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The influence of concomitant medial wall fracture on the results of orbital floor reconstruction☆

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ABSTRACT

Introduction: Up to 35% of orbital floor fractures extend to the medial wall. This results in restriction of both abduction and adduction, leading to horizontal diplopia. The greater the defect, the more pronounced the enophthalmos.
Aim of the study: The aim of the study was to determine the influence of concomitant medial wall defects on enophthalmos and diplopia, and the influence of intraoperative revision on the results of surgical reconstruction in patients with orbital floor fracture.
Material and methods: 78 cases of orbital floor fracture, with or without concomitant medial wall defect, were retrospectively analyzed. Reconstruction surgeries were performed in a similar fashion, but with variation in the alloplastic materials used. Careful investigation of the area was performed during the surgery.
Results: Patients with associated medial wall defects had significantly more pronounced enophthalmos than those with isolated floor fracture, with no such difference after the orbital reconstruction. Postoperative vertical diplopia was more common in patients with an associated medial defect.
Conclusions: Associated medial wall defect leads to more severe enophthalmos at presentation. However, if the medial aspect of the orbital wall is revised properly, postoperative outcomes are not inferior to those in cases of isolated floor fracture.

1. Introduction

Blunt trauma to the periocular area usually results in orbital wall fracture, often located in the orbital floor. However, in 27%–35% of such cases, the fracture extends to the medial aspect of the orbit (Loba et al., 2012; Burm et al., 1999; Nolasco and Mathog, 1995). Such extension of the wall defect often remains undiagnosed on computed tomography scans (Merle et al., 1998), but additional clinical signs can suggest associated medial wall fracture. These include periorbital edema and ecchymosis, subcutaneous emphysema, and also epistaxis (Joseph and Glavas, 2011; Nolasco and Mathog, 1995). As the size of orbital wall defect is larger in such cases, more pronounced enophthalmos is noted (Nolasco and Mathog, 1995). Enophthalmos is an uncommon sign in patients with isolated medial wall fractures but is twice as common in patients with combined medial wall and floor fractures (Nolasco and Mathog, 1995). In addition to vertical incomitant strabismus, which results from orbital floor fracture, medial wall defects are associated with restriction of abduction and, less commonly, of adduction, eliciting horizontal diplopia (Brannan et al., 2006). Orbital reconstruction surgery with the use of alloplastic materials is used to alleviate diplopia, restore proper orbital volume, and create a rigid barrier between the orbit and sinuses (Kim et al., 2011; Clauser et al., 2008; Hoşal and Beatty, 2002). It serves well in isolated floor fractures, but additional defects of the medial wall might negatively impact the results if not identified by careful investigation of this area during surgical reconstruction in patients with orbital floor fracture.

The aim of this study was to determine the influence of concomitant medial wall defects on enophthalmos and diplopia,

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and the influence of surgical revision of the medial aspect of the orbit on the results of surgical reconstruction in patients with orbital floor fracture.

2. Materials and methods

The study was designed as a retrospective analysis of medical records. Over a 2-year period, all patients with radiographic evidence of orbital floor fracture, with or without concomitant medial wall defect, who subsequently underwent reconstruction surgery were evaluated. 78 cases were identified. Data concerning age, sex, the timing of the surgery, and the type of implant material used for orbital reconstruction were obtained. Computed tomography (CT) examination was performed in order to detect the presence of visible medial wall defects or tissue herniation, and to determine the type of fracture (linear-or hole-shaped).

Individual implant reconstruction was performed in planned cases. Then, raster data from CT (digital imaging and communications in medicine format) were converted into a one-bit image, with the segmentation procedure leading to construction of the solid part of the orbit (Szymor et al., 2016). Pseudo-foramina in the orbital walls resulting from the segmentation procedure were repaired. Then, mirrored geometry of the lower or lower and medial wall was taken from the intact orbit and a CAD/CAM implant was manufactured.

In unplanned cases, the reconstructive material was intraoperationally bent (Zielinski et al., 2017). In bilateral injuries, the acrylonitrile butadiene styrene prototype series of models was used to pre-bend titanium mesh for reconstruction of affected orbital walls.

Orbital reconstruction surgery was performed in a similar fashion in all cases, with the only variable being the alloplastic material used. In cases of general anesthesia, a lower eyelid, transconjunctival approach was taken, with a vasoconstrictor (adrenaline 1:200 000) used in the incision line. After eversion of the eyelid, the position of the inferior border of the tarsal plate was identified. Inferior fornix incision and a retroseptal route was used. The lower lid was retracted downwards to expose the periorbita just behind the edge of the infraorbital rim. Next, the periorbita was incised, allowing direct entry into the destruction area.

In all cases, despite radiographic evidence and clinical suspicion of associated medial wall fracture, careful investigation of the area was performed during the surgery. If necessary, alloplastic material was extended to the medial aspect of the orbit. As the medial wall was additionally involved in the reconstruction, the implant was first inserted in an angulated way over the lower wall towards the medial wall. This meant that no transcaruncular extension was needed in the conjunctival membrane.

In all cases, the results of the orthoptic assessment conducted before and 3 months after the surgery were noted. These included: Hertel exophthalmometry, type and direction of diplopia, and vertical and horizontal angle of strabismus, measured by prism and cover test in the main gaze directions.

The results were a subject to statistical analysis (STATISTICA 10.0) using a t-test for paired measurements ($p < 0.01$). The methods applied in the study adhered to the tenets of the Declaration of Helsinki and were accepted by the Board of Ethics (RNN/144/09/KE).

3. Results

78 patients who underwent reconstruction surgery due to orbital floor fracture were included in the study. They were initially divided into two groups based on the intraoperative findings of concomitant medial wall defects. Group I, consisted of 45 patients (38 males) with isolated lower wall defects. In group II there were 33 patients (27 male) with associated medial and floor fractures. Mean ages were 36.1 ± 14.9 and 42.5 ± 16.5 years respectively. There were no significant differences in age distribution in both groups ($p = 0.08$).

Analysis of computed tomography scans revealed that tissue herniation was more common in group II (96%) than in group I (73%). Large hole-type defects were more frequent in group II (73%) compared with 44% in group I. Time elapsed from the trauma to the surgery did not differ significantly between groups (group I 19.4 ± 12.5 days; group II 21.2 ± 13.3 days; $p = 0.53$). A summary of alloplastic materials used is presented in Fig. 1.

Comparision of exophthalmometric measurements revealed a significant ($p = 0.02$) difference between groups in preoperative assessment. Patients with associated medial wall defects had larger enophthalmos than those with isolated floor fractures. However, there was no such difference after the orbital reconstruction ($p = 0.42$). Detailed results are presented in Fig. 2.

There was no statistically significant difference concerning the preoperative vertical angle of deviation between groups in any of the gaze positions. However, the horizontal angle of deviation was significantly larger in group II ($p = 0.045$). Orthoptic examination showed that the vertical angle of deviation in both groups significantly improved in upgaze (group I $p = 0.001$; group II $p = 0.022$) and primary position (group I $p = 0.000$; group II $p = 0.000$) after surgery. No significant changes were noted in downgaze and in horizontal deviation. A detailed summary of orthoptic measurements is presented in Table 1.

Vertical diplopia was reported by the patients before the surgery, mostly in upgaze (group I 77.8%; group II 84.8%) followed by primary position (group I 40.0%; group II 42.4%) and downgaze (group I 28.9%; group II 30.3%). 3 months after surgery persistent vertical diplopia was more common in group II (group I 11.1%; group II 15.2%).

There was no horizontal diplopia noted in group I either before or after the reconstruction surgery. In group II horizontal preoperative diplopia was noted in five (15.1%) cases. Careful evaluation of those patient records revealed that three of them had small-angle esotropia (mean angle $+14.5 \pm 1.5\Delta$; range $+10\Delta$ to $+16\Delta$). In only one case was there an evident restriction, with a large horizontal angle of deviation ($+35\Delta$). In two cases the type of ocular motility impairment was suggestive of a post-traumatic weakness of the medial rectus muscle, leading to moderate exotropia increasing in adduction (-18Δ and -24Δ respectively). In the postoperative evaluation, only those two patients still exhibited horizontal diplopia, but the angle diminished with time (-10Δ and -14Δ respectively). The rest of those patients were ultimately asymptomatic.

4. Discussion

Enophthalmos, which is one of the major complications occurring in patients with orbital wall fracture, is caused not only by orbital wall defect, but also by changes in the volume of the orbit due to herniation of the orbital tissues through the defect area into an enlarged cavity. Several studies (Zhang et al., 2012; Clauser et al., 2008) have also considered the atrophy of herniated orbital fat and scarring processes in intraorbital soft tissue to be important mechanisms related to the development of enophthalmos.

One of the purposes of our study was to determine the influence of concomitant medial wall defect on enophthalmos, in comparison with isolated wall fracture, as well as to identify the most significant factors in enophthalmos.

In our study, comparison of exophthalmometric measurements revealed a significant difference between groups in

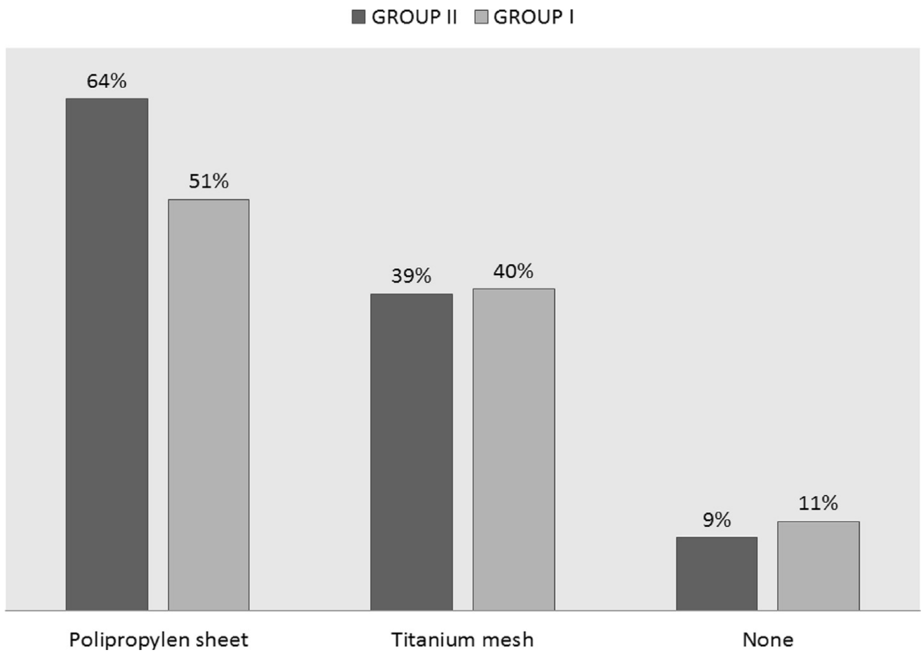

Fig. 1. Alloplastic materials used in reconstruction surgery in both groups.

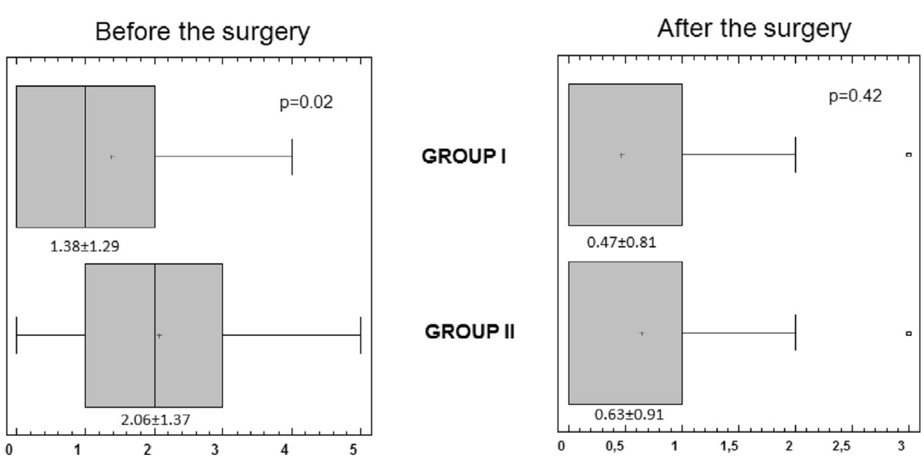

Fig. 2. Hertel exophthalmometry (differences between eyes in millimeters) before and after reconstruction surgery in both groups.

Table 1
Summary of orthoptic examination before and after surgery in both groups.

Mean angle of vertical deviation (Δ)	GROUP I		GROUP II	
	Preop	Postop	Preop	Postop
Upgaze	9.64 ± 7.56	3.74 ± 4.56	9.86 ± 6.37	4.47 ± 6.80
Primary position	5.56 ± 5.10	1.52 ± 2.70	7.44 ± 8.77	1.36 ± 1.11
Downgaze	2.55 ± 2.99	1.94 ± 1.28	2.76 ± 3.43	3.49 ± 4.45
Horizontal angle in primary position (Δ)	2.29 ± 2.07	2.29 ± 1.75	3.82 ± 4.33	3.12 ± 3.04

preoperative assessment. Patients with associated medial wall defects had more pronounced enophthalmos than those with isolated floor fractures.

We believe that a larger area of orbital bony defect leads to more pronounced enophthalmos. Moreover, a medial wall fracture associated with the orbital floor fracture may significantly contribute to enophthalmos because of prolapse of the orbital tissues into the sinuses.

Our beliefs are consistent with the results reported by Choi et al. (2016). Their study revealed that herniated muscle and fat volumes were positively correlated with defect area in the medial orbital. Defect area was more related to enophthalmos than other analyzed metrics. Many other studies have evaluated the factors influencing level of enophthalmos in patients with medial wall fractures. The study by Jin et al. (2000) investigated the relationship between the extent of fracture and enophthalmos in blowout fractures of the medial orbital wall. Enophthalmos increased proportionally as the area of fracture or the volume of herniated orbital tissue increased.

Zhang et al. (2012) also analyzed the correlation between the volume of herniated orbital contents and the amount of enophthalmos in orbital floor and wall fractures. 16 out of 23 cases involved in their study showed combined orbital floor and medial wall fractures; isolated floor fracture was found in four cases. The overall volume of herniated orbital contents correlated significantly with the amount of enophthalmos. However, contrary to our results, their study revealed that the orbital floor was the site most significantly correlated with the amount of enophthalmos (although only if herniation occurred posterior to the vertical eyeball equator).

One of the possible explanations for these differences in results may be that in their study the amount of enophthalmos was not only measured by Hertel exophthalmometry, but also by computed tomography. In our study, we compared the amount of enophthalmos only on the basis of Hertel exophthalmometry, which is commonly used in clinical examination. Perhaps, we need more studies to confirm the measurement accuracy of Hertel exophthalmometry.

In conclusion, a recent review of the literature on this topic, as well as the results of our study, show that the orbital defect area in medial orbital wall fracture, as well as herniated fat volume, are widely considered to be the most significant predictors of enophthalmos.

The medial wall is a challenging surface for a surgeon due to its proximity to the medial palpebral ligament, the lacrimal system, ethmoidal arteries, paper-thin bone, the brain (in the upper half), and the optic nerve. These well-known anatomical features are difficult to recognize post-traumatically.

It requires careful dissection, because a fracture line running from the lower wall upwards to the medial wall, can sometimes to be left without reconstruction. In constrast, iatrogenic expansion of injury in the medial wall is easy i.e. linear fractures may convert to bone defects by careless preparation. It should be taken into consideration that a few millimeters posteriorly to the posterior ethmoidal artery lies the beginning of the optic canal, and that dura mater can cover up to 1 cm of the intraorbital optic nerve run. Last but not least is the issue of angulation between medial and lower wall — this should be considered during reconstruction. It is difficult to reconstruct this anatomical relationship when autologous bone is applied, but plenty of reconstructive alloplastic materials and alloys are available, together with the most accurate individual/personalized CAD/CAM implants (Kim et al., 2017; Kozakiewicz, 2014; Kozakiewicz et al., 2009). Radio-opaque materials are preferable in orbital wall reconstruction, i.e. titanium mesh, but the freedom of volumetric correction offered by polymetric implants has prompted a search for new polyethylene, radio-opaque orbital wall reconstruction technology (Kozakiewicz et al., 2017; Jazwiecka-Koscielniak and Kozakiewicz, 2014).

All of the above make medial wall reconstruction a challenging and demanding procedure, which some surgeons may choose to avoid where possible. However, our results support the necessity of performing surgical reconstruction in this area in order to achieve better outcomes. The results obtained in such patients are no different from those with isolated orbital floor fracture.

Accurate anatomical reconstruction requires complete assessment of fracture margins and proper implant contouring and positioning. The implementation of new technologies for implant shaping and intra-operative assessment of reconstruction will hopefully lead to improved patient outcomes (Boyette et al., 2015). Serious complications in patient with orbital wall fractures include diplopia and limitation of extraocular muscle movement. The most commonly cited cause for restricted extraocular muscle motility and diplopia is entrapment of muscle within the defect. However, those serious conditions can also occur due to intraorbital hemorrhagic edema, entrapment of other orbital tissues such as orbital fat within the fractured bone, or direct damage to the extraocular muscles, nerves, or vessels. Several authors have found correlation between the location of orbital fractures and orbital symptoms such as diplopia and limitation of extraocular muscle motility.

A study by Park et al. (2012) reported that diplopia was more commonly associated with floor fractures (21.4%) and extended-type fractures (23.6%) than with medial wall fractures (10.4%). Regarding limitation of extraocular muscle motility, they reported that the incidence was 7.1% in floor fractures, 3.6% in extended fractures. and 1.7% in medial wall fractures. However, there were no significant differences among the types of fracture.

A study by Burm et al. (1999) reported that diplopia was associated with 25% of medial wall fractures, 80% of orbital floor fractures, and 80.9% of combined medial and floor fractures. Regarding extraocular movement, Burm et al. (1999) reported that the incidence of extraocular movement limitation was 12.5% in medial wall fractures, 73.3% in floor fractures, and 47.6% in extended-type fractures.

Both of the above studies therefore indicate that diplopia is more commonly associated with floor and extended-type fractures. These findings are compatible in some parts with our study, in which both preoperative and postoperative diplopia were more common among patients with extended-type fractures.

Vertical diplopia was reported by the patients before the surgery mostly in upgaze (77.8% for isolated orbital floor fractures and 84.8% for extended-type fractures), followed by primary position (40.0% for isolated orbital floor fractures and 42.4% for extended-type fractures) and downgaze (28.9% for isolated orbital floor fractures and 30.3% for extended-type fractures).

We also believe that the presence of concomitant medial wall fracture influences the results of treatment in terms of diplopia. 3 months after surgery persistent vertical diplopia was more common in patients with extended-type fractures (group II, 15.2%), rather than with isolated orbital fracture (group I, 11.1%).

Another study showed that, in the early postoperative period, a higher rate of diplopia was observed in patients with combined inferior and medial wall fractures, and with longer time intervals from trauma to the (Kasaee et al., 2017). In our study, the time elapsed from trauma did not differ significantly between groups (19.4 ± 12.5 days for isolated orbital floor fractures and 21.2 ± 13.3 days for extended-type fractures), so its influence on the rate of diplopia in all patients was similar. Our findings would seem to imply that the type of the fracture appears to be the most influential factor for diplopia and extraocular movement limitation. In comparison with orbital floor fractures, medial wall fractures present less often with medial rectus entrapment, but this is remains a potential risk. However, diplopia in horizontal gaze is not common. Unlike orbital floor fractures, where an entrapped inferior rectus usually leads to restricted elevation of the globe, patients with medial rectus entrapment in medial wall fractures are more likely to present with findings consistent with paresis of the trapped muscle rather than with restricted limits of excursion.

Horizontal diplopia in patients with associated medial wall defects is more common than in those with isolated floor fractures, but is rarely severe. Wang found a significant positive correlation between fracture of the medial orbital wall and increase in width of the medial rectus muscle, which simply indicates the injury to the muscle belly (Wang and Wang, 2012). A severe limitation of eyeball movement in horizontal versions occurs sporadically. Our study shows that true restriction of medial rectus muscle is rare.

There was no horizontal diplopia noted in patients with isolated floor fractures either before or after reconstruction surgery. In patients with concomitant medial wall fractures, horizontal preoperative diplopia was noted only in five (15.1%) cases. In only two of them, the type of ocular motility impairment was suggestive of a post-traumatic weakness of the medial rectus muscle, leading to moderate exotropia increasing in adduction. This deviation is usually a temporary pathology and typically resolves spontaneously within a few months (Clauser et al., 2008).

5. Conclusions

In conclusion, we would like to stress that concomitant medial wall fracture in patients with orbital floor defects affects the severity of enophthalmos and has to be addressed during reconstruction surgery. If done so, the results of the procedure are not inferior to those obtained in patients with isolated orbital floor fracture.

Horizontal diplopia is more common in such patients, whilst severe limitation of horizontal ocular motility is rare.

Conflicts of interest

None.

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