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ARTICLE

Surgical management of isolated orbital floor and zygomaticomaxillary complex fractures with focus on surgical approaches and complications

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ABSTRACT

Zygomaticomaxillary complex (ZMC) and orbital blow out fractures are commonly encountered midfacial fractures that may result in aesthetic and functional impairment. This retrospective study reports on the surgical treatment and associated postoperative complications in our patient collective. We evaluated 100 patients who underwent open reduction and internal fixation of midfacial fractures between 2010 and 2015. Preoperative clinical features, surgical technique and postoperative complications were analyzed. Surgery was performed with a mean latency of 7 days after trauma. We used titanium mesh and polydioxanone sheets to reconstruct the orbital floor. Most ZMC fractures were stabilized with two point fixation with titanium plates. Preoperative symptoms were present in 70 patients (70%). Infraorbital hypesthesia occurred in 49 patients, diplopia in 41 patients and ocular motility impairment in 24 patients. Postoperative symptoms persisted during a mean follow-up time of 4.5 months in 47 patients (47%) showing infraorbital hypesthesia in 24%, diplopia in 17%, ectropion in 7% and ocular motility impairment in 4%. Complications requiring revision were retrobulbar hematoma 3% ($n = 3$), ectropion 3% ($n = 3$), diplopia 1% ($n = 1$), exophthalmos 1% ($n = 1$), implant dislocation 1% ($n = 1$), implant discomfort 2% ($n = 2$), persisting fracture dislocation 1% ($n = 1$). All patients recovered without significant impairment. Surgery is required in the majority of the patients with midfacial fractures. Among others ectropion is challenging due to its aesthetic and functional impact on patients. To prevent ectropion, additional canthopexy or the transconjunctival surgical approach are reasonable options in selected cases.

Level of Evidence: Level V, descriptive study.

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Abbreviations: CT: computed tomography; OF: orbital floor; PDS: polydioxanone; ORIF: open reduction and internal fixation; ZMC: zygomaticomaxillary complex

Introduction

The zygomaticomaxillary complex (ZMC) is an important functional and aesthetic landmark of the midface [1]. Due to its anatomically prominent convexity, the ZMC is very vulnerable to injuries [2].

In fact fractures of the ZMC represent the most common midfacial fractures [3]. One subcategory of ZMC fractures are the so called blowout fractures – isolated fracture to the orbital floor and medial wall, which is in part formed by the ZMC. They are caused by direct trauma either to the zygomatic bone or to the bulbus and often lead to soft tissue (periorbital fat or extraocular muscles,) entrapment within the maxillary sinus, ethmoid cells or pterygopalatine fossa [4]

Typical clinical findings of ZMC fractures include painful swelling of the affected cheek, step-offs at the orbital rim/zygomatic arch/ZM buttress, circumorbital ecchymosis, subconjunctival hemorrhage, nose bleeding, altered globe level, enophthalmos, limited eye excursions, diplopia, infraorbital paresthesia or trismus.

The indications for operative treatment of ZMC fractures are aesthetic and/or functional impairment. In isolated orbital floor fractures smaller defects can often be treated conservatively unless diplopia persists after serial examinations over two weeks or enophthalmus >2mm is present [4]. Large defects involving more than 50% of the orbital floor should be operated on regardless of symptoms because enophthalmos is likely to occur [5]. Also ZMC fractures with significant posterior displacement (>1 cm) warrant an intraoperative exploration [6].

A variety of surgical approaches for open and closed reduction as well as different techniques of internal fixation can be used for these fractures.

This study evaluates and reviews the etiology, incidence, preoperative clinical findings and surgical management of ZMC fractures and reports on the incidence, the specific characterization, and the potential risk factors of common postoperative complications.

Patients and methods

After approval by the local ethics committee (KEK PB_2016-01296) the files of all patients treated for a ZMC fracture in our department between January 2010 and December 2015 were reviewed retrospectively. All patients who underwent open reduction and internal fixation of a fracture of the zygomaticomaxillary complex

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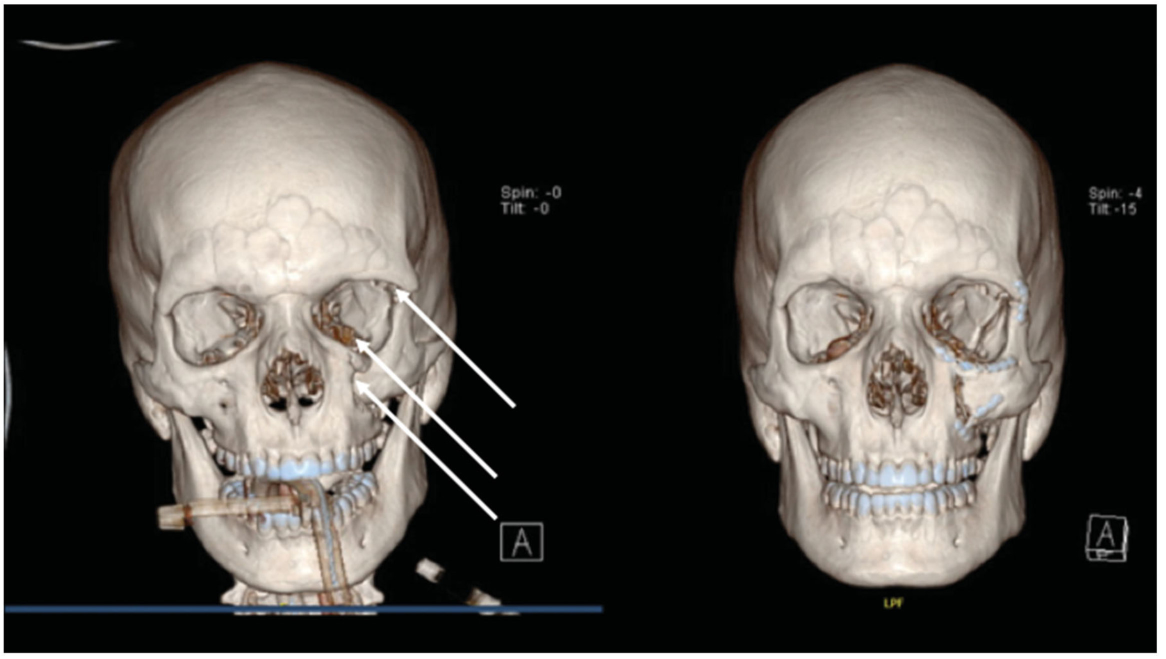

Figure 1. Pre- and postoperative CT-Scan depicting a ZMC fracture. The separate fracture lines are marked with arrows in the preoperative scan. On the postoperative scan the fractures lines are bridge with plates.

were included in this study. For each patient case included in the study the following data were recorded: patients' demographical data (age and sex), mechanism of injury/cause of trauma, radiological findings, indications for surgical intervention, applied operative technique including surgical approach and implant material as well as the duration of surgery, postoperative complications and surgical outcome in general.

All patients were carefully examined and underwent a Computed Tomography (CT) to verify the diagnosis and to plan the operative therapy. Preoperatively an ophthalmologic examination was conducted to rule out injury to the bulbus or optic nerve. Surgery was always performed under general anesthesia and patients routinely received a single-shot antibiotic prophylaxis preoperatively. Depending on the fracture type the surgeon decided on the surgical approach as well as number and type of implants used. During surgery a bulbus protection was used on the affected side and at the end of the surgery the forced-duction test was performed in all fractures with orbital floor involvement to rule out any mechanical ocular motility impairment. Postoperatively another CT scan was carried out in order to verify the implant position before the patients were discharged. The patients were seen for routine follow up visits in our outpatient clinic (Figure 1).

Patient data was collected in Microsoft Excel and descriptive statistics were used for interpretation.

Results

The study cohort consisted of 78 men and 22 women with a mean age of 38 years (range 16–84; Table 1). Notably the mean age for just the 22 female patients was higher with 52 years (range 21–84) compared to the male patients' mean age of 34 years (range 16 to 80). The most common mechanism of injury was physical assault (45) followed by daily life injuries (25), sport injuries (15), traffic accidents (12) and work accidents (3) (Figure 2). Regarding specific fracture patterns we operated on 57 patients who had suffered an isolated orbital floor fracture while

Table 1. Study cohort.

Number of patients: 100	
mean age: 38 years, range: 16–84	
men: 78	women: 22
mean age: 34 years (range 16–80)	mean age: 52 years (range 21–84)
Mechanism of injury	
Physical assault	45
Daily life injuries	25
Sport injuries	15
Traffic accidents	12
Work accidents	3
Type of fracture	
Isolated orbital floor fractures: 57	ZMC fractures: 43
Indication for surgery	
Functional impairment	75
Displacement in CT scan	21

the remaining 43 presented complex fractures of the ZMC. The findings that led to the indication for surgery in 75 patients were functional impairment of the eye (ocular motility, diplopia, optic nerve), mandibular opening or infraorbital nerve affection. In 21 cases, the indication for surgery was an impression of the zygomatic arch (clinical or radiological) or a large defect of the orbital floor visible in the CT. Four patients could not be examined clinically prior to surgery due to their neurological condition.

Patient evaluation was done in two groups. One group including patients with ZMC fractures in general and the other group including just patients with blow out fractures ($n = 57$), a subcategory of ZMC fractures.

Preoperative clinical findings

The patients with an orbital floor fracture showed diplopia in 63% ($n = 36$), ocular motility impairment in 35% ($n = 20$), infraorbital hypesthesia in 44% ($n = 25$), retrobulbar hemorrhage in 4% ($n = 2$) or enophtalmos in18% ($n = 9$; Table 2).

Preoperative clinical findings in the general ZMC fracture cohort ($n = 43$) were as follows: diplopia 17% ($n = 5$), ocular motility impairment 9% ($n = 4$), infraorbital hypoesthesia 56% ($n = 24$),

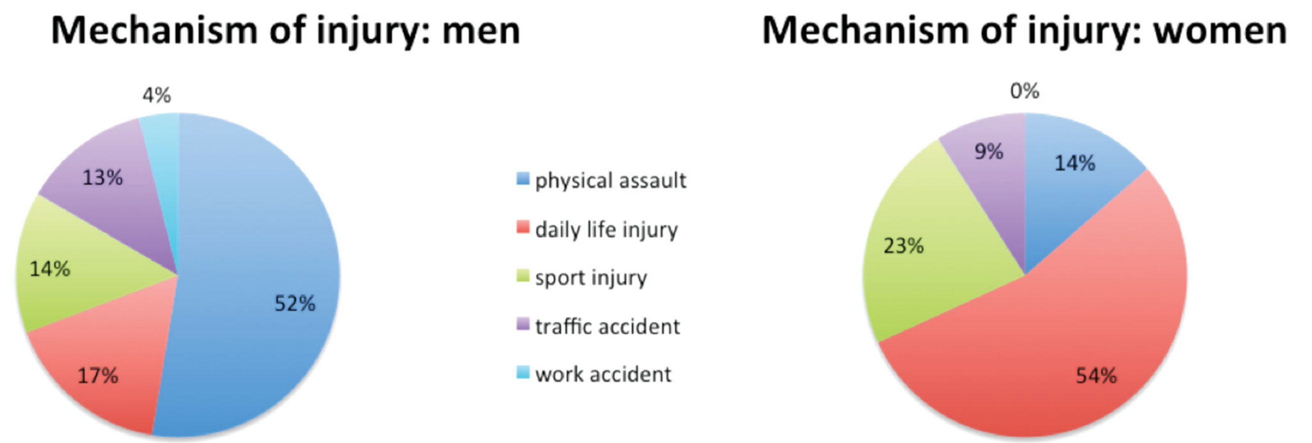

Figure 2. Mechanism of injury.

Table 2. Preoperative clinical findings.

	Isolated orbital floor fractures	ZMC fractures
Dipolopia	36	5
Ocular motility impairment	20	5
Infraorbital hypesthesia	25	24
Retrobulbar hemorrhage	2	
Enopthalmos	9	1
Exopthalmos	/	2
Visual impairment	/	2
Trismus	/	6
Malocclusion	/	3
Oto-/rhinoliquorroe	/	/

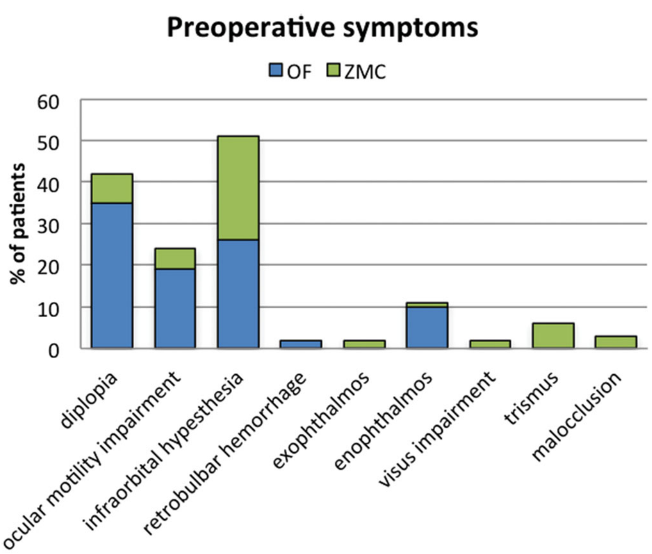

Figure 3. Preoperative symptoms.

exophthalmos 5% ($n = 2$), enophtalmos 2% ($n = 1$), visual impairment 5% ($n = 2$), trismus 14% ($n = 6$), malocclusion 7% ($n = 3$).

No patient in either group presented with oto- or rhinoliquorrhoe (Figure 3).

Surgical treatment

To access the orbital floor in the blow out fracture cohort, a lower eyelid skin incision subciliary was performed in 45 out 57 patients and subtarsally in eight patients (Table 3).

In four patients, the surgical approach was *via* a preexisting wound. For the ZMC fractures, we used a subciliary approach in 30 patients and never a subtarsal approach. Additional fracture approaches were performed *via* lateral eyebrow incisions ($n = 30$), temporal Gillies approaches ($n = 35$) and *via* preexisting wounds ($n = 1$).

Table 3. Surgical technique.

	Isolated orbital floor fractures	ZMC fractures
Surgical approach		
Subcilliar incision	45	
Subtarsal incision	8	30
Approach via preexisting wound	5	1
Lateral eyebrow incision		30
Gillies approach		35
Reconstruction with		
Titanium mesh	7	2
PDS sheet	10	11
Both	40	3
Plates on infraorbital rim		34
Plates on the frontozygomatic crest		27
Plates on the zygomaticolveolar crest		14
Reduction without fixation		9
Mean duration of surgery	76	91

All 57 patients with an isolated orbital floor fracture received a reconstruction of the orbital floor with either a titanium mesh ($n = 7$), a PDS-Sheet ($n = 10$) or both ($n = 40$). In two cases, an additional plate for the stabilization of the infraorbital rim was used.

For the patients in the general ZMC fracture group we used a PDS-Sheet (26%, $n = 11$), a titanium mesh (5%, $n = 2$) or the combination in 7% ($n = 3$) to reconstruct the orbital floor component. In addition, the internal fixation was done as follows. Plates on the infraorbital rim in were used in 79% ($n = 34$), on the frontozygomatic 63% ($n = 27$) and on the zygomaticoalveolar crest 33% ($n = 14$) (Figure 4).

In 21% ($n = 9$) an open reduction over a Gillies approach without any fixation was performed. One of the ZMC fracture patients received only an orbital floor reconstruction with titanium mesh and PDS-sheet. In most of the cases a two-point fixation 51% ($n = 22$) was necessary. Only one case (2%) could be treated with just a one point plate fixation over the infraorbital rim.

Intraoperatively, we always placed the first plate over the infraorbital rim. The second plate was typically used to fix the frontozygomatic buttress ($n = 18$), in some cases ($n = 4$) it was placed over the zygomaticoalveolar crest instead. In 21% ($n = 9$) a three point fixation was necessary. No case required a four point fixation.

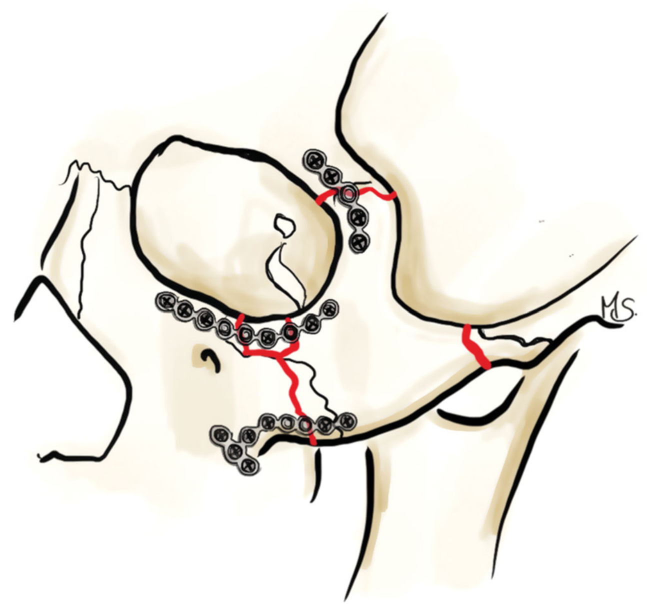

Figure 4. Illustration of a three point fixation in a ZMC fracture. Fracture lines are drawn in red and all but the zygomatic arch fracture are bridged with plates.

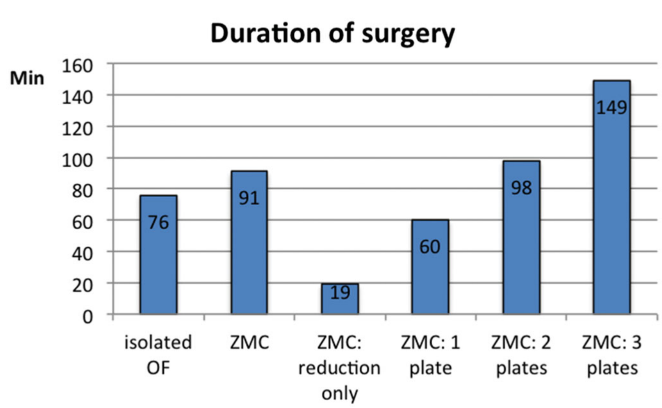

Figure 5. Duration of surgery.

The duration of the surgery was correlated to the complexity of the fracture.

For the isolated orbital floor fractures the mean duration of surgery was 76 min.

The mean duration of surgery for the other ZMC fractures was 91 min The more implants we used the longer the surgery went on for: An open reduction of the zygomatic arch without any internal fixation took on average 19 min ($n = 8$). If plates were used the mean duration was 60 min (1 plate, $n = 1$), 98 min (2 plates, $n = 22$) and 149 min (3 plates, $n = 11$) (Figure 5).

The median delay between surgery and trauma for all patients was 7 days (±6.7, range 2–58 days). Antibiotics were given in 90% of the cases, exception were the reductions of the zygomatic arch without any internal fixation.

Postoperative findings

Follow-up ranged from 1 to 37 months with a mean of 4.4 months (± 4.9) for all patients (Table 4).

In total, there were 12% ($n = 12$) revision surgeries for the following indications: retrobulbar hematoma 3% ($n = 3$), ectropion 3% ($n = 3$), diplopia 1% ($n = 1$), exophthalmos 1% ($n = 1$), implant dislocation 1% ($n = 1$), implant discomfort 2% ($n = 2$), persisting fracture dislocation 1% ($n = 1$). These complications arose in the blow out fracture cohort in six cases and in the ZMC fracture cohort in six cases.

Table 4. Postoperative clinical findings.

	Isolated orbital floor fractures	ZMC fractures
Revision surgery	6	6
Infraorbital hypesthesia	16	15
Enophthalmos	1	2
Exopthalmos	2	/
Entropion	/	/
Diplopia	13	2
Ocular motility impairment	4	/
Scleral show	/	6
Ectropion	3	7
Asymmetry of the cheek contour		6

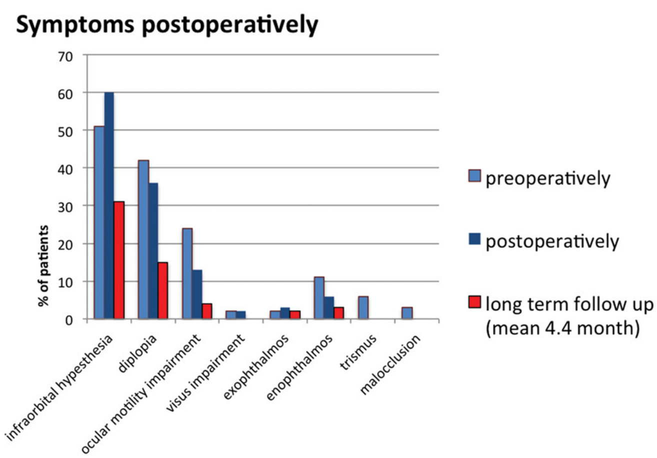

Figure 6. Symptoms postoperatively.

When specifically considering the preoperative symptoms and postoperative findings for all patients we observed a significant reduction of symptoms after surgery from an over all of 182 recorded symptoms as listed above to 72 symptoms.

Of the 49 patients with preoperative hypesthesia of the infraorbital nerve, it persisted in 17 patients longer than 4 months and 14 patients showed a not pre-existing hypesthesia postoperatively.

Diplopia persisted in 12 patients (29%) and 5 patients (5%) showed a newly diagnosed diplopia postoperatively. Ocular motility impairment persisted in three patients, in one patient it occurred only postoperatively. Fifteen patients (15%) showed an ectropion the early postoperative controls, but only in three of those cases (3% overall) an operative treatment was necessary.

Postoperatively we did not see any patients suffering from an entropion.

At the end of the follow-up period, six patients (6%) showed a slight asymmetry of the cheek contour (Figure 6).

Discussion

The facial appearance can be dramatically altered by fractures of the zygomaticomaxillary complex (ZMC) which represent a common type of maxillofacial trauma, potentially impairing function and/or aesthetics.

We found a higher incidence of ZMC fractures in young male patients with a male-to-female ratio of 3.5:1. Our data are in concordance with the literature where ratios from 2.3 to 9:1 are reported [7–9].

The main causes of midfacial fractures reported in the literature are traffic accidents, falls, sports injuries and interpersonal violence [8]. Whereas in various reports the most common etiology was a traffic injury, some authors observed an increase in personal assaults as cause of midfacial fractures [9,10]. In our patient cohort, the most common cause of injury in men was a physical assault whereas in women the most common cause was a daily life injury. This might also explain the overall younger median age of our male patients, a correlation that is in accordance with findings published by other groups [11].

Preoperative clinical findings

Our preoperative findings are in concordance with those published in the literature, some authors suggest that a certain set of symptoms can already predict orbital fractures [12]. We would agree with this assumption but do rely on the CT scan for exact diagnostic and surgery planning when we have any suspicion of a facial fracture.

Surgical treatment

The basis of operative treatment of ZMC-fractures is fracture reduction with or without internal fixation. The indication for a reduction only is an isolated, dislocated fracture of the zygomatic arch. In these cases reduction can be achieved over a Gillies approach or a percutaneous cheek access (Marinho and Freire-Maia, 2013). In nine cases, we performed said fracture reduction of the zygomatic arch over a Gillies approach without internal fixation. None of these patients had postoperative complication, in one out of three an infraorbital hypesthesia persisted during the follow up visits. As no patient suffered from complete anesthesia or dysesthesia nerve revision surgery was not discussed especially as this remains controversial [13,14]

Our overall outcome concerning infraorbital hypesthesia postoperatively reflects numbers similar to those that have been published for example by Das et al. [15] who found a relatively complete recovery occurred in 76.92% of their patients.

In fractures where an internal fixation is necessary an open approach is indicated. The surgical sites for ORIF of a ZMC fracture are the zygomaticoalveolar crest, inferior orbital rim, frontozygomatic buttress and the zygomatic arch. There are many described approaches and we also used different surgical approaches in different types of fractures.

The discussion about the ideal approach to the inferior orbital rim and orbital floor is ongoing. Lower eyelid incisions (subciliary and subtarsal) have a higher risk of postoperative ectropion or scleral show compared to a transconjunctival approach. Authors report on development of an ectropion after subciliary incision in from 5 to 42% of their cases. When comparing subciliary with subtarsal approach a better aesthetic result due to a less visible scar has been attributed to the subciliary approach which is one of the reasons this approach had been preferred in our department [16]. On the downside however ectropion as well as scleral show have been more commonly attributed to the subciliary incision in previous studies [17]. With the transconjunctival approach a postoperative ectropion appears to be a rare complication but with this approach the risk for a postoperative entropion is reported with rates of 0–20% [18–20]. As one clinical consequence of the present study we have since switched our general surgical approach for these type of fractures to the transconjuctival approach

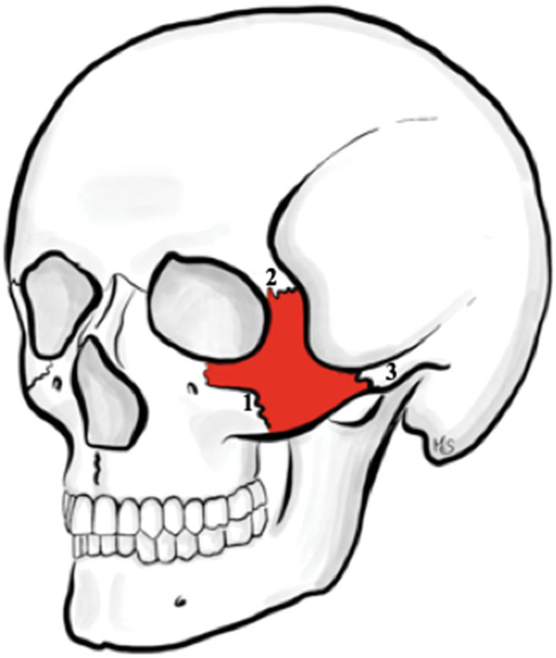

Figure 7. Tetrapod structure of the ZMC: Os zygomaticum: 1 zygomaticomaxillary suture; 2 frontozygomatic suture; 3 zygomaticotemporal suture.

In the early follow-up visits, we saw an ectropion in 15% of cases. The majority of which could be treated conservatively and at the 4 months postoperative control an ectropion could only be documented in eight cases. Three of these patients underwent revision surgery. In all of them, the surgical approach in the initial surgery had been a subciliary incision.

For a proper fracture exposure in a ZMC fracture over a transconjunctival incision a lateral canthotomy is necessary and with this the rate of complications increases [21]. We thus preferred the subciliary approach and used it in 70% of patients with a general ZMC fracture and in 79% of patients with a blowout fracture.

For access to the zygomaticofrontal buttress we always used a small incision directly below or above the lateral eyebrow. In our experience the scar here is inconspicuous and we did not observe any complications. Other authors report on using an upper eyelid access through a natural skin crease in the outer third of the upper eyelid with apparently similar success [1,22].

An exploration of the orbital floor is not recommended routinely because of potential complications. The indications are diplopia, ocular motility impairment, enophthalmos, nonresolving oculocardiac reflex, large defect on the CT scans or entrapment of extraocular muscles [23]. In our experience dislocated ZMC fractures often show one of those criteria and an exploration of the orbital floor is therefore often indicated. The defect of the orbital floor will often become apparent only intraoperatively after fracture reduction. In this series the orbital floor was reconstructed in 37% ($n = 16$) of the ZMC fractures. As, considerable morbidity, including impaired ocular mobility and/or visual acuity, has been attributed to untreated orbital floor defects it is recommended to explore the orbital floor in ZMC fractures with dislocation >1cm [5]. The identification and of course appropriate reconstruction of orbital floor defects are prerequisites for minimizing the overall morbidity associated with ZMC fractures [24].

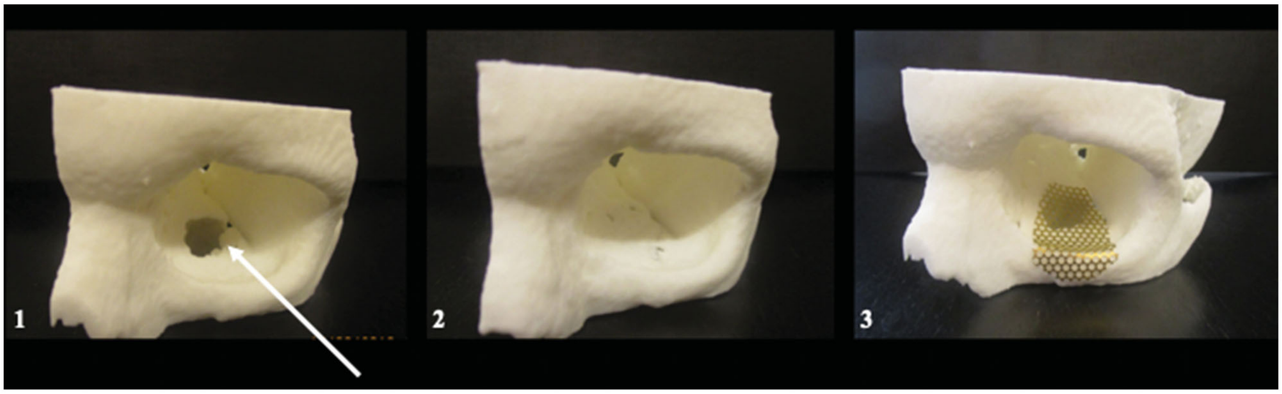

Figure 8. Example of a customized titanium mesh: Picture 1 shows the 3D model of an orbital floor fracture. Two depicts a mirrored 3D model of the patient's right orbit. Three shows a prebent Titanium mesh covering the orbital floor defect created on the basis of the mirrored contralateral orbit.

The zygoma is a tetrapod structure (Figure 7), thus, depending on the fracture type, up to a four point fixation can be required. The more unstable the fracture, the more extensive fixation needs to be done. A sequential surgical approach gives the surgeon the option to decide intraoperatively how much more fixation is indicated [1]. As a basic principle it is recommended to always explore the zygomaticomaxillary buttress, the infraorbital rim and the zygomaticofrontal buttress in order to restore the orbitozygomatic architecture most accurately [22]. A one point fixation of a ZMC fracture typically involves the zygomaticoalveolar crest which can be done over an enoral approach [1].

In most cases we place the plates for zygomatomaxillary fixation on the infraorbital rim.

It is often recommended to place the plate for zygomatomaxillary fixation on the zygomaticoalveolar crest, we however did not see a disadvantage of primarily positioning the plate at the infraorbital rim. Only one patient wished an implant removal due to cold intolerance and the plate being palpable. If necessary we placed a second plate to stabilize the frontozygomatic buttress and a third for the zygomaticoalveolar crest. In our series it was never necessary to perform a fixation of the zygomatic arch. When considering the reconstruction of the orbital floor Titanium mesh is a widely accepted material due to its good biocompatibility [25–27]. Intraoperative manual adjustment of titanium implants to the individual anatomy in orbital reconstructive surgery is challenging and time consuming, especially in larger defects involving more than one orbital wall, the retrobulbar bulge, or deep orbital cone. Computer assisted methods to prepare a pre-bent titanium mesh have shown to be more precise, less invasive and less time consuming [28].

In the mean time we also started to pre-bend titanium mesh with individual 3D-prints of the patients orbit. The mesh is custom fitted to the mirrored healthy orbit and refined according to the fractured side. We find this technique helpful for faster implant positioning especially if the dorsal ledge is missing (Figure 8).

When looking at the number of plates utilized for a stable fracture fixation we are aware that a single plate can theoretically stabilize one segment for both translation and rotation in the two axes perpendicular to the plane of the plate. In some cases, the remaining motion can be neutralized by bony buttressing at the fracture interface. In other cases a second, appropriately positioned plate must be used to compensate the remaining instability. Naturally even more stability can be achieved by employing a three point fixation when plates are not collinearly placed [29,30]. In our cohort a two point fixation was sufficient to achieve overall stability in 22 of the 43 ZMC fracture cases. Davidson et al. [31] reported on similar experiences showing that simple fractures can be adequately fixated using plates and screws with as few as two points at the zygomaticofrontal suture, infraorbital rim, and/or zygomaticomaxillary buttress.

The zygoma is under constant biomechanical strain. With this comes the possibility of hardware failure when reduction stability is insufficient [32] Keeping this in mind we escalated towards a three point fixation in 11 of our patients thus gaining a significantly more stable fixation.

Another frequently discussed procedure to reduce complication rates is the use of intraoperative imaging. Up to date the level of evidence for intraoperative imaging in zygomaticomaxillary complex fractures is still slim due to the lack of comparative studies [33]. Nevertheless it may facilitate less invasive surgery by allowing a visualization of non-exposed buttresses and the orbital floor. In addition it replaces the postoperative CT scan and in the case of an implant malpositioning a direct revision is possible [34].

Conclusion

The basis of operative treatment of ZMC-fractures is fracture reduction with or without internal fixation. The discussion about the ideal approach to the inferior orbital rim and orbital floor is ongoing. Lower eyelid incisions, especially the subciliary approach, show a relevant rate of postoperative complications like ectropion, scleral show and lower eyelid edema. Based on the results of this analysis we now favor a transconjunctival approach but are aware that when a lateral canthotomy is necessary the complication rate of this approach increases. If there is no indication to explore the orbital floor an enoral approach to the zygomaticomaxillary buttress could be favorable but in our experience an exploration of the orbital floor is often necessary. In our small series we did not observe a disadvantage of positioning the plate for zygomaticomaxillary fixation at the infraorbital rim instead over the zygomaticoalveolar crest. The use of computer-assisted methods with pre-bent titanium mesh according to a 3D print of the patients orbits has not been evaluated in this study, this technique however could potentially improve surgeons' convenience and optimal anatomical reduction and since this study has been included in our surgical algorithm.

Ethical approval

This study has been approved by the Ethics Committee Zurich.

Disclosure statement

The authors declare that there is no conflict of interest.

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