) Presence of eye diseases, such as cataracts or glaucoma that affect vision; (4) Pre-existing strabismus or severe ocular diseases causing visual impairment or impaired motor function. Patients' baseline data included gender, age, cause of injury, time from injury to surgery, and type of orbital wall fracture, as detailed in **Table 1**.

Methods

All patients underwent routine eye examinations before surgery, including assessments of visual acuity, intraocular pressure, corneal topographic map, slit-lamp examination. In addition, 64-slice spiral CT scans were performed in the horizontal, coronal and sagittal plans to reconstruct three-dimensional images. All patients underwent repair and filling procedures for orbital blowout fractures, with surgical approaches and subconjunctival methylene blue injection tailored to individual examination results. For patients with isolated medial wall fractures, an incision was made in the skin at the inner canthus; For patients with isolated inferior wall fracture, an incision was made below the lower eyelid near the roots of the eyelashes; For patients with combined fractures involving both the medial and inferior walls, incisions were made in both locations.

Table 1. Basic information of patients

Item	N
Sex	
Male	52 (53.06)
Female	46 (49.94)
Age (years)	32.13±5.64
BMI (Kg/m^2)	23.67±2.42
Eye category	
Left eye	45 (45.92)
Right eye	53 (54.08)
Cause of injury	
Fist and foot injury	48 (48.98)
Injuries caused by traffic accident	23 (23.47)
Blunt force injury	13 (13.27)
Falling Damage	14 (14.29)
Time from injury to surgery (d)	25.48±7.82
Type of orbital wall fracture	
Fracture of intraorbital wall	35 (35.71)
Fracture of the infraorbital wall	30 (30.61)
Fracture of inferior orbital wall	33 (33.67)
Maxillofacial paresthesia	
Yes	48 (48.98)
None	50 (51.02)
Complications	
Diabetes	3 (3.06)
Hypertension	4 (4.08)
Coronary heart disease	2 (2.04)

The skin and subcutaneous tissue were incised successively, hemostasis was achieved using electrosurgical knife. The orbicularis muscle was carefully separated from the orbital septum to ensure protection of blood vessels, eyeballs and nerves, with continuous monitoring of pupil response. Fracture sites were fully exposed, bone fragments removed, and the periosteum, extraocular muscles, intraorbital soft tissues, and fat were cleaned. In cases of extraocular muscle adhesion with surrounding tissues, blunt dissection was performed with special care to preserve muscle integrity. Once herniated tissue was fully restored, the fracture window size was estimated, and a trimmed Medpor implant was inserted into the bone defect. Extraocular muscle traction test yielded negative results. The orbital septum was repaired, and incisions were sutured and bandaged under pressure. Following the surgery, the patient was instructed to rest in a supine position while receiving mannitol to reduce orbital pressure. Additionally, suitable antibiotics and local hemostatic drugs were administered based on the specific conditions of the patient. Two days after the operation, a reexamination and dressing change were conducted to assess the ocular protrusion, followed by postoperative functional exercises guided by medical professionals. Subsequently, all patients were followed up for six months.

Observation index

The primary observation indicators included extraocular muscle function, eye movement disorders, and diplopia. Secondary indicators were total fracture area, enophthalmos, orbital volume, abnormal sensation in the maxillofacial region, and complications.

(1) Total fracture area: Prior to surgery, orbital CT examination (coronal axial position) was conducted to quantitatively measure the fracture lines in both coronal and horizontal planes. The shortest distance of all defect edges was measured, and the total fracture area was calculated based on the CT section thickness [15].

(2) Enophthalmos: Measurements were taken before and after surgery using an exophthalmometer with an isosceles right triangle optical glass prism. The corneal vertex and scale ruler were projected onto the front of the prism through the total reflection of its inclined plane, allowing precise measurement of the height (in mm) of the corneal vertex protruding from the orbital margin on both sides [16, 17]. The difference between each side was measured, with the average of three measurements recorded. The relationship between the degree of enophthalmos before and 6 months after surgery and the total fracture area was analyzed.

(3) Orbital volume: The orbital volume of both eyes and the volume difference were calculated based on preoperative and postoperative (6 months later), orbital CT scan data.

(4) Extraocular muscle function: The diplopia image and a same-vision machine were utilized to assess the function of the extraocular muscle. Based on classification criteria, muscle function was categorized into two types: extraocular muscle paralysis and extraocular muscle restriction. The resolution rate before and 6 months after surgery was calculated. Some

patients displayed both paralysis and restriction, while others showed dysfunction in specific muscles, such as the internal rectus, inferior rectus, or inferior oblique muscle. All cases were included in the statistical analysis, leading to a total count of 98 cases of extraocular muscle dysfunction.

(5) Eye movement function: Six months post-surgery, eye movement function was evaluated through active contraction, passive traction, and corneal imaging tests. Level 0: no limitations, representing recovery; Level I: limited movement in one or more directions; Level II: unstable eyeball fixation with significant movement limitations; Level III: fixed eyeball position with no movement. Levels I and II were categorized as improvement, while Level III was deemed ineffective [18]. Total improvement rate = (recovery + improvement)/total cases ×100%.

(6) Diplopia: Six months post-surgery, diplopia was examined using mallet rod, prism and synopter. Grade 0: no diplopia, indicating recovery; Grade I: diplopia only in the peripheral visual field; Grade II: diplopia in all directions except for directly in front and at the reading position; Grade III: diplopia both directly in front and at the reading position. Grades I and II indicated improvement, with Grade 0 representing complete recovery [19].

(7) Maxillofacial sensory abnormalities: Therapeutic efficacy was evaluated based on sensory changes. Absence of abnormal sensation six months post-surgery, when previously present, was considered a cure. If abnormal sensation persists but with reduced range and severity, it is considered as an improvement. No change or worsening of sensation after surgery was considered ineffective.

(8) Complications: Patients were followed for 6 months to assess complications, including Medpor displacement, prolapse, infection, or rejection.

Statistical analysis

SPSS 29.0 statistical software was utilized for data analysis. Categorical variables were described as [n (%)] and analyzed with the χ^2 test. The Rank sum test was used for ordinal data. Metric data, confirmed by the K-S test to follow a normal distribution, were described as mean ± sd and analyzed using independent sample-tests. Pearson correlation analysis was used for correlation analysis. $P < 0.05$ was considered statistically significant.

Results

Correlation between enophthalmos degree and total fracture area before and after surgery

Before surgery, the degree of enophthalmos (2.01±0.92 mm) was significantly correlated with the total fracture area (3.22±0.84 cm^2) in the enrolled patients (r = 0.323, P = 0.001). Ater surgery, no significant correlation was found between the degree of enophthalmos (1.26±0.60 mm) and the total fracture area (3.23±0.81 cm^2) (r = -0.053, P = 0.603), as shown in **Figure 1**.

Postoperative orbital volume

Postoperative measurements revealed an orbital volume of 25.15±0.94 cm^3 in the affected eye, with an orbital volume difference of 2.37±1.23 cm^3, compared to the preoperative orbital volume of 27.52±1.04 cm^3 and a volume difference of 3.14±1.32 cm^3 (both P < 0.05), as shown in **Figure 2**.

Motor function of extraocular muscles and postoperative changes after repair surgery in patients with different types of orbital wall fractures

Extraocular muscle motor function in patients with different types of orbital wall fractures before surgery: Before surgery, no significant differences were observed in the motor function of extraocular muscles among the three groups of patients with different types of orbital wall fractures (P > 0.05). See **Table 2** for details.

Comparison of recovery rates for postoperative rectus muscle restriction at different surgical times: As shown in **Table 3**, there were 72 patients with orbital wall fractures who experienced rectus muscle restriction, with 17 patients undergoing operation within 3 weeks and 55 patients undergoing surgery after 3 weeks. The cure rate of rectus muscle restriction was 94.12% in those who had surgery within 3 weeks, significantly higher than the 67.27%

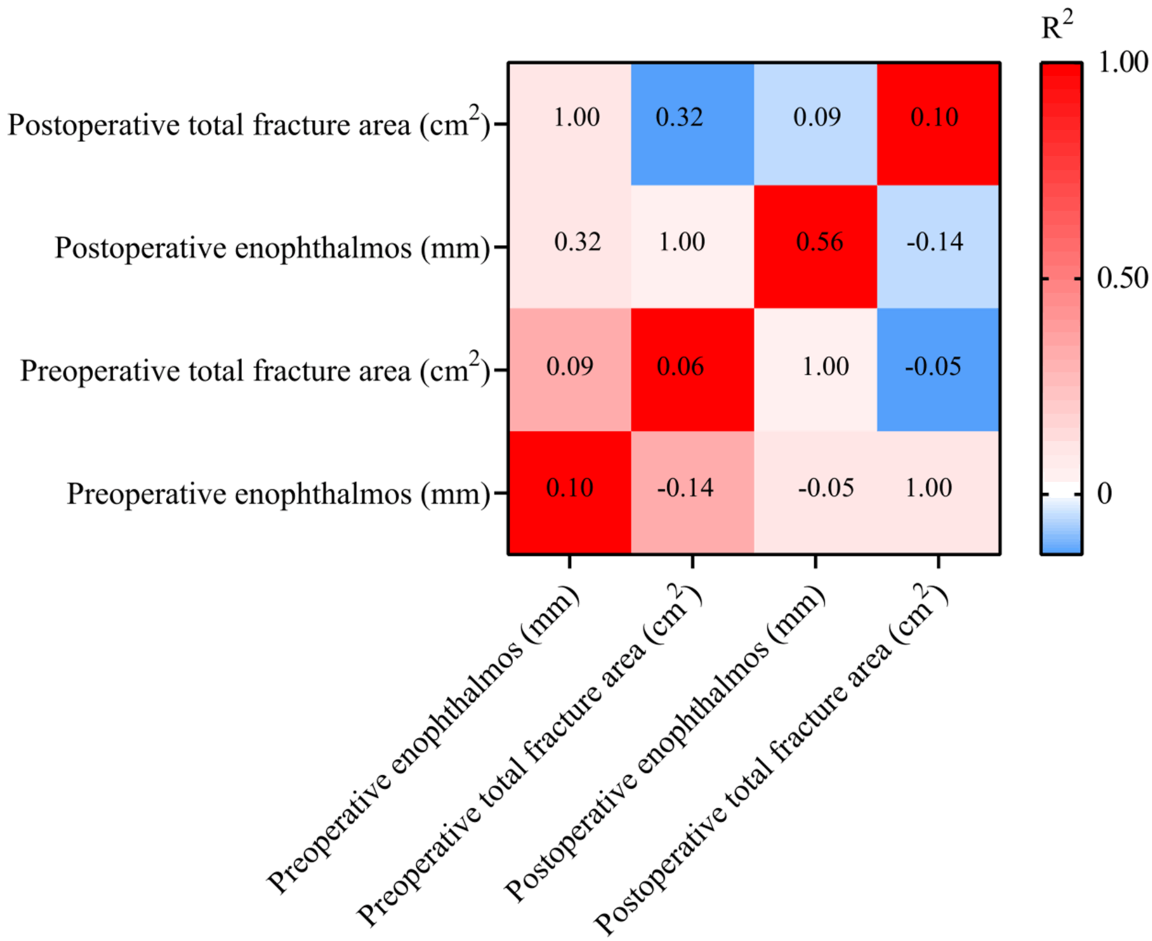

Figure 1. Heat map of the correlation between enophthalmos degree and total fracture area before and after surgery.

cure rate in patients who had surgery after 3 weeks (P < 0.05).

Comparison of cure rates for extraocular muscle paralysis in patients undergoing surgery within 3 weeks versus over 3 weeks after injury: As shown in **Table 4**, there were 41 cases of internal rectus muscle paralysis in patients with orbital wall fracture. Among them, 9 cases underwent surgery within 3 weeks, and 32 cases underwent surgery after 3 weeks. The cure rate of extraocular muscle paralysis was 100.00% for those who underwent surgery within 3 weeks, compared to 65.63% for those operated on after 3 weeks (P < 0.05).

Comparison of changes of eye movement function, diplopia grade, and maxillofacial paresthesia before and after surgery

Post-surgery, significant improvements were observed in eye movement disorders, diplopia grade, and maxillofacial paresthesia compared to pre-surgery levels (all P < 0.05). The overall improvement rates for eye movement disorders at 1, 3 and 6 months after surgery were 84.69% (83/98), 90.82% (89/98), and 96.94% (95/98), respectively. For diplopia classification, improvement rates at 1, 3, and 6 months were 89.79% (88/98), 91.84% (90/98), and 95.92% (94/98), respectively. Among the 48 cases with maxillofacial dysesthesia before surgery, symptoms improved following surgery and associated drug treatment, with no cases of worsening reported. Please refer to **Table 5** for details.

Complications

No complications such as Medpor displacement, prolapse, infection or rejection occurred in the 98 patients. One case of lower eyelid skin scar caused by conjunctiva incision was

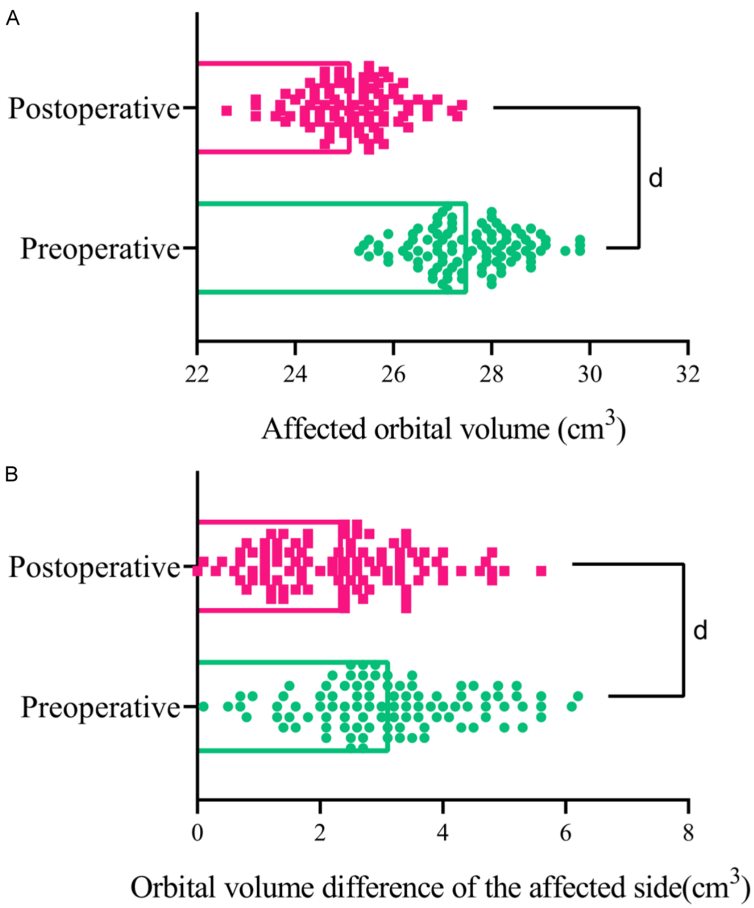

Figure 2. Comparison of orbital volume of the affected eye before and after operation. A. Orbital volume in the affected eye before and after operation. B. Comparison of orbital volume difference of two eyes before and after operation. $^{d}P < 0.00001$.

relieved after treatments with detumescence, laser scar dilution and skin scar excision.

Discussion

Orbital wall fractures are common in ocular trauma, and surgical repair is the preferred treatment when surgical indications are present [20]. Dong et al. [21] believed that patients with a fracture area ≥ 2 cm^2, severe extraocular muscle entrapment, obvious periorbital soft tissue prolapse, eyeball recession > 2 mm, and restricted eye movement should be given early surgical treatment within 24-48 h. However, some advocate for surgery within 1-2 weeks, as surrounding tissue edema around the orbital wall typically subsides after one week, making surgical indications more apparent [22]. This study demonstrated a significant positive correlation between the degree of enophthalmos and the total fracture area before surgery. The possible reason is that larger fracture areas before surgery are associated with increased protrusion and incarceration of periocular tissue through the fracture site, leading to greater eyeball depression due to traction. Research results indicate that orbital volume increase, peripheral fat atrophy, and orbital tissue adhesion caused by orbital wall fracture are important factors for eyeball invagination [23]. Foreign studies have also shown that 1 ml increase in orbital volume correlates with about 0.9 mm eyeball depression [24].

This study also confirms that the absence of significant correlation between the postoperative enophthalmos and total fracture area, suggesting that implant materials should be tailored according to the degree of preoperative enophthalmos to achieve satisfactory correction of postoperative depression. Given the irregular orbital anatomy, conventional measurement methods struggle to precisely calculate fracture defect shapes. Orbital volume, however, can directly reflect changes in orbital structure. In this study, CT scan data were imported into 3D image processing software to create a 3D model of the orbital volume, enabling a more convenient and precise calculation. The results of this study showed that both the orbital volume and the volume difference of the affected eye were improved after surgery. These results support Medpor implantation as an effective treatment for orbital wall fractures, offering precise orbital volume restoration and yielding favorable postoperative symmetry and appearance.

Most scholars agree that early surgery for orbital wall fractures yields better results, while delayed surgery is generally less effective and often requires additional treatment [25, 26]. However, there is currently no standardized

Table 2. Comparison of extraocular muscle motor function in patients with different types of orbital wall fractures before surgery

Group	Restriction	Paralysis	Paralysis + Restriction	χ^2	P
Orbital wall fracture group (n = 35)	20 (57.14)	9 (25.71)	6 (17.14)	0.839	0.933
Suborbital wall fracture group (n = 30)	16 (53.33)	9 (30.00)	5 (16.67)		
Fracture group of inferior orbital wall (n = 33)	21 (63.64)	8 (24.24)	4 (12.12)		

Table 3. Comparison of recovery rates for postoperative rectus muscle restriction in patients undergoing surgery at different times (n = 72)

Operation time	Cure	Non-cure	Cure rate (%)
Surgery within three weeks (n = 17)	16 (94.12)	1 (5.82)	16 (94.12)
More than 3 weeks surgery (n = 55)	37 (67.27)	18 (32.73)	37 (67.27)
χ^2			4.818
P			0.028

Note: Some patients also had extraocular muscle paralysis and extraocular muscle limitation, which were included in the statistical data repeatedly.

Table 4. Comparison of recovery rates for postoperative extraocular muscle paralysis in patients undergoing surgery at different times (n = 41)

Operation time	Cure	Non-cure	Cure rate (%)
Surgery within three weeks (n = 9)	9 (100.00)	0 (0.00)	9 (100.00)
More than 3 weeks surgery (n = 32)	21 (65.62)	11 (24.38)	26 (65.62)
χ^2			4.228
P			0.040

Note: Some patients also had extraocular muscle paralysis and extraocular muscle limitation, which were included in the statistical data repeatedly.

definition of "early surgery". Most scholars consider an operation within 2-6 weeks after trauma as early surgery, and after 4-6 months as late. Studies by Hakelius and Ponten et al. [27] revealed that following early surgery within 2 weeks, 17% of patients reported diplopia symptoms when they were tired, while 83% had no diplopia. In the late surgery group, 24% experienced diplopia.

Diplopia presence has often served as a marker for treatment effectiveness, yet there has been limited focus on the qualitative and categorical classification of extraocular muscle dysfunction contributing to diplopia. Additionally, detailed analysis of the recovery trajectory for different extraocular muscle dysfunctions following orbital fracture repair, particularly as it relates to operative timing and varying types of orbital burst fracture, has also been sparse. In this study, patients who received surgery within 3 weeks of injury exhibited higher cure rates for different types of orbital wall fractures compared to those treated later, indicating a strong correlation between recovery outcomes and operative timing. However, this study also found no significant difference in cure rates for extraocular paralysis among patients undergoing surgery within 3 weeks compared to those who received surgery later. This suggests that once extraocular muscle paralysis is present, the prognosis is generally poor. Generally speaking, 3 weeks after trauma, the congestion and swelling of extraocular muscle are significantly reduced, and the degree of ophthalmic invagination are typically stabilized. At this point, implant material size can be more accurately estimated, leading to satisfactory recovery of enophthalmos post-surgery [1, 28-30]. During this timeframe, intraorbital soft tissue adhesion is generally minimal, and tissue embedded in the paranasal sinus can often be successfully separated during repair. Post-surgery, both the intraorbital soft tissue and extraocular muscles can return to their normal anatomical positions, supporting a favorable surgical outcome.

According to literature [31], the incidence of diplopia in orbital fractures is as high as 63%. Ozturker et al. [3] found that using conjunctival technique and implantation of porous polyethylene film can effectively repair the eye socket. After surgery, patients showed significant improvement in restricted eye movement

Table 5. Comparison of changes of eye movement function, diplopia grade and maxillofacial paresthesia before and after surgery [n = 98, n = 98, n = 48, n (%)]

Time	Eye movement function				Grading of diplopia				Maxillofacial sensory abnormalities		
	Level 0	Level I	Level II	Level III	Level 0	Level I	Level II	Level III	Cure	Improvement	Ineffective
Before surgery	0 (0.00)	48 (48.97)	30 (30.61)	20 (20.41)	0 (0.00)	46 (46.94)	38 (38.78)	14 (14.29)			
One month after surgery	34 (34.69)	29 (29.59)	20 (20.41)	15 (15.31)	23 (23.47)	34 (34.69)	31 (31.63)	10 (10.20)	21 (43.75)	18 (37.50)	9 (18.75)
Three months after surgery	64 (65.31)	12 (12.22)	13 (13.27)	9 (9.18)	46 (46.94)	28 (28.57)	16 (16.33)	8 (8.16)	28 (58.33)	15 (31.25)	5 (10.42)
Six months after surgery	85 (86.73)	7 (7.14)	3 (3.06)	3 (3.06)	72 (73.47)	15 (15.31)	7 (7.14)	4 (4.08)	38 (79.17)	10 (20.83)	0 (0.00)
Z	136.332				103.565				14.890		
P	< 0.001				< 0.001				0.001		

(88.2% to 23.5%, P = 0.002), diplopia (70.6% to 23.5%, P = 0.008), and intraocular vision (1.41 mm to 0.82 mm, P = 0.012). Blessing et al. [32] conducted surgery on 34 orbits of 33 patients using prefabricated porous polyethylene titanium implants and discovered that these implants can effectively address complex orbital bone defects, enhancing diplopia, eyeball invagination, and extraocular muscle function, with minimal complications or need for revision surgery. In this study, postoperative outcomes showed improvements in eye movement disorders, diplopia grade, and maxillofacial paresthesia compared to preoperative conditions, supporting the efficacy of Medpor implantation for these issues in orbital wall fractures. Medpor remains one of the common non-absorbable reconstructive materials for orbital wall reconstruction due to its excellent biocompatibility, high stability, and strong plasticity [33, 34]. Furthermore, its mesh structure is conducive to rapid fibrotic vascular proliferation, ensuring adequate blood transportation for effective tissue repair and infection prevention. Immediate repair effectively mitigates enophthalmos and eye movement disorders, maintains aesthetic outcomes, and allows patients to achieve early functional and cosmetic recovery [35, 36]. Successful orbital wall fracture repair requires several key considerations. Firstly, it is essential to utilize 3D CT imaging for a comprehensive assessment of the patient's condition before surgery, to clearly understand the lesion location, size and relationship with surrounding tissues. Secondly, it is necessary to strictly grasp the operation timing and the operation approach during the operation. Finally, it is essential to choose biocompatible filling materials during surgery to guarantee the surgical effect and reduce the occurrence of complications like rejection and infection [37]. However, none of the 98 patients in this study experienced complications such as Medpor displacement, prostration, infection, or rejection after surgery. Only 1 case developed lower eyelid skin scar due to conjunctival incision, which was alleviated after postoperative detumescence, laser scar dilution and skin scar resection. Thus, it can be concluded that Medpor implantation is a safe and effective option in the treatment of patients with orbital wall fracture.

Conclusion

Medpor implantation effectively restores extraocular muscle function in patients with orbital wall fractures, significantly alleviating diplopia, eye movement disorders, and maxillofacial abnormalities.

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Disclosure of conflict of interest

None.

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