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Implant malposition and revision surgery in primary orbital fracture reconstructions

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A B S T R A C T

The aim of the study was to assess factors leading to revision surgery and implant position of primary orbital fracture reconstructions.

A retrospective cohort included patients who underwent orbital floor and/or medial wall fracture reconstruction for recent trauma. Demographics, fracture type, surgery and implant-related variables, and postoperative implant position were analyzed.

The overall revision surgery rate was 6.5% (15 of 232 surgeries). The rate was highest in combined midfacial fractures with rim involvement (14.0%), lower in zygomatico-orbital fractures (8.7%), and lowest in isolated blowout fractures (3.8%). Fracture type, orbital rim fixation and implant malposition predicted revision. The best positioning was achieved with patient-specific milled titanium implants (mtPSI) and resorbable materials, whereas the poorest with preformed three-dimensional titanium plates.

Combined midfacial fractures with rim involvement in particular have a high risk for orbital revision surgery. Within the limitations of the present study, mtPSIs should be preferred in the reconstruction of primary orbital fractures if possible.

1. Introduction

Common indications for surgical repair of isolated orbital fractures are globe malposition (GMP) i.e., enophthalmia or hypoglobus, severe restriction of ocular motility, large area of fracture, orbital volume change, volume of herniated soft tissue and non-resolving symptomatic diplopia (Alinasab et al., 2011; Ellis and Tan, 2003; Bianchi et al., 2019; Jansen et al., 2020). Both orbital fractures and reconstruction of the fractures can lead to long-term sequelae such as diplopia, ocular motility impairment, deformity due to GMP, hypoesthesia in the infraorbital nerve region, lid malposition, disturbances in visual acuity, and even blindness (Girotto et al., 1998; Chi et al., 2010; Brucoli et al., 2011; Zhang et al., 2012; Boyette et al., 2015; Al-Moraissi et al., 2018; Schönegg et al., 2018; Causbie et al., 2020).

Revision surgery after orbital reconstruction is common, with revision rates ranging from 2% to 18%. However, these figures are mostly derived from studies with limited patient populations (Scolozzi et al., 2009; Gordon et al., 2012; Cho and Davies, 2013; Schlittler et al., 2018; Causbie et al., 2020). The most common cause of orbital fracture revision surgery is radiologic implant malposition combined with a clinical symptom or finding (Schlittler et al., 2018). Such symptoms can include, for example, globe malposition (GMP), visual acuity disturbances, restricted ocular motility, or diplopia (Schlittler et al., 2018). Complications may be at least partially attributable to poor surgical techniques (Brucoli et al., 2011; Boyette et al., 2015; Kim et al., 2017). In addition to factors related to surgical technique, previous research evaluated the size and type of fracture and the implant material as predictors for surgical outcome (Whitehouse et al., 1994; Raskin et al., 1998; Gosau et al., 2011; Avashia et al., 2012; Bruneau et al., 2016; Choi et al., 2016; Snäll et al., 2019). Implant materials commonly used in orbital reconstruction are titanium, polymer of polylactide acid, polyglycolic acid, or both (PLA, PGA, PLGA), bioactive glass, autologous bone, porous polyethylene, and polyetheretherketone (Avashia et al., 2012). As such, different implants carry advantages and limitations depending on the clinical situation, although no

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evidence exists indicating an obvious superiority of any material (Avashia et al., 2012).

The aim of the study was to assess factors leading to revision surgery and implant position of primary orbital fracture reconstructions. The hypothesis was that different fracture types and the reconstruction material used correlate with revision rates.

2. Materials and methods

2.1. Study design

Patient data from all orbital floor and/or medial wall fracture reconstructions performed at the Department of Oral and Maxillofacial Diseases, Helsinki University Hospital, from January 1, 2011 to October 30, 2019 were collected retrospectively.

2.2. Inclusion and exclusion criteria

The patients included underwent reconstruction of the orbital floor, medial wall, or both due to recent trauma (≤3 weeks). Patients without postoperative imaging were excluded.

2.3. Study variables

The outcome variable was revision surgery of orbital reconstruction.

The primary predictor variable, scoring of implant position, was classified as good, acceptable, or poor. Additional predictor variables were reconstruction location (orbital floor, medial wall, or combined floor and medial wall), material of primary reconstruction, screw fixation of orbital implant, orbital rim plate fixation, and surgical approach (transconjunctival or skin approach).

Explanatory variables were fracture type (isolated blowout fracture, i.e. orbital floor and/or medial wall fracture without fracture of the orbital rim, zygomatico-orbital fracture, and other midfacial fracture extending to orbit), indication for surgery (classified into two categories: volume change as the only indication and clinical symptoms with or without volume change), reconstruction difficulty (normal or difficult), and time from injury to surgery.

2.4. Radiological evaluation

Two researchers with expertise in orbital fractures (M.N., J.S.) reviewed the pre- and postoperative radiological scans using coronal, axial, and sagittal plane images. CT images were viewed once independently. Differing ratings between the researchers were resolved by re-evaluating the imaging data together. The final grading of implant position and reconstruction difficulty were set according to the lower assessment.

Implant position was graded at three sites (anterior, middle, and posterior part of the reconstruction) with a three-point scale according to the classification by Ellis and Tan (2003). An overall score of implant position based on the worst site-specific rating was formed. Unless otherwise specified, scoring of implant position refers to this overall score.

To assess the difficulty of reconstruction, Jaquiery's classification of orbital defects was used. Category IV is defined as “defect of the entire orbital floor and the medial wall, extending into the posterior third with a missing bony ledge medial to the infraorbital fissure”. In category V, the defect also extends to the orbital roof. Categories I-III were considered as normal difficulty of reconstruction and categories IV and V as a difficult reconstruction (Jaquiery et al., 2007).

2.5. Statistical analyses

Data were analyzed using GraphPad Prism, version 5.00 (GraphPad Inc.). The two-tailed Mann-Whitney test was applied to assess the significance of differences in continuous variables. Fisher's exact test was used to examine the association between variables with nominal scales. P-values of less than 0.05 were considered statistically significant.

2.6. Ethical approval

The internal review board of the Head and Neck Center, Helsinki University Hospital (HUS/356/2017) approved the study protocol.

3. Results

3.1. Characteristics of population

A database search of all orbital reconstruction surgeries yielded 265 reconstructions. Of these, 18 were excluded for being late or secondary reconstructions (all of these were over six weeks from trauma), 10 for being tumor surgery, and five for lack of postoperative scans. Of the remaining 232 orbital reconstruction surgeries on 230 patients, two patients received bilateral reconstruction. All patients were imaged postoperatively to evaluate implant position: 229 patients with CT and one patient with magnetic resonance imaging (MRI). Thus, a total of 230 patients with 232 orbital fracture reconstructions with adequate medical records were analyzed to determine the revision rate of orbital reconstructions and to characterize predisposing factors.

Two-thirds (67.8%) of the patients were men (Table 1), and the mean age was 47.6 (range 13–91) years. The most common injury mechanism was assault (42.2%), followed by fall on level ground (26.7%) and motor vehicle accident (9.5%). The mean follow-up time was 153 days (range 0–862).

Orbital reconstruction materials used were manually bent titanium mesh (Synthes/DePuySynthes, Stryker), preformed three-dimensional titanium plate (Synthes/DePuySynthes, KLS Martin, Stryker), patient-specific milled titanium implant (mtPSI) (Planmeca Ltd. (Kärkkäinen et al., 2018)), bioactive glass (BAGS53P4 BonAlive Biomaterials Ltd (Stoor et al., 2015)), and polymer of polylactide acid or polyglycolic acid or both (PLA/PGA/PLGA,

Table 1
Descriptive statistics of 230 patients with 232 orbital fracture reconstructions.

	All n (%)	Nonrevision n (%)	Revision n (%)
Number of patients	230	215	15
Age (years)			
Median	45.8	46.4	50.6
Mean ± SD	47.0 ± 17.9	47.6 ± 18.3	48.6 ± 19.3
Range	90.8–12.8	90.8–12.8	82.0–20.5
Sex			
Male	156 (67.8)	143 (91.7)	13 (8.3)
Female	74 (32.2)	72 (97.2)	2 (2.7)
Injury mechanism			
Assault	98 (42.2)	91 (92.9)	7 (7.1)
Fall on level ground	62 (26.7)	57 (91.9)	5 (8.1)
Motor vehicle accident	22 (9.5)	20 (90.9)	2 (9.1)
Sports	21 (9.1)	21 (100)	0
High energy fall	15 (6.5)	15 (100)	0
Bicycle	10 (4.3)	9 (90.0)	1 (10.0)
Other	2 (0.9)	2 (100)	0
Follow-up time (days)			
Mean ± SD	153 ± 171	146	219 ± 149
Range	0–862	0–862	2–484
Median	98.0	90.0	195

Table 2
Differences between explanatory variables and need for revision surgery after primary orbital fracture reconstruction.

	All reconstructions n (%)	Nonrevision n (%)	Revision n (%)	P value
Number of reconstructions	232	217 (93.5)	15 (6.5)	
Fracture type				
Isolated blowout	159 (68.5)	153 (96.2)	6 (3.8)	.03
Floor	98	94 (95.9)	4 (4.1)	
Combined floor and medial	60	58 (96.7)	2 (3.3)	
Medial	1	1 (100)	0	
Zygomatico-orbital	23 (9.9)	21 (91.3)	2 (8.7)	
Combined midfacial fracture with rim involvement	50 (21.6)	43 (86.0)	7 (14.0)	
Indication for surgery				
Volume change as the only indication	118 (50.9)	110 (93.2)	8 (6.8)	1.0
Clinical indication(s) for surgery	114 (49.1)	107 (93.9)	7 (6.1)	
Several symptoms	30	30	2	
Restricted eye movements	33	30	3	
Double vision	37	35	2	
Globe malposition	14	12	0	
Reconstruction difficulty				
Normal (Jaquiéry et al. I-III)[a]	217 (93.5)	205 (94.5)	12 (5.5)	.06
Difficult (Jaquiéry et al. IV-V)[a]	15 (6.5)	12 (80.0)	3 (20.0)	
Time from injury to surgery ± SD (days)				
Mean ± SD	6.8 ± 4.1	6.8 ± 4.1	6.1 ± 3.4	.31
Range	0–21	0–21	1–13	
Revision rate	15/232 (6.47)			
Revision delay (days from primary surgery) ± SD			35.8 ± 68.0	
Range			0–236	
Median			6	

[a] Jaquiery C, Aeppli C, Cornelius P, Palmowsky A, Kunz C, Hammer B: Reconstruction of orbital wall defects: critical review of 72 patients. Int J Oral Maxillofac Surg 36(3):193–199. https://doi.org/10.1016/j.ijom.2006.11.002, 2007.

Synthes, Stryker). All manually bent titanium meshes were modified to their final shape intraoperatively.

3.2. Characteristics of injuries and initial reconstruction

Orbital volume change as the only indication for orbital reconstruction was noted in more than half (50.9%) of the 232 reconstructions, while one or more clinical indications were present in the rest. The mean time from injury to initial reconstruction was 6.8 days (range 0–21 days) for all reconstructions. The mean time from injury to surgery for different implant materials were as follows: 5.6 days (range 0–18 days) for manually bent titanium meshes, 6.3 days (range 0–17 days) for preformed three-dimensional titanium plates, 9.6 days (range 4–21 days) for mtPSIs and 5.0 days (range 1–12 days) for resorbable materials. Manually bent titanium mesh was the most commonly used reconstruction material (43.5%), followed by preformed three-dimensional titanium plate (26.7%), mtPSI (25.4%), bioactive glass (3.0%), and PLA/PGA/PLGA resorbable sheet (1.3%). In 144 reconstructions (62.1%), the surgical approach was transconjunctival and in 88 transcutaneous (37.9%); six of the latter used an existing laceration. Intraoperative CT or navigation technique was not used.

Overall, 15 patients needed revision surgery (6.5%). The mean delay from initial surgery to revision was 35.8 days (range 0–236, median 6). Indications for revision surgery were as follows: radiologically unsatisfying implant placement without clinical symptoms in six patients (all of these implants were protruding to the maxillary sinus or ethmoids and were graded as poor), combination of suboptimal position and clinical symptoms in seven patients (restriction in ocular motility in three, several symptoms in three, and double vision in one), and a clinical symptom with radiologically ideal implant position in two patients (ocular motility restriction). One patient underwent two revision procedures. None of the revisions were caused by infection, retrobulbar hematoma, or other immediately vision-threatening conditions. At least 9 months from primary surgery to data collection was completed in all patients.

3.3. Predisposing factors

Differences in fracture type were statistically significant between nonrevision and revision groups ($P = .034$) (Table 2). Revision surgeries were least frequent in isolated blowout fractures (3.8%), more common in zygomatico-orbital fractures (8.7%), and most frequent in combined midfacial fractures with rim involvement (14.0%). The use of orbital rim fixation correlated significantly with revision surgery ($P = .043$) (Table 3). Scoring of implant position was significantly related to subsequent revision ($P < .0001$). Other variables remained nonsignificant for revision surgery.

Implant malposition was common; 21.6% of all reconstructions received an acceptable score in at least one part of the reconstruction, and a poor score was given to 5.6% (Fig. 1 and Fig. 2) (Table 3). Thus, a total of 27.2% of reconstructions were less than ideal. In the revision group, 60.0% of reconstructions were scored as poor and 26.7% as acceptable, in contrast to 1.8% and 21.2%, respectively, in the nonrevision group. The site-specific scores (Fig. 3) show that the posterior site of reconstruction, i.e., the posterior edge of the implant, was most often scored as acceptable (15.1%) or poor (4.7%).

Differences between implant materials were significant in scoring of implant position (Table 4) ($P = .0011$). The best positioning was achieved with mtPSIs and biomaterials, whereas reconstruction with the preformed three-dimensional titanium plate was most often suboptimal.

4. Discussion

Orbital reconstruction surgery is challenging, as reflected by the relatively high revision rates (Scolozzi et al., 2009; Gordon et al., 2012; Cho and Davies, 2013; Schlittler et al., 2018; Causbie et al., 2020), and exposes the patient to significant sequelae (Girotto et al., 1998; Boyette et al., 2015; Causbie et al., 2020). The study aimed at assessing factors leading to revision surgery and implant position of primary orbital fracture reconstructions. The hypothesis

Table 3
Differences between predictor variables of nonrevision and revision groups after primary reconstruction of orbital fractures.

	All reconstructions n (%)	Nonrevision n (%)	Revision n (%)	P value
Number of reconstructions	232	217	15	
Scoring of implant position				
Good	169 (72.8)	167 (98.8)	2 (1.2)	
Acceptable	50 (21.6)	46 (92.0)	4 (8.0)	
Poor	13 (5.6)	4 (30.8)	9 (69.2)	<.0001
Reconstruction location				
Floor	196 (84.5)	185 (94.4)	11 (5.6)	
Combined floor and medial	35 (15.1)	31 (88.6)	4 (11.4)	
Medial	1 (0.4)	1 (100)	0	0.42
Material of primary reconstruction				
Manually bent titanium mesh	101 (43.5)	96 (95.0)	5 (5.0)	
Preformed three-dimensional titanium plate	62 (26.7)	54 (87.1)	8 (12.9)	
Patient-spesific milled titanium implant	59 (25.4)	57 (96.6)	2 (3.4)	
Bioactive glass	7 (3.0)	7 (100)	0	
Polylactide acid and/or polyglycolic acid polymer	3 (1.3)	3 (100)	0	0.18
Screw fixation of orbital implant				
Yes	25 (10.8)	21 (84)	4 (16.0)	
No	207 (89.2)	196 (94.7)	11 (5.3)	0.06
Orbital rim plate fixation				
Yes	68 (29.3)	60 (88.2)	8 (11.8)	
No	164 (70.7)	157 (95.7)	7 (4.3)	0.04
Surgical approach				
Transconjunctival	144 (62.1)	137 (95.1)	7 (4.9)	
With cantholysis or canthotomy	48	44 (91.7)	4 (8.3)	
Skin incision	88 (37.9)	80 (90.9)	8 (9.1)	0.27
Employment of existing laceration	6	6 (100)	0	

was that fracture type and reconstruction material correlate with revision rate.

Our hypothesis was partially confirmed; scoring of implant position and fracture type were associated significantly with revision surgery, and the posterior part of the reconstruction was the most common site of implant malposition. Also, revision correlated with fracture complexity, i.e. fracture type and orbital rim fixation. Even though the differences between reconstruction materials and need for revision remained nonsignificant, statistical significance was found between the materials used and implant position. Among the materials most often used, mtPSIs (Fig. 4 and Fig. 5) and biomaterials received the highest scoring of implant positioning, although the number of the latter were small. Perhaps a little surprisingly, the poorest positioning was found with preformed three-dimensional titanium plates (Table 4).

Revision rate for all orbital reconstructions was 6.5%, which is at the lower end of the spectrum compared with the rates found in the literature (2–18%) (Scolozzi et al., 2009; Gordon et al., 2012; Cho and Davies, 2013; Schlittler et al., 2018; Causbie et al., 2020). It should be noted that implant position was suboptimal (poor or acceptable) in 86.7% of orbits in the revision group. Only two (1.2%) of 169 radiologically ideal reconstructions required revision, which was based exclusively on clinical symptoms. In contrast, 13 (20.6%) of 63 suboptimal reconstructions had revision surgery, and seven of these cases also had significant clinical symptoms. Thus, clinical symptoms follow the radiological success of the reconstruction. Implant malposition was common; more than one-fourth of all reconstructions had a suboptimal score in at least one location. This is lower than rates reported in the study by Schlittler et al., in 2018 (27.2% vs. 53.4%), perhaps reflecting the frequent use of mtPSIs in the current study.

Fig. 1. A coronal view of an orbital fracture reconstruction graded as poor both medially and posteriorly. The difficulty of reconstruction was graded as difficult. The patient presented with double vision and globe malposition postoperatively and eventually underwent a successful revision surgery. A manually bent titanium mesh was used in both reconstructions.

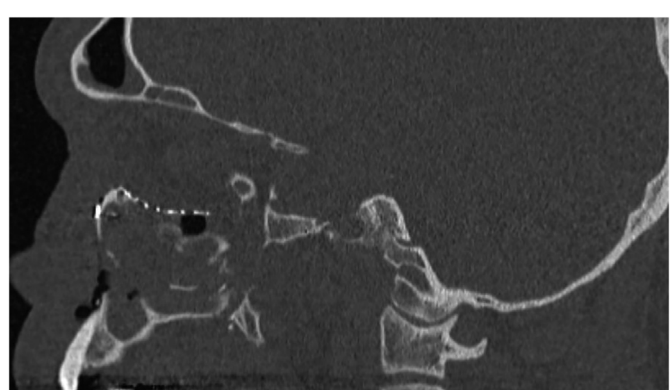

Fig. 2. The same reconstruction as in Fig. 1 from a sagittal view.

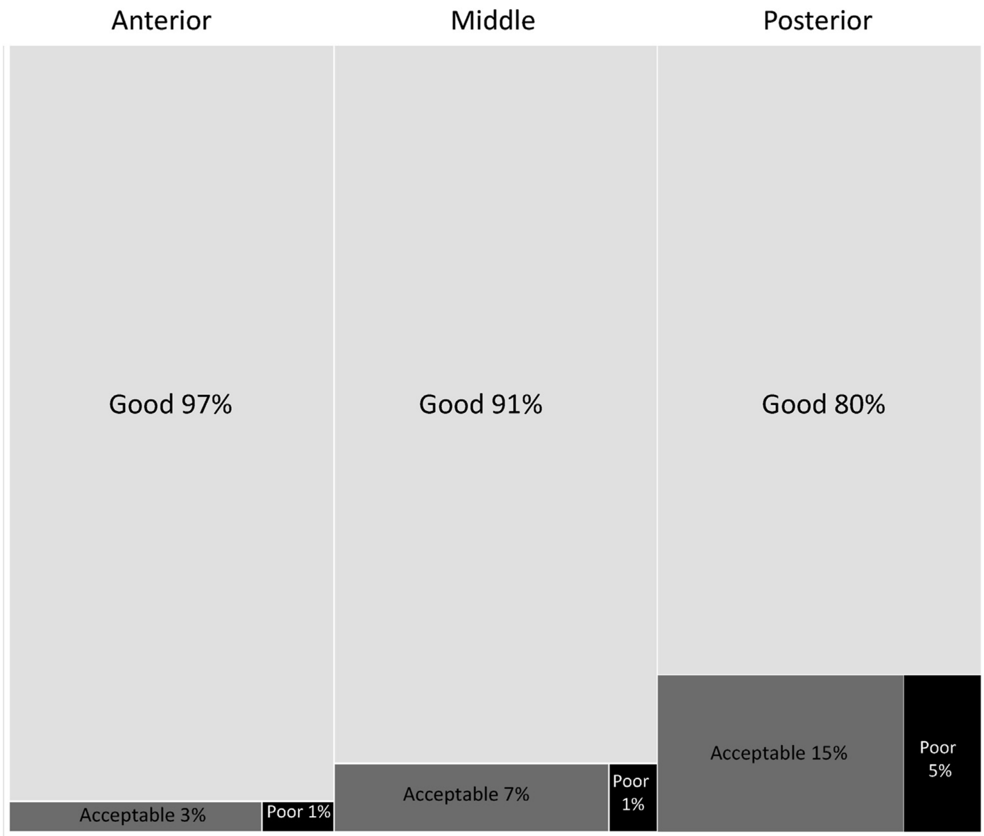

Fig. 3. Scoring of implant position by site (all reconstructions, n = 232).

Table 4
Implant material versus scoring of implant position after orbital fracture reconstruction.

Material		Scoring of implant position			P value
		Good	Acceptable	Poor	
		n (%)	n (%)	n (%)	
Manually bent titanium mesh	101	78 (77.2)	17 (16.8)	6 (5.9)	.001
Preformed three-dimensional titanium plate	62	31 (50.0)	25 (41.7)	6 (9.7)	
Patient-spesific milled titanium implant	59	50 (84.7)	8 (13.6)	1 (1.7)	
Bioactive glass	7	7 (100)	0	0	
Polylactide acid and/or polyglycolic acid polymer	3	3 (100)	0	0	

The preformed three-dimensional titanium plate had the highest revision rate of 12.9%, while manually bent titanium mesh had a revision rate of 5.0% and mtPSIs 3.4%. None of the ten fractures reconstructed with resorbable implants required revision. Wide fractures as well as fractures extending to both the orbital floor and medial wall are difficult to reconstruct at the primary stage with the resorbable implants used in this study, thus, the most challenging fractures were reconstructed with titanium. Although the differences were not statistically significant, the high revision rate of the preformed three-dimensional titanium plate raises concerns. It is designed to mimic the average anatomy, but it is stiff and poorly malleable. As presented previously, reconstructing large orbital defects with non-customized plates may lead to incomplete fracture coverage (Schlittler et al., 2020). This lack of adjustability may cause suboptimal fit and soft tissue entrapment—possibly leading to more revision surgeries and other complications.

Customized implants can be manually formed intraoperatively or on a 3D template preoperatively, or preoperatively created with a CAD/CAM process, as mtPSIs in this study. These results are in concordance with a previous multicenter study showing that customized implants in general provide more accurate restoration of orbital volume than non-customized implants (Zimmerer et al., 2016). The traditional manually bent titanium mesh is affordable and versatile in use, enabling its application in emergent situations, but the intraoperative shaping of these implants requires experience and skill of the surgeon in order to adequately replicate the natural anatomy.

mtPSIs received a significantly better scoring of implant position than the other two types of titanium implants (Table 4). Using these implants in late reconstructions is common, but using them in primary reconstructions presents challenges, especially treatment delay (Schlittler et al., 2020). The protocol developed in our clinic enables their use in primary reconstructions as well, without delaying the treatment (Kärkkäinen et al., 2018). In the current study, the mean time from injury to surgery was 6.8 days for all materials and 9.6 days for mtPSIs. During recent years our pre— and postoperative protocols and techniques for orbital surgery have

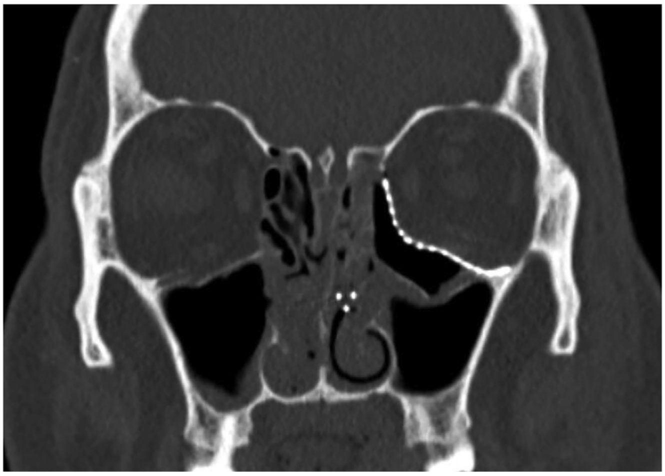

Fig. 4. An optimal orbital fracture reconstruction of an extensive fracture of the orbital floor and medial wall, with clinical globe malposition. The difficulty of reconstruction was graded as difficult. The fracture was reconstructed at two weeks from trauma with a two-piece patient-specific milled titanium implant.

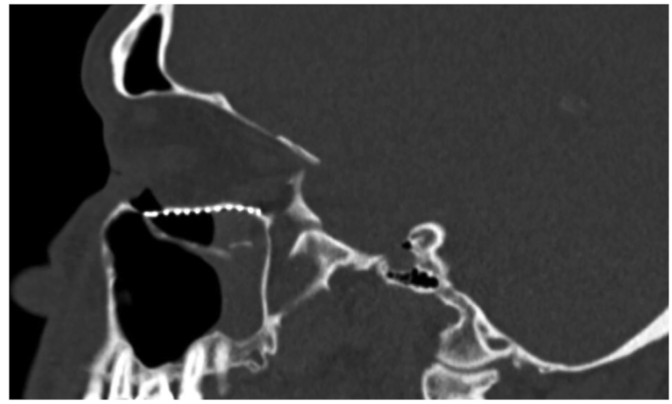

Fig. 5. The same reconstruction as in Fig. 4 from a sagittal view.

developed, and in the last few years of the study mtPSI use in more complex fracture types had increased. It is also worth noting that of the two mtPSIs needing a revision surgery both were placed within the first year of the study (in 2011), likely reflecting the learning curve and development of the technology. These implants can be designed to engage fracture edges and anatomical landmarks and are a good alternative for navigation use and intraoperative imaging (Stoor et al., 2014).

As hypothesized, implant malposition was most common in the posterior part of the reconstruction, with 15.1% given an acceptable and 4.7% a poor score. The posterior site and its importance in orbital reconstruction have been previously emphasized (Evans and Webb, 2007; Harris, 2014; Purnell et al., 2018; Ahmad Nasir et al., 2018). The posterior site is not usually directly visualized, particularly in fractures with extensive soft tissue prolapse and edema. The tapering shape of the orbit and the fragile medial wall complicate soft tissue preparation, implant positioning, and identification of anatomical structures such as infraorbital fissure and sinuses. Exposing the fracture in the posterior area is challenging, especially for inexperienced surgeons. Intraoperative CT and navigation can be used for anatomical guidance with good results (Shaye et al., 2015; Zimmerer et al., 2016; Zavattero et al., 2017; Tel et al., 2019; Causbie et al., 2020). These technical solutions were not available in surgeries of the present study.

Notably, screw fixation of the orbital implant was used in only 10.8% of surgeries, but is present in 26.7% of the reconstructions requiring revision surgery. In our unit, the tradition has been to aim for a passive fit of the implant without screw fixation and resort to screw fixation only when this fails. As a result, screw fixation may be favored in more difficult reconstructions. While the much lower revision rate (5.3%) of reconstructions with unfixed implants might be explained by less difficult surgeries, this data does support the practice of not using screw fixation if clinically stable implant position is achieved. Fixation may appear necessary when facing adversities in implant placement, when in fact the problem might be soft tissue entrapment or poor fit. Screw fixation can be necessary with complicated defects, but even then, it is crucial to first ensure good implant placement and unrestricted ocular movement afterward.

A fracture involving the orbital rim adds another degree of freedom to the orbit. These results show that optimal reconstruction of the orbit is most difficult in complex midfacial fractures. These situations require particular attention and good preoperative planning. A two-stage approach may be a good option in select cases; for example, if it is appropriate to confirm the reduction of the other midfacial fractures before orbital reconstruction, but intraoperative imaging is not available. In some cases, soft tissue swelling or acute eye injury may also delay orbital reconstruction. Naturally, a second surgery will cause an additional soft tissue trauma and require a second time under general anesthesia, which is why priority should be given to high-quality single-stage surgery, and especially its careful planning. A good option is to create virtual reduction and a reduced physical 3D-model of the orbit. A titanium plate can be prebent according to the model to achieve a good approximation of a truly customized implant. Furthermore, development of virtual methods enables more versatile options for customized surgery and implants without intermediate steps.

Postoperative CT scan is part of our routine protocol. There have been specific concerns of cataract formation due to CT scans (Chodick et al., 2008), but recent studies have alleviated these worries (Gaudreau et al., 2020). Despite visual control during the surgery, implant malposition rates tend to be high and revision surgeries fairly common. In our view, this and the possibility of severe preventable complications going unnoticed justify the radiation exposure.

The retrospective design and low number of revisions are the main limitations of this study. The follow-up period varied; however, symptomatic patients are likely to seek treatment. Unfortunately, orbital reconstruction experience of the surgeons or intraoperative challenges could not be clarified, which would have given more impact to the results. Also, the surgical approach, which may influence the end-result (Mohamed et al., 2020), was not described in detail. Diplopia was classified only as present or absent and during the study period minor diplopia symptoms were not categorically examined. In our current practice, all patients with orbital fractures are routinely examined by an ophthalmologist. The reliability of implant position evaluation would have been enhanced by the involvement of more evaluators and even better reliability may be achieved in the future with computer-assisted technologies that have been implemented in measuring orbital volumes (Gomes de Oliveira et al., 2019; Chepurnyi et al., 2020). Additional studies are needed to assess the cost-effectiveness of different implant materials, including analyses of revision rates and clinical outcomes. The current study focused on revision rates and implant position, but several other complications and disadvantages may occur after orbital fracture surgery.

5. Conclusion

Despite advances in materials, complex orbital fractures remain challenging to reconstruct and suboptimal implant positioning is common. Fortunately, severe vision-threatening postoperative conditions leading to revision surgery are rare. Implant malposition, with or without clinical symptoms, was the main reason for revision. Suboptimal implant positioning and need for revision surgery can be reduced with careful surgical planning especially in combined midfacial fractures. To attain optimal surgical outcomes and sufficient experience for the surgeon, it would be beneficial to centralize orbital fracture surgery to surgeons specialized in facial fracture surgery. Within the limitations of the present study, mtPSIs should be preferred in primary orbital fracture reconstructions if possible.

Authorship confirmation statements

Study design: M.N, J.S. Study conduct: M.N, J.S. Data collection: M.N, H.R. Data analysis: M.N, E.M. Data interpretation: M.N, E.M, J.S. Drafting manuscript: M.N. Revising manuscript content: E.M, H.R, J.S. Approving final version of manuscript: M.N, H.R, E.M, J.S.

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Declaration of competing interest

The authors declare that there is no conflict of interest.

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