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Thema: Orbital injury in severe trauma – CT findings

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Abbreviations

AG	public company
ax.	axial
CCF	carotid-cavernous fistula
cor.	coronal
CT	computed tomography
dCCF	direct carotid-cavernous fistula
DSA	digital subtraction angiography
Fig.	figure
iCCF	indirect carotid-cavernous fistula
IOFB	intraocular foreign bodies
IOP	intraocular pressure
MIS	medical information system
mmHg	Torr
MPR	multi-planar reformation
MRI	magnetic resonance imaging
PACS	Picture Archiving and Communication System
sag.	sagittal
SAS	statistical analysis system
UKB	Unfallkrankenhaus Berlin, Germany
UK	United Kingdom
US	ultrasound
V1	ophthalmic nerve
V2	maxillary nerve

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1. Introduction

1.1 Polytrauma

“Polytrauma” as medical term implies the severe condition of a patient, who suffered from multiple traumatic injuries. The injuries concern more than one organ system and/or specific region of the body. At least one injury or the combinations of two injuries are life-threatening for the patient. Debus et al. determined data from polytrauma patients out of the register of the German Society for Emergency Surgery in 2012. Between 18,200- 18,400 patients sustain severe traumata in Germany each year, which complies with an incidence of 0.2% of 81,000,000 German inhabitants [1]. Medical costs for acute care and rehabilitation are estimated with approximately 106,000 € per patient. If it is not possible for the patient to return into working life, the treatment costs will multiply [1].

The first priority of a polytrauma patient consists in stabilizing the general condition and to identify injuries which otherwise might lead to fatal consequence. The accident mechanism can point out typical injury patterns, which help to estimate the severity of damage. For example, causes of traumatic injuries are accidents, assault or fall from great height. An accident is possible as a driver, a (motor) cyclist or as a pedestrian. After stabilization early diagnostic and therapy is needed to increase the survivability.

The Unfallkrankenhaus Berlin (UKB) in Germany is specialized in the care of acute patients with severe trauma and burn victims. It is a main hospital in Berlin with over 25 different specializations and treats approximately 100,000 in- and outpatients each year. The department of radiology and neuroradiology on-site provides fast and accurate imaging workup diagnostic for their patients using modern techniques. After a first clinical check-up, any patient with critical injuries will receive a standard computerized tomography (CT) scan from the pubis to the cranium [2]. CT is nowadays the established method for diagnostics in a polytrauma patient. Axial multi-slice CT scans within a short time are suggested to be the safest and first-line imaging method under these circumstances. With this standardized method of radiological imaging, bones and organs can be illustrated easily. Possible fractures and organ damage and/or other sequels of injuries, for instance herniation, emphysema, hematoma or even foreign bodies can be detected rapidly [3]. If the examining physician identifies either a soft tissue trauma or a fracture of the midface in the first clinical whole-body check-up, the radiologist will be able to add a multi-slice CT scan of the midface in thin-film spiral data sets (3 mm) with secondary reconstruction in sagittal and coronal sections additionally to the whole-body scan. CT scans of the midface identify orbital wall fractures and intraocular injuries, especially optic nerve injuries, hematoma and intraocular foreign bodies (IOFBs) [4-6] by using low-dose images. The different orbital tissues vary in their density. Other methods to diagnose an orbital trauma are known modalities such as conventional radiography, ultrasound (US) and magnetic resonance imaging (MRI) [2, 3]. Conventional radiography is still very sensitive in picturing fractures of the midface but has a low sensitivity for diagnosing soft tissue injuries [3].

1.2 Midface anatomy and traumatic fracture patterns

The anatomy of the midface includes the viscerocranium comprising of maxilla and the orbital cavity. The orbital cavity can be seen as a four-sided pyramid which consists of a base, an apex and four walls. It contains the eye and its appendage. Anatomically, it is configured out of seven facial bones. The orbital roof is formed by the frontal bone as the superior orbital margin. The lesser wing of the sphenoid near the apex of the orbit shapes the optic canal and the greater wing of the sphenoid arranges the lateral posterior portion. The floor is composed of portions of the maxillary, palatine and zygomatic bones and is relatively short with 35-40 mm. The inferior rectus muscle lies in near proximity to the orbital floor [7, 8]. Laterally, the wall is formed by the zygomatic bone. The medial wall is the thinnest wall of the orbit. It consists of multiple osseous septae of the ethmoid bone and is contributed by the lacrimal and maxillary bone [9]. Each of the four walls and/or the optic canal can be affected due to trauma to the midface. Fractures of the orbital skeleton might appear isolated as a single-wall fracture or as multiple fragment fracture. However, often there is more than one fractured wall in the orbital skeleton.

To begin with naming common fractures, there is the blow-out fracture which concerns the orbital floor and rarely the medial wall (Fig. 1). The injury mechanism is an increased intraorbital pressure due to a hitting object whereby forces are being transmitted to the orbit [8]. Periorbital tissue can herniate into the maxillary sinus.

Fig. 1: Schemating drawing of a blow-out fracture of the left orbital floor in coronal plane after a reformatted CT image from *Caranci F, Cicala D, Cappabianca S et al.* Orbital fractures: role of imaging [10]. Arrows indicate the fracture of the left orbital floor. The inferior rectus muscle is attracted inferiorly towards the maxillary sinus indicating entrapment.

A tripod fracture (zygomaticomaxillary complex) includes the zygomatic arch, the floor of the orbit, the lateral orbital rim and the sphenozygomatic suture (Fig. 2) [10]. It represents a fracture line which expands from the zygomaticofrontal suture to the lateral orbital rim and extends along the lateral floor to the edge of the orbit in caudal course [3].

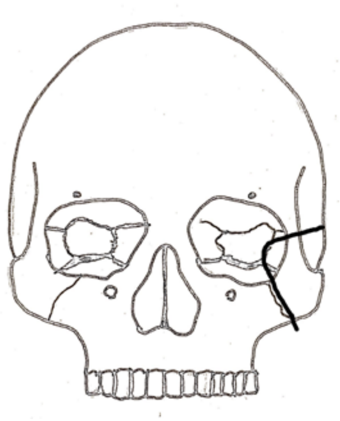
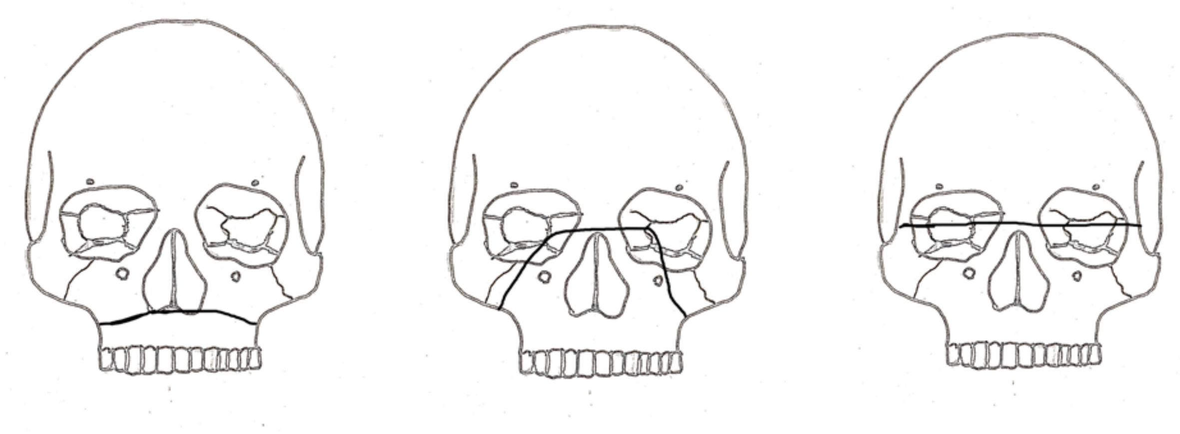


Fig. 2: Schemating drawing of a tripod fracture after *Caranci F, Cicala D, Cappabianca S et al.* Orbital fractures: role of imaging [10].

A third well-known classification of midface fractures is named after Le Fort (Fig. 3). Le Fort 1° indicates a fracture of the maxillary bone which is dissociated from the facial skull above the teeth. It does not apply to the orbit. Le Fort 2° is defined as a fracture of the nasal bone, the orbital medial wall (ethmoid bone) and the maxillary sinus. The fracture line expands from the nasofrontal suture along the frontomaxillary suture over the lacrimal bone to the orbital floor. The Le Fort 3° complex is characterized by a fracture from the medial wall to the orbital floor affecting the frontomaxillary and the nasofrontal sutures. The fracture line continues through the lateral wall of the orbit via the zygomaticofrontal suture to the zygomatic arch. It results in a dissociation of the midface from the cranial skull. Conventionally, an isolated Le Fort fracture is rare. Usually, there is a multifariousness of fracture patterns [10].

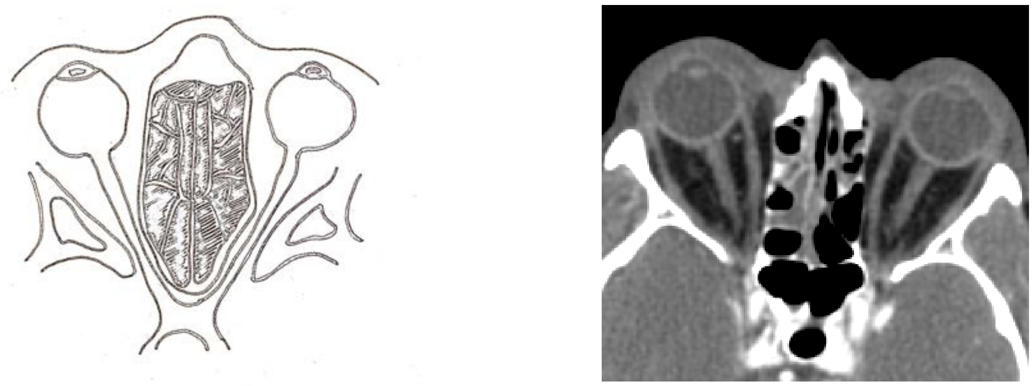


Le Fort 1° Le Fort 2° Le Fort 3°

Fig. 3: Schemating drawing of the classification of midface fractures: Le Fort 1°, 2° and 3° after *Kühnel TS, Reichert TE*, Trauma of the midface [3].

1.3 Contents of the orbital cavity

The orbital cavity contains the ocular globe including lens, the optic nerve, the extraocular muscles and vessels, which are enlaced by fat tissue [11]. There are seven extraocular muscles within the orbit: four right muscles, the superior and the inferior oblique muscles and the levator palpebrae muscle. All muscles except the inferior oblique muscle have their seeds in the annular tendon and attach the globe, thus forming the muscle cone [12]. On the basis of the ocular globe there are retinal nerve fibres, which form the orbital disc and represent the first part of the visual nerve, which can be divided into four parts. The second part is defined as the part within the orbit and measures a length of 25-30 mm. The annular tendon encircles the nerve at the entrance into the optic canal, where it passes about 6-8 mm intracanalicularely through the sphenoid wing accompanied by the ophthalmic artery (Fig. 4) [3]. From there the optic nerve follows an intracranial part of 10 mm to the optic chiasm and carries on as optic tract followed by optic radiations. Embryonically the optic nerve is a direct descendant of the diencephalon and surrounded by three meningeal layers: the pia mater – in close contact with the optic nerve – surrounded by the arachnoid mater and dura mater. The subarachnoid space extends between pia mater and arachnoid mater [3]. Intraorbitally the dura mater splits into two leaflets. One adapts to the optic nerve and the outer leaflet complies as periosteum of the orbital bones. The optic nerve consisting of nerve fibres has a diameter of 4 mm, a length of approximately 46 mm to the geniculate bodies and is s-shaped. In case of sudden globe movement the spare length is beneficial.



a b

Fig. 4 (a/b): Schemating drawing of the course of the optic nerve through the optic canal (a) after *Luxenberger et al.* Endoscopic optic nerve decompression [20]. Axial CT showing the course of the optic nerve through the optic canal (b).

Looking at the superior and inferior ophthalmic vein they usually unite in front of the superior orbital fissure next to the optic canal and enter the cavernous sinus. The two cavernous sinuses are dural venous sinuses which are located laterally of the sella turcica [13]. Each sinus contains the venous plexuses (draining from the inferior and superior ophthalmic vein, the sphenoparietal sinus and cerebral veins), the carotid siphon surrounded by sympathetic fibres and the cranial nerves (oculomotor, trochlear, abducens and branches of the trigeminal nerve V1/V2). The ophthalmic artery accompanies the optic nerve through the optic canal. Assessing the orbital vessels includes identifying any potential carotid-cavernous fistula (CCF). The CCF occurs as an abnormal communication between the internal carotid artery and the cavernous sinus. There are direct CCF (dCCF) and indirect CCF (iCCF). The direct CCF can result from (severe) head traumata. In contrast, the indirect CCF is caused by ruptured meningeal branches of the carotid artery within the cavernous sinus due to high blood pressure [14].

1.4 Diagnostic and therapeutic tools of orbital injuries

If the patient is clinically stable, suspected serious trauma to the midface should seek attention during the initial examination in the emergency unit. The physician can push for early ophthalmological consultation to catch an increased intraocular pressure IOP, visual dysfunction and/or limited ocular movement [15, 16]. Even the eye examination on conscious patients can still be aggravated due to poor compliance and/or other restricted visibility because of swelling and/or hemorrhage in the range of the orbit. If the patient is sedated and intubated, the ophthalmological consultation is possible to a minimum of measuring the IOP. Therefore the multi-slice CT scan of the midface in thin-film spiral data sets is essential to diagnose orbital injuries, which might lead to severe limitations of quality of life such as visual loss. For that reason, treatment of ocular injuries should be preferred to treatment of simple fractures [17]. Depending on the extent and localization of the orbital injuries the ophthalmologist or oral-maxillofacial surgeon need to suggest treatment options. Conservative and/or surgical treatment options are possible. For example, an elevated IOP is easy to treat with medications like carbonic anhydrase inhibitors or surgically by draining the aqueous fluid. An undetected increased IOP can lead to irreversible loss of vision and/or defect in the visual field. The therapy of orbital fractures is different depending on the dislocation of the osseous fragments. Slight dislocations are managed conservatively in contrast to major dislocations, which can be treated by osteosynthesis procedures.

2. Aims of dissertation

On the basis of the imperative to prioritize injuries of a patient with multiple traumata which might be potentially fatal and to stabilize the patient's condition first, detailed examinations of the orbit and eyes are considered as secondary at the accident and emergency department. Performing axial multi-slice CT scans within a short time is the standardized method of radiological first-line imaging in emergencies. A CT scan of the midface is not part of the whole-body scan. Therefore, visible traumatic injuries of the midface and/or conspicuous examination findings are generally an indication to add a maxillofacial CT scan to the whole-body scan. However, it may not be sufficient for a decidedly radiological assessment. Nevertheless, traumatic orbital injuries need to be diagnosed sooner than later as it has an enormous impact for the patient. They should not be neglected as visual loss and/or a restricted ocular movement will lead to severe limitations of quality of life.

Patients, who suffered from a polytrauma are mostly sedated and intubated, wherefore the oculist cannot test the vision and ocular movements. This circumstance may lead to further delay in diagnosing orbital injuries or may even prevent their detection at all.

In our study we aimed to research for polytrauma patients at the UKB which had maxillofacial CT scans due to facial injuries additionally to the whole-body scan. Various results of possible trauma sequela to the orbit were gathered and we analyzed the correlation between suffering from a polytrauma and the extent of orbital injuries, which we categorized in osseous involvement and soft tissue traumata of the orbit.

3. Materials and methods

3.1 Population and study design

In our retrospective study we revised 6,000 patients who suffered from life-threatening trauma and received a polytrauma CT scan between February 2006 and August 2014 at the UKB. 1,061 patients who sustained multiple traumata with injuries to the midface and therefore received additive CT scans of orbit and sinuses were included in our study. The study population consisted of 806 males and 255 females. Out of them N = 250 patients presented with osseous and/or soft tissue traumata of the orbit. Median patient age was 44.53 years (range, 3-98 years) with a standard deviation of ± 7.3 years. Clinical data were available in N = 204 patients. For data collection we categorized the cause of traumatic orbital injuries in accidents, assault, fall and other. “Other” is defined as not further specified in medical history. It also describes an uncommon etiology in our lines of latitude such as an explosion.

No further criteria of exclusion were defined. To assess the maxillofacial CT scans in a standardized way, we designed a list of inclusion criteria, which is defined below.

3.2 CT technique and image analysis

The criterion for inclusion for this study was the existence of a maxillofacial CT scan: This was only acquired with suitable results or symptoms in connection with a whole-body scan from the cranium to the pubis. In the picture archiving and communication system (PACS) at the UKB 1,061 CT scans were analyzed with regard to the presence of injuries to the osseous orbit and surroundings. The radiologist performs a multi-slice unenhanced CT scan of the skull, followed by contrast enhanced orbital imaging after administering a contrast agent intravenously [2]. We used Philips iSite®Radiology as software program for image processing. The majority of scans (N = 645) were sinus CT scans obtained with a 64-slice scanner (Diamond Select Brilliance, Philips, Eindhoven, Netherlands). This machine has been the standard CT scanner from February 2006 until January 2012 at UKB. Studies of patients (N = 395) examined between January 2012 and August 2014 have been obtained with a 128-slice scanner (Ingenuity Elite, Philips, Eindhoven, Netherlands). In rare cases a 16-slice scanner was used (Diamond Select Brilliance, Philips, Eindhoven, Netherlands) (N = 21). Out of the 1,061 CT images 1,050 were enhanced with 11 scans remaining unenhanced.

The original images are in axial plane with thin cuts. We examined the images in bone and soft tissue windows first. Following, we performed coronal and sagittal reconstructions with an axial slice thickness > 2 mm to optimize the assessment of orbital fractures and intraocular structures. These images were labelled as multi-planar reformations (MPR) coronal and sagittal. We used the axial CT scans predominantly to assess fractures of the lateral and medial orbital walls. The coronal reconstructions were beneficial to determine orbital floor and roof fractures and in sagittal reconstructions we were able to assess fractures of the floor more precisely if needed. In the axial and coronal views we evaluated the orbital soft tissue structures as described in our standardized list of criteria. The CT images were reviewed by two long-time experienced neuro-radiologists with over 20 years of experience.

3.3 Bony structure of the orbit – diagnostic criteria

To identify patients with orbital trauma of the midface, we assessed each orbit in the axial, coronal and sagittal planes to detect any fractures in the bone window. CT scans of orbit and sinuses without a trauma to the midface were excluded. The same applied to fractures concerning nose or jaw. To fulfil the diagnostic criteria, we included the detection of a fracture gap with or without a degree, a rough dislocation of bony fragments and the detonation of osseous sutures between facial bones which form the orbit.

We assessed the anatomical sites according to the orbital walls in all three sections. Evaluating a fracture of the orbital floor, we also examined the sagittal image for a better view. Concerning the optic canal, we looked at the axial image.

3.4 Soft tissue structures of the orbit

From the orbital apex to the anterior septum, the orbital contents are enlaced by fat tissue [11]. In our study, we assessed the ocular globe including the lens, extraocular muscles, the optic nerve and orbital vessels individually.

3.4.1 Ocular globe and lens – diagnostic criteria

Criteria in appraising the ocular globe were the following: protrusion (exophthalmus) or recession (enophthalmus) of the globe, the sphere (round or unshaped), the lens and the delimitation of the anterior and posterior chamber by the lens. A ruptured globe is diagnosed in the presence of retractions and irregularities of the bulbar wall such as the uveoscleral infolding and volume loss [18]. The presence of intraocular air can be a sign of a ruptured globe, too [19]. Potential consequences of trauma are posttraumatic hemorrhages, which usually appear as increased density in the fat tissue or as almond-shaped beddings on the osseous wall (subperiostal hematoma) and/or foreign bodies. Especially ferromagnetic foreign bodies can easily be detected as they hold a high density and are radiopaque. In contrast to them, foreign bodies made of glass or wood are of low density and appear hypodense in the CT scan. Wood presents isodense to muscle and/or bone and may therefore be detected with difficulties [10]. Regarding the ocular lens, a dislocation or absence might be possible.

3.4.2 Extraocular muscles – diagnostic criteria

Looking at the extraocular muscles in the CT images, we assessed the appearance and size of each muscle and the intraconal space with reference to the following criteria: ocular muscle dislocation or entrapment, penetration of osseous fragments and/or foreign bodies. We measured hemorrhages, which appear intramuscular, intra- or extraconal, and looked for foreign bodies. Metal objects for example can be detected and localized at sizes smaller than 1 mm in size.

3.4.3 Optic nerve – diagnostic criteria

In our study, we analyzed the morphology and the elongation of the optic nerve in the coronal, axial and sagittal planes. In the coronal image we examined the orbit and orbital apex. The orbital canal and the superior orbital fissure might be seen as continuous structures at certain coronal planes. In the sagittal and transversal images we appraised the intraorbital course of the visual nerve. Compared to MRI, CT cannot distinguish between the different meningeal layers of the optic nerve.

3.4.4 Orbital vessels – diagnostic criteria

The difference between the high density of blood and contrast agent relative to the surrounding orbital fat and muscles allows the reliable identification of orbital veins and arteries. CCF may lead to ocular proptosis in imaging. Other characteristics in tomography include an enlarged and tortuous superior ophthalmic vein as well as an enlarged cavernous sinus. Extraocular muscles may be enlarged and orbital edema may be seen [20].

3.5 Clinical assessment

After assessing the images of each patient with a severe midface trauma, we used the MIS software medico (Siemens AG, Erlangen, Germany), which contains the electronic health records. It includes the medical history and physical examinations. Besides collecting clinical data of ophthalmologists' records, we looked at the oral and maxillofacial consultations whether surgery or conservative treatment was performed. On occasion, a discharge letter was accessible.

On the basis of three criteria we appraised the ophthalmic diagnostic findings: the intraocular pressure, the vision and eye movements. Clinical data for measuring the IOP could be retrieved in N = 197 out of 250 patients which were included in our survey. We checked whether the IOP was increased or not and how the intended treatment had improved the IOP. The remaining N = 53 were neither tested nor documented. The second category we looked at was the vision. An ophthalmologist examined the eyesight and if possible the ocular movement of conscious patients. However, due to the severity of the multiple traumata most patients were sedated. Therefore an oculist could neither test the vision nor the ocular movement properly. Searching through the MIS 57.6% (N = 144) of the 250 enclosed patients were documented with performing an eyesight test and 42.4% (N = 106) without a vision test. In the third and last category "ocular movements" clinical data showed that only 52.8% (N = 132) were tested and 47.2% (N = 118) of a total of 250 patients were not. The clinical data of eye examinations are diagramed in Figure 6.

3.6 Statistical analysis

CT imaging reports and medical records via MIS were documented into a worksheet for storage (Excel 2010; version 14, Microsoft Cooperation, Redmond, Washington, United States). For statistical analysis the data were transferred into statistical analysis system (SAS® 9.4 for Windows 10 [SAS Institute Inc., Cary, North Carolina, United States]).

4. Results

4.1 Trauma prevalence and demographics

From 1,061 patients with additive CT scans of orbit and sinuses, 811 patients had no trauma to the orbit (Figure 5), 143 revealed fractures of nose and/or jaw. The remaining 250 patients presented with fractures of the osseous orbit or soft tissue traumata to the eye. 59.6% (N = 149) revealed fractures of the bony orbit exclusively. 1.2% (N = 3) showed trauma to the soft tissue structures of the eye without any detection of a fracture. The residual percentage of 39.2% (N = 98) represented combined injuries of osseous and soft tissue structures. After further revision, 101 cases of the total collective of 250 CT images displayed eligible alterations of the orbit including the vitreous body, lens, the optic nerve, ocular muscles and orbital vessels.

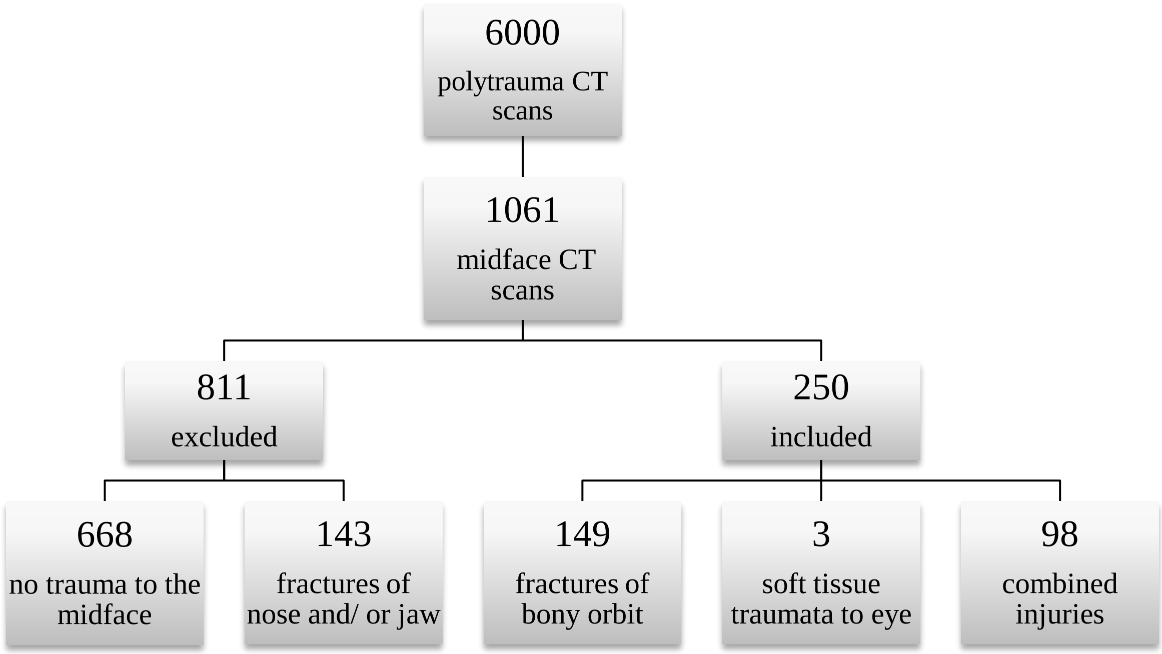


Fig. 5: CT findings of orbital and/or ocular traumata.

The demographic data of patients with traumatic orbital injuries are summarized in Table 1. Their age range showed two peaks: on the one hand we identified young adults aged between 20 and 29, on the other hand we had elderly patients between 50 and 59 years. Out of 1,061 included study participants with CT scans of the midface, 24.03% were females (N = 255) and 75.97% were males (N = 806). 393 patients represented a trauma to the midface, whereas 250 revealed traumatic orbital injuries. From those, the median patient age was 44.53 years (range, 3-98 years) with a standard deviation of ± 7.3 years. The remaining N = 143 had fractures of nose and/or jaw and were excluded from the study. Regarding the mechanism of accidents with the result of orbital osseous and/or soft traumata, the most affected patients had fallen from great height, followed by patients driving a car. Below-mentioned patients got injured riding a bicycle, driving a motorcycle or being on the way as pedestrian. Injuries due to assault had the least impact of orbital traumata. Taking a closer look to gender, we did not appraise any difference of trauma mechanism between females and males. Female patients also suffered most falling from great height, followed by driving a car or being on the way as pedestrian.

Table 1: Demographics of the patients with orbital traumata at baseline (N = 1,061)

Characteristics	
Sex – no. (%)	
Male	806 (76)
Female	255 (24)
Age in years – no. (%)	
0-9	6 (0.6)
10-19	93 (8.8)
20-29	219 (20.6)
30-39	140 (13.2)
40-49	174 (16.4)
50-59	187 (17.6)
60-69	93 (8.8)
70-79	85 (8.0)
80-89	59 (5.6)
90-99	5 (0.5)
Cause of traumatic orbital injuries – no. (%)	
Accidents	581 (54.7)
- driving a car	280 (26.4)
- riding a bike	110 (10.4)
- driving a motorcycle	95 (8.9)
- as pedestrian	96 (9.0)
Fall	305 (28.8)
Assault	40 (3.8)
Other	135 (12.7)

4.2 Clinical outcome

In our study we reviewed the documented eye examination of study participants and focused on the measured results of the IOP, vision and eye movements, which are summarized in figure 6. The average IOP ranges between 10-21 mmHg with a median of approximately 15 or 16 mmHg [21]. 59.6% of the evaluated patients (N = 250) had an IOP in range, 19.2% of the patients had an increased IOP and the remaining 21.2% were either not measured or documented. An increased IOP was documented as conservatively managed when treated with carbonic anhydrase inhibitors to reduce aqueous humor. Concerning the eyesight, 144 from our cohort of 250 patients had a visual test by an ophthalmologist. 52.8% of them presented with a normal vision despite of orbital injuries and 4.8% were documented with a loss of vision. The remaining 42.4% of the patients did not have an eyesight test. Our third category included the function of the ocular movements. 42.8% of the examined patients (N = 250) did not show any pathological findings. In 10% a limited ocular movement was documented and 47.2% of the patients were not tested. Out of 250 patients 39.2% were not treated or did not need any treatment. In 60.8% of the cases a conservative treatment was sufficient. This refers especially to the elevated IOP, which was treated with eye drops. 26.0% of 250 patients were documented with having surgery due to a reduced or lost vision and/or a limited ocular movement. The method of surgery was not further specified in our study design. Summing up, orbital images might detect severe lesions in early stage, especially if the patient is sedated and cannot follow clinical tests. Using imaging of the orbit and its structures can improve the outcome of the patient's vision and/or ocular movements if not noticed initially due to sedation/intubation.

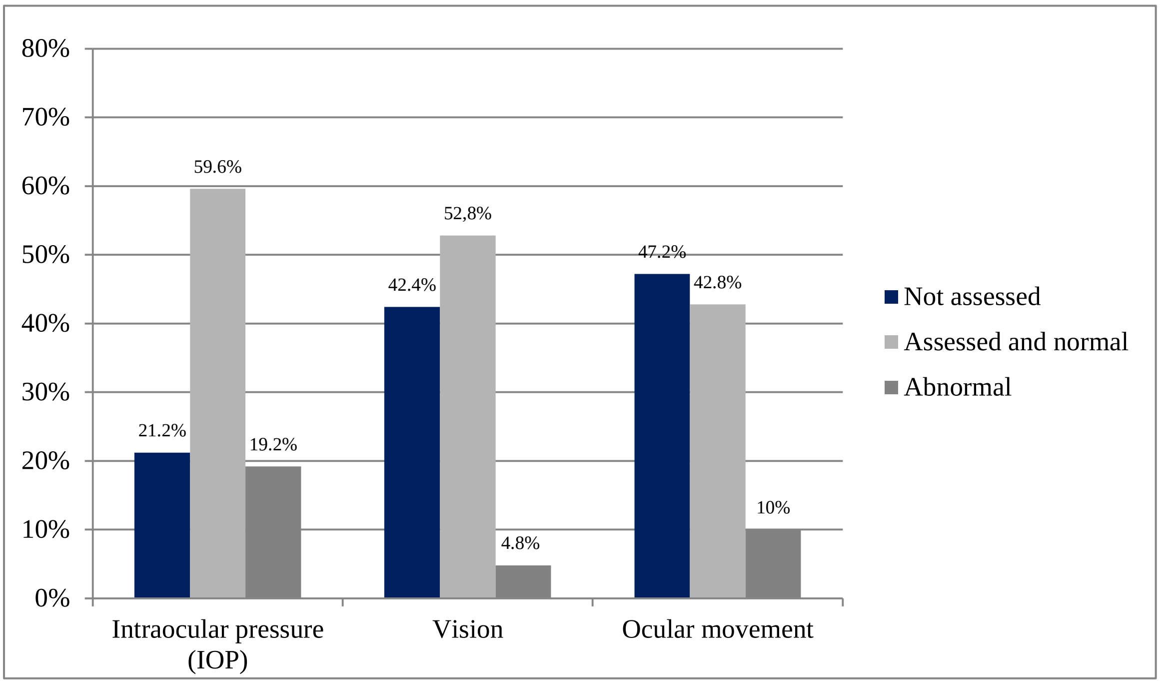


Fig. 6: Clinical outcome of eye exams from the 250 patients included in the study - clinical data divided in three categories: IOP, vision and ocular movement.

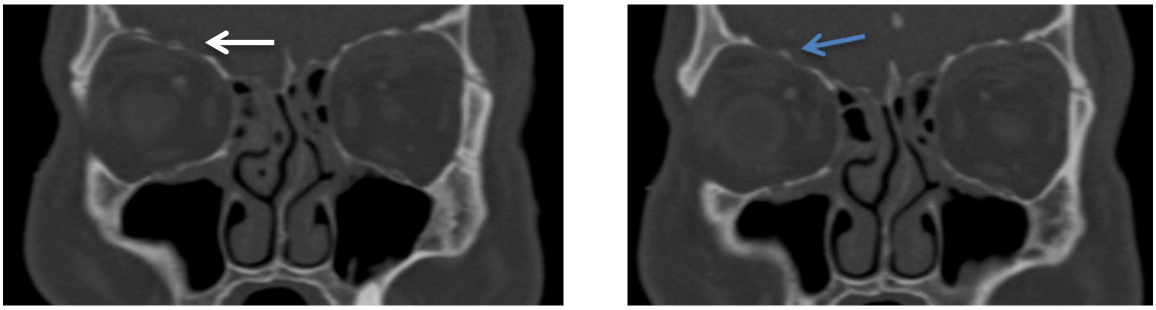
4.3 Osseous traumata of the orbit

247 patients showed osseous involvement of the orbit. Therefrom, 149 CT images presented with fractures of the orbital cavity without participation of soft tissue structures. The remaining 98 images had additional injuries to the soft tissue structures. 143 scans with fractures of the nose and/or jaw were excluded from the study. The right orbit was affected in 35.6% and the left orbit in 32.8%. In 31.6% of our cases orbital walls of both cavities were damaged. Table 2 demonstrates the number of fractured walls of each orbit.

Table 2: Osseous traumata of the orbit (N = 247)

Type of fracture	
Right orbit – no. (%)	
single wall	51 (58)
two walls	21 (23.9)
three walls	13 (14.8)
four walls	2 (2.2)
four walls and orbital apex	1 (1.1)
Total	**88 (35.6%)**
Left orbit – no. (%)	
single wall	40 (49.4)
two walls	22 (27.2)
three walls	12 (14.8)
four walls	6 (7.4)
four walls and orbital apex	1 (1.2)
Total	**81 (32.8%)**
Both orbits – no. (%)	
Total	**78 (31.6%)**

A single wall fracture of the orbital skeleton was the prevailing type of fracture (the right orbit was affected in 58%, the left orbit nearly in 50% in our series). In the majority of cases the orbital roof, floor or lateral wall were rather involved than the medial wall. Examples of single wall fractures are shown below.



a b

Fig. 7 (a/b): Roof fracture, right eye (52-year-old male with elevated IOP without further restraints). CT, coronal section (a): Fracture line of the right orbital frontal bone (white arrow) and (b) fracture line of the lesser wing of the sphenoid (blue arrow).

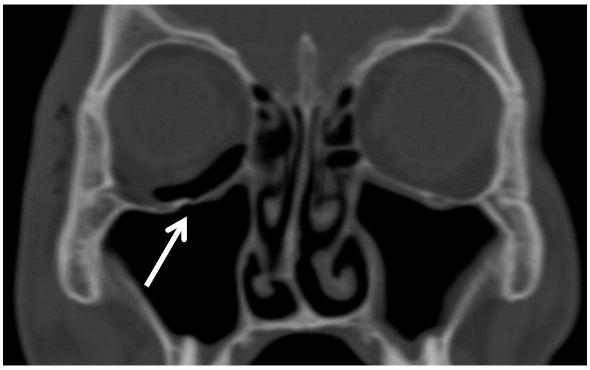


Fig. 8: Blow-out fracture with herniation of soft tissue, right eye (23-year-old male). CT, coronal section: fracture of the orbital floor (white arrow), the eye socket is filled with air from the maxillary sinus. Due to the loss of the abutment, the eye sinks in the orbital cavity (enophthalmus).

The orbital floor was affected most frequently with 67%, irrespective of isolated fracture or combination with other wall fractures, followed by the orbital roof with 47%. Fractures of the lateral wall were documented in 43% in our series. The medial wall was the less frequent type of fracture with only 31.6%. Patients with two orbital walls fractured had an incidence between 24-27%. Characteristic fractures involving more than one orbital wall are displayed in Figures 9-11.

Fig. 9: Fracture of two orbital walls, right eye (52-year-old male with a clinically documented oculomotor palsy). CT, coronal section: Fracture of orbital roof (blue arrow) and floor (white arrow). The lateral and medial walls are intact.

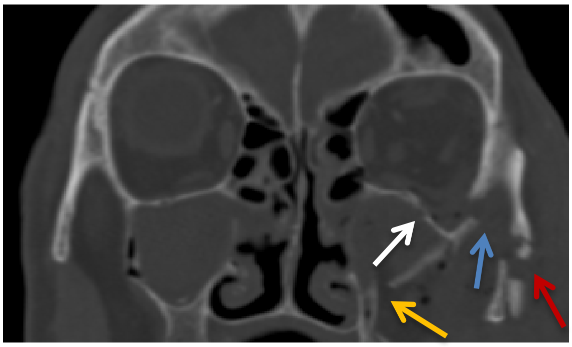


Fig. 10: Tripod fracture, left eye (72-year-old female with limited ocular movements, especially of the left eye reduction). CT, coronal section: Fracture of the orbital floor (white arrow), lateral orbital rim (blue arrow) and zygomatic arch (red arrow). Air from the maxillary sinus is trapped within the orbit and the inferior rectus muscle presents signs of hemorrhage within its body. The maxillary sinus is fractured, too (yellow arrow).

Fig. 11: Le Fort 2°, right eye (15-year-old adolescent without clinical limitations). CT, coronal section: Fracture of the medial wall (white arrow) and orbital floor (blue arrow).

We did not detect a Le Fort 3° complex fracture in our series. As listed in Table 2, less than 15% of the patients presented with osseous impairment of three walls. Patients with fractures of the complete orbit added up to 1-7%. In about one third of 247 patients both cavities were damaged. 18% of them showed one fractured wall of each orbit. The remaining 64 scans presented with more than two walls broken with a multifariousness of fracture patterns.

4.4 Soft tissue traumata of the orbit

40.4% (N = 101) of the 250 CT images which were included in this study revealed alterations of the soft tissue structures of the orbit. Table 3 summarizes the results of the injuries, categorized on the basis of the location in ocular globe and lens, extraocular muscles, optic nerve and vascular traumata.

Table 3: Soft tissue traumata of the orbit (N = 101)

Location of injury	
Ocular globe and lens – no. (%)	
unshaped vitreous body	24 (23.8)
(partially) ruptured globe	7 (6.9)
dislocated lens	6 (5.9)
foreign body pre-orbital	2 (2)
foreign body within orbital conus	1 (1)
Extraocular muscles – no. (%)	
dislocation	45 (44.6)
pierced by bone	8 (7.9)
muscle trauma by foreign body	1 (1)
Optic nerve – no. (%)	
elongation	13 (12.9)
altered morphology	10 (9.9)
optic nerve trauma by foreign body	1 (1)
Vascular traumata – no. (%)	
prominent ophthalmic vein	10 (9.9)
confirmed posttraumatic dCCF	6 (5.9)

4.4.1 Ocular globe and lens

23.8% of 101 midface CT images exhibited a conspicuous vitreous body appearing unshaped and irregular. A deformed ocular globe of the right eye with a crescent (almond)-shaped vitreous hemorrhage presents Figure 12.

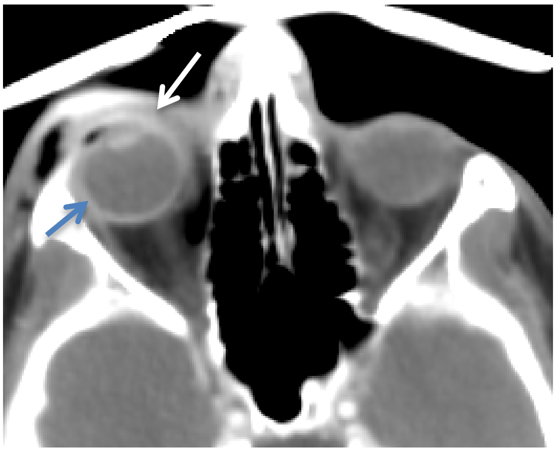


Fig. 12: Unshaped vitreous body, right eye (23-year-old male with blurred vision). CT, axial section: Unshaped globe (white arrow) with an almond-shaped vitreous hemorrhage (blue arrow).

In 6.9% the vitreous body showed signs of irregularities of the bulbar wall and volume loss. Regarding the lens, 5.9% were dislocated due to trauma. Examples of a ruptured globe are illustrated in Figures 13 and 14.

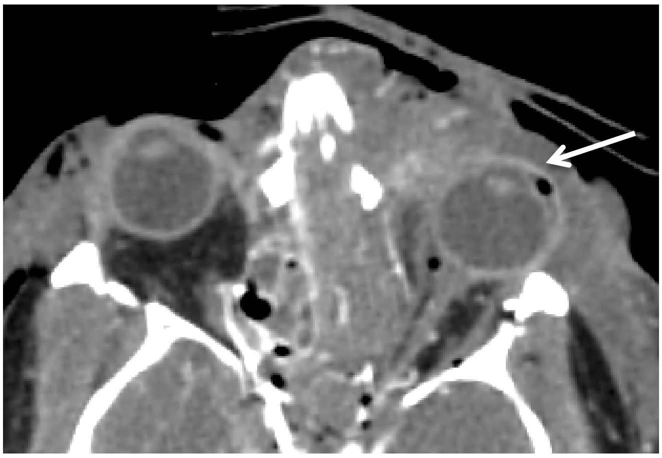


Fig. 13: Partially ruptured globe, left eye (49-year-old male). CT, axial section: Ocular globe partially ruptured, apparent by retractions of the bulbar wall with entrapped air (white arrow) and dislocated lens.

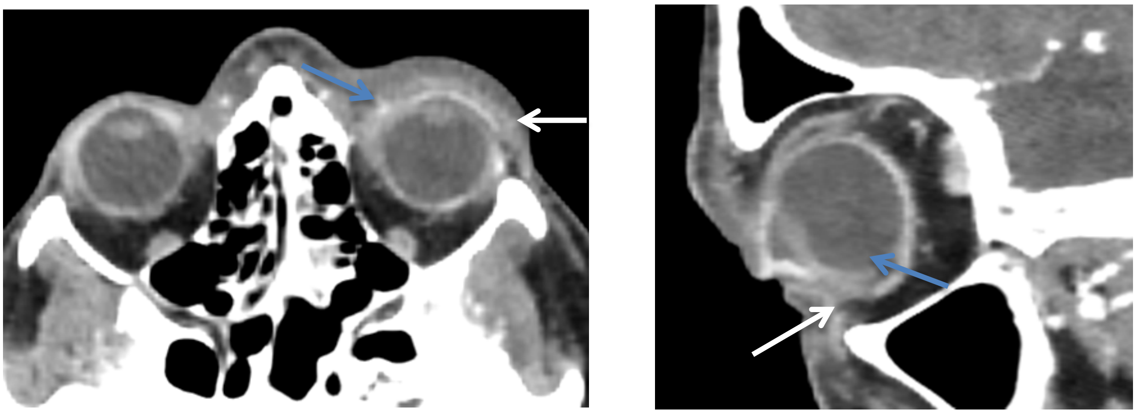


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Fig. 14 (a/b): Totally ruptured globe, left eye (37-year-old female, wearing sunglasses while accident). CT, axial section (a): Irregularities of the bulbar wall (white arrow), volume loss and dislocated lens (blue arrow). Sagittal reconstruction (b).

In our series we had three patients who had metallic foreign bodies pre-orbital or within the conus due to traumata. Figure 15 demonstrates two examples.

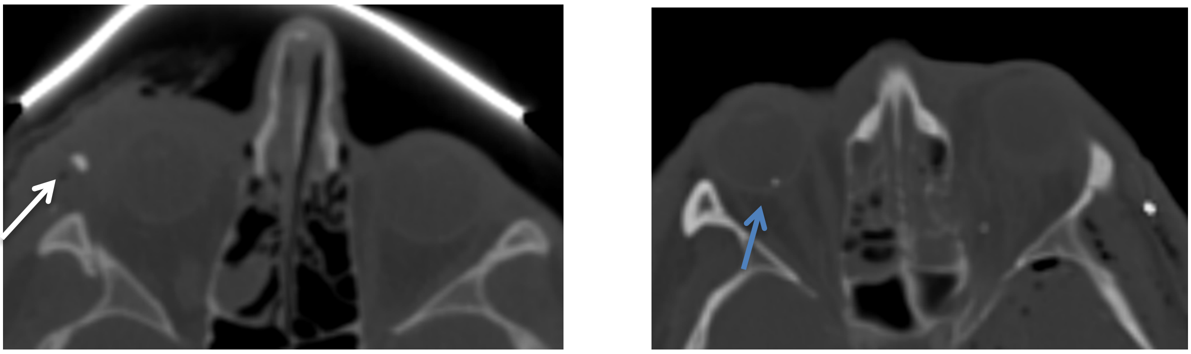

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Fig. 15 (a/b): Foreign body pre-orbital, right eye (15-year-old boy). CT, transverse section (a): Metallic foreign body (white arrow) in edematous tissue with high density and radiopaque. Metallic foreign body, right eye (40-year-old male). CT, axial image (b): Metallic foreign body within the right conus (blue arrow) at the rear bulbar wall of the right globe. Left globe appears unshaped.

4.4.2 Extraocular muscles

The dislocation of an extraocular muscle occurs far more often than the piercing of a muscle by bone or foreign bodies. 44.6% of 101 CT images with soft tissue traumata presented with a dislocation of an extraocular muscle. 7.9% of our total collective showed a muscle pierced by a bone fragment.

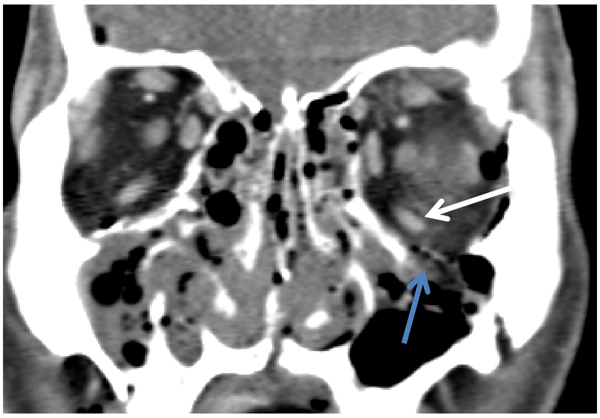

Fig. 16: Extraocular muscle dislocation, left eye (27-year-old male after fall with a restriction of lowering the left eye). CT, coronal section: Diverse fractures of both orbital cavities with dislocation of left inferior rectus muscle (white arrow) due to orbital floor fracture (blue arrow). The orbital floor functioned as abutment.

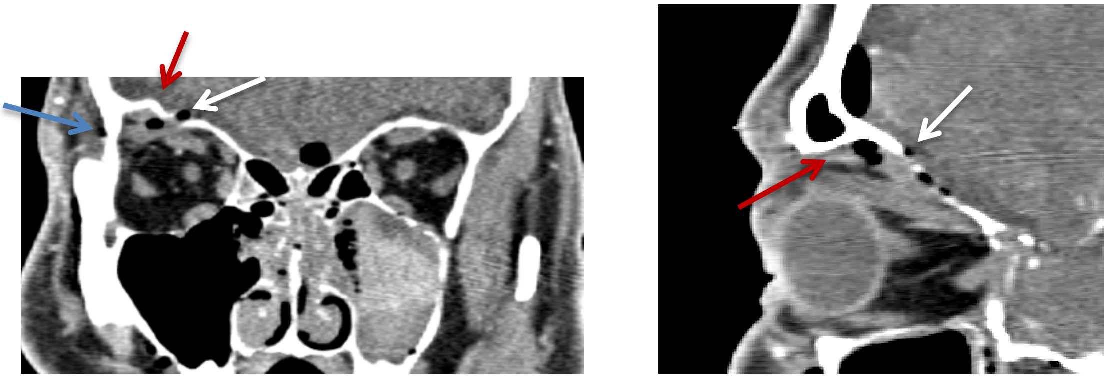

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Fig. 17 (a/b): Extraocular muscle dislocation (53-year-old male with a decreased elevation of the right eye). Unenhanced CT, coronal image (a): Fractures of right orbital roof (white arrow) and lateral wall (blue arrow) with an extraconal hemorrhage (red arrow) between frontal bone and right upper rectus muscle causes dislocation of the muscle. CT, sagittal section (b): Dislocation of right upper rectus muscle due to extraconal hemorrhage (red arrow) after orbital roof fracture (white arrow).

Fig. 18: Muscle pierced by bone, left eye (18-year-old male). CT, transverse section: Left lateral rectus muscle pierced by osseous fragment (white arrow) from the greater wing of the sphenoid with intramuscular hemorrhage.

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Fig. 19: Muscle pierced by bone, right eye (21-year-old male with elevated IOP). CT, sagittal image: Osseous fragment of 2 cm of the frontal bone (white arrow) spears the right superior rectus muscle vertically. The optic nerve is displaced.

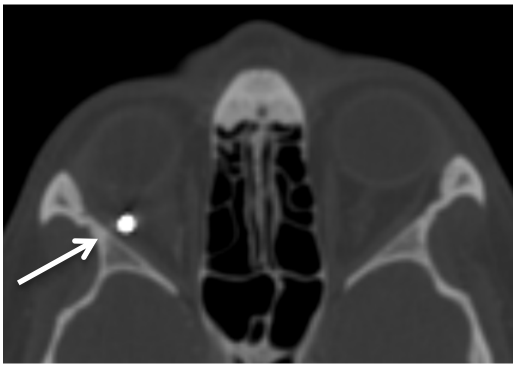 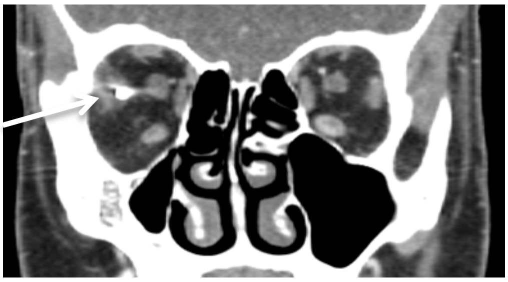

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Fig. 20 (a/b): Metallic foreign body from a car bomb intramuscularly (27-year-old male with a restriction of movement and a reduced vision of the right eye). CT, axial image (a) and coronal image (b): Metallic foreign body of 4 mm in diameter (white arrow) sticks in right lateral rectus muscle. No osseous fractures.

4.4.3 Optic nerve

On inspection of the optic nerve, 12.9% of 101 CT images presenting soft tissue traumata submitted an elongated optic nerve. An example is given in Figure 21.

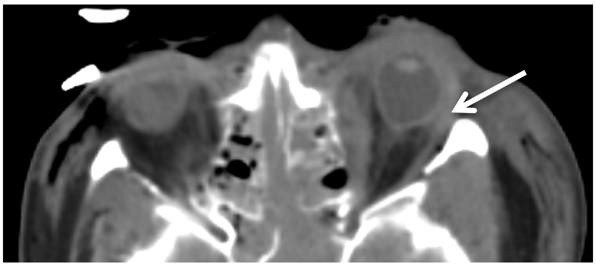

Fig. 21: Elongation of left optic nerve (49-year-old male with elevated IOP). CT, transverse section: Elliptical-shaped left globe (white arrow), the optic nerve presents elongated accompanied by diverse fractures of the osseous orbit.

In nearly 10% the optic nerve exposed with an altered morphology. For example, the visual nerve appeared hyperdense due to hemorrhage or due to intraconal hemorrhage.

Fig. 22: Altered morphology of left optic nerve (55-year-old male with reduced vision of left eye). CT, axial section: Left visual nerve appears hyperdense due to hemorrhage (white arrow).

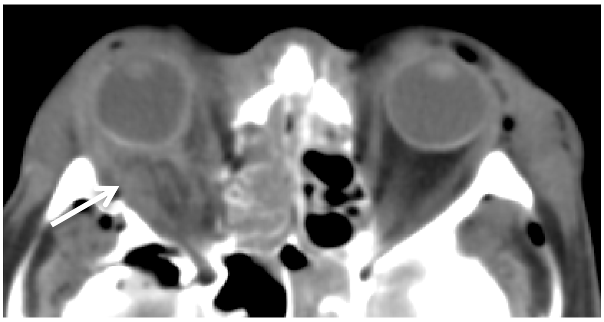

Fig. 23: Altered morphology of right optic nerve with hemorrhage within the conus (75-year-old male). CT, transverse section: The vitreous body represents unshaped with a hemorrhage behind the globe (white arrow). The complete orbital portions are fractured. Extraocular muscles could not be identified individually.

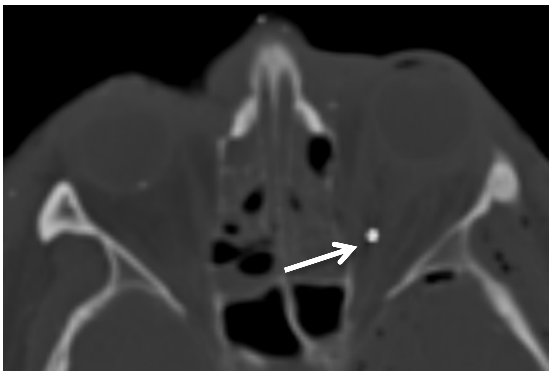

Fig. 24: Metallic foreign body (white arrow) in course of left optic nerve (40-year-old male with complete vision loss). CT, axial section: The optic nerve is transected.

4.4.4 Orbital vessels

Nearly 10% of 101 soft tissue traumata revealed a conspicuous prominent ophthalmic vein as listed in Table 3. A dilated ophthalmic vein and a proptosis of the concerned globe are indirect signs of an arteriovenous fistula such as the posttraumatic carotid-cavernous fistula (CCF). The diagnosis dCCF was confirmed in 6 (5.9%) patients.

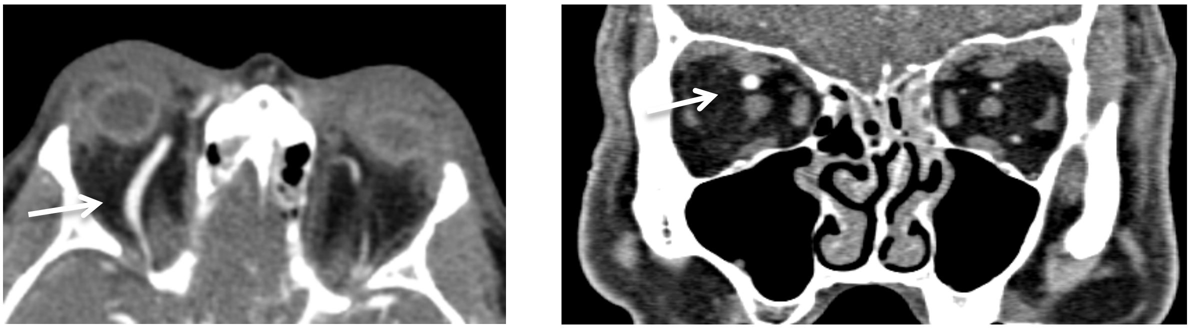

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Fig. 25 (a/b): Prominent right ophthalmic vein (52-year-old male). CT scan, axial section (a): Besides a fracture of the orbital roof, an enhanced superior ophthalmic vein (white arrow) appears intense due to a defective venous drainage. Exophthalmus of the right eye. CT, coronal reconstruction (b).

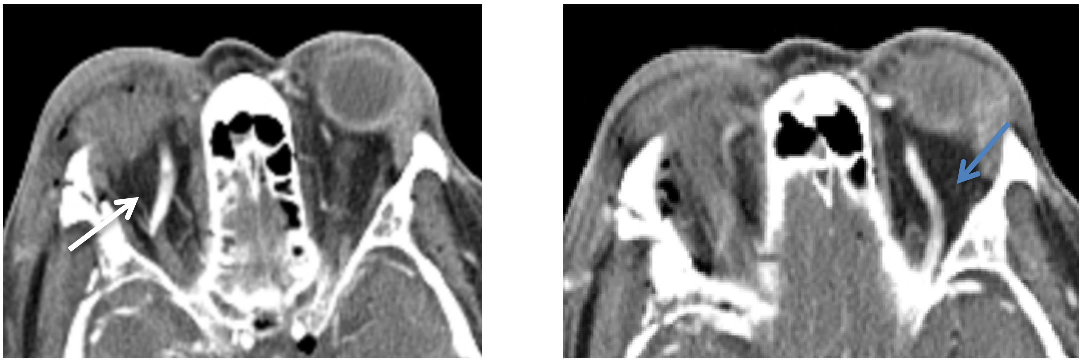

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Fig. 26 (a/b): Prominent dilated ophthalmic veins (54-year-old female after fall, both eyes). CT scan, axial section (a): Dilated right ophthalmic vein (white arrow). CT, axial section (b): Dilated left ophthalmic vein (blue arrow).

Fig. 27: Prominent dilated ophthalmic veins (white arrows) (55-year-old male). Posttraumatic carotid cavernous fistula of the left cavernous was documented. CT, axial section.

5. Discussion

We evaluated 1,061 midface CT scans by the frequency and severity of trauma to the eye and orbit in major trauma patients at a single center. In 1,061 of 6,000 polytrauma patients a maxillofacial CT was performed in addition to the whole-body scan as further injuries to eye and orbit could not clinically be excluded. 75% (N = 811 patients) had no trauma to the midface except fractures of the osseous nose and/or jaw. A representative trauma was found in about 25% (N = 250 patients) of our collective. Therefrom, 59.6% (N = 149 patients) had sheer osseous and 1.2% (N = 3 patients) had pure soft orbital injuries. 39.2% (N = 98 patients) presented with bony and orbital pathologies. The osseous orbit had been affected by trauma in the majority of 247 patients. Approximately 9.5% from 1,061 polytrauma patients presented with associated ocular injuries. Guly et al. reported in their study from 1989 to 2004 that 10.4% had a facial fracture of the orbit or the zygomaticomaxillary complex and 9.8% of them had concomitant injuries of the eye. 1.4% had lacerations of the soft tissue without any osseous fractures. Altogether, 2.3% of the major trauma patients had associated ocular injuries [15]. The data revealed smaller dimensions of orbital injuries associated with life-threatening trauma than in our study. This might be due to an increased number of cases (N = 39,073), which were from the Trauma Audit Research Network database from the United Kingdom and dissimilar inclusion criteria. For instance, they did consider orbital fractures as facial fractures and looked at the injuries caused by foreign bodies but not at the type of foreign body. Another Australian study from 1990 to 1997 published that 16% of the multiple traumata cohort had injuries to eye and orbit [22]. Poon et al. classified orbital fractures with ocular injuries and included eyelid lacerations, damage to the adnexa and the anterior chamber which we did not analyze in our study [22]. However, this study and our findings had a similar size of cohort. A study about serious ocular trauma in Scotland from 2008 found that 6-7% of patients with life-threatening trauma had a collateral ocular damage [23]. It displays that we are within the range with our incidence of ocular trauma in major trauma patients. Serious eye injuries involving the orbit and the orbital soft tissue structures are predominantly uni-ocular. In our sample we had a unilateral event in approximately 70%. On the one hand Desai et al. proclaimed a prevalent majority of unilateral incidents in ocular injuries [23]. On the other hand the involvement of both eyes in ocular trauma is mostly severe in patients who suffered from major trauma for instance. Analyzing the incidence of orbital injuries in males compared to females we had 76% male and 24% female patients in our findings. Previous studies, such as the analysis in the UK by Guly et al. showed identical results [15]. In our cohort the patients were between zero and 99 years old with a median age of 44.53 years. The maximum peak of patients suffering from orbital injuries occurred in young adults at a median age of 20.5 years, which has been confirmed in other studies [3, 16]. A second incidence peak was noted among the elderly from 50 to 59 years. Reasons might be a poor vision due to various ocular conditions such as glaucoma or cataract [15] or even the self-esteem of experienced practice by virtue of decreased cognitive abilities.

The etiology of traumatic ocular injuries seems to vary in urban and rural areas. In our study we used the data from the emergency hospital, where we mostly looked at metropolitan patients who sustained a major trauma. Road traffic accidents still generated a vast proportion of 54.7%. In our series the accidents by motor vehicle constituted 26.4%, by bike 10.4% and by motorcycle 8.9%. Pedestrians who suffered from multiple traumata represented with 9%. This is identical with other studies. Likewise Guly et al. had an incidence of 57.3% in road crashes [15] and a study from Washington Hospital Center in Washington, D.C. had a prevalence of 52% [24]. The seatbelt legislations and the frontal air bags in vehicles as well as the helmets in bikers could avoid any fatal injuries but they even might increase the risk of ocular damage as the impact of the face is enormous [15, 24]. Other causes of traumatic injuries of the eye and orbit were falls from great height (in our series 28.8%) and assault-related accidents in 3.8%.

Most patients with a life-threatening event have multiple injuries to their organs more than to orbit and/or intraorbital soft tissue structures. They might even be unconscious, intubated and/or suffer instancing from head or spine injuries. Therefore, ocular injuries are often not given first concern and authors push for early ophthalmological consultations to catch any visual dysfunction sooner than later [15, 16]. Predictable information about the possible outcome of serious eye injuries has an enormous significance for physician and patient. For the patient, visual loss could lead to severe limitations of quality of life and morbidity. Therefore treatment of ocular injuries should be preferred to treatment of simple fractures. However, the priority consists in stabilizing the general condition of the patient and to identify injuries which otherwise might lead to fatal consequences. CT as the standardized method of fast and accurate radiological imaging represents bones and organs, so that fractures and organ damage can be detected rapidly by the radiologist [3]. If the patient is sedated and intubated, it will be difficult to examine vision and ocular movement. Visual acuity is the utmost factor in an emergency condition. It will give the ophthalmologist important information about the condition of the patient’s vision. Even the indication of an enophthalmus should seek any attention as it might be a result of orbital fractures [16]. If possible, an ophthalmologist should examine the visual faculty, pupils, the intraocular pressure and the ocular movement [15]. If the patient is unable to open his eyes during the clinical examination due to his general condition, lid edema or pain, it will be very challenging for the examiner. Nevertheless a gentle examination of orbit and intraocular structures should definitely be performed by an ophthalmologist. MRI, known as a time-consuming procedure, is contraindicated in patients with severe injuries who need initial trauma evaluation and it is a hazard for patients who might have a metallic foreign body in the orbital cavity or elsewhere. Ultrasound as a rapid method of examination can be useful in the evaluation of a displaced lens and the globe. This should be done cautiously as the globe might be perforated or ruptured. It can provoke extravasation of intraocular contents or eye decompensation due to the pressure of the transducer. Other detectable ocular injuries are vitreous hemorrhage, detachment and traumatic cataracts. Ultrasound in combination with a doppler can confirm the diagnosis of a cavernous sinus fistula. Studying the possible diagnostic modalities in ocular traumata, the orbital CT scan is known to be the first-line imaging method nowadays as it identifies orbital wall fractures and intraocular injuries such as optic nerve injuries, hematoma and IOFBs [3-6]. However, Wang et al. pointed out that the crystalline lens is a radiosensitive organ, too much radiation can cause cataracts [25]. Furthermore, CT imaging is the preferred and most sensitive method in appraising the size, the localization (near vital tissue) and the chemical structure of intraocular foreign bodies. Lin et al. designated in their study that the sensitivity of the CT scan to recognize IOFB was 90% [26]. In the remaining 10% the CT failed to identify fragments. They substantiated it in the phenomenon of overestimating the size of metallic foreign bodies, which is due to the fact that IOFBs made of metal produce artifacts. Accordingly, nonmetallic structures of foreign bodies, such as dry wood, cannot be detected in CT scans as they appear hypodense. In contrast glass fragments can often be seen in CT even more accurately than in MRI and US. Consequently, the CT scan is a useful imaging method in the preoperative preparation of removing the IOFB [11, 26, 27].

5.1 Osseous traumata of the orbit

In our data 23.3% out of 1,061 midface CT scans had osseous traumata of the orbital cavity. Noticeable is the distribution of fractured walls. A single wall fracture was the prevailing type of fracture followed by two- and three-fractured walls.

Among all osseous traumata of the orbit, the orbital floor was the prevalent affected wall, irrespective of isolated impact or in combination with other wall fractures. Floor fractures were followed by fractures of the orbital roof and lateral wall. Interestingly, the medial wall was the least frequent type of fracture in our series. This is controversial as it is the thinnest orbital wall. Consistently, Merle et al. stated that the medial wall is not the most common type of fracture [28]. The reason might be the strength of the perpendicular septa which separate the ethmoidal air cells. Patients appear asymptomatic and are mostly diagnosed incidentally. The scan often only represents a minimal shifting of fragments [9, 28]. Considering the incidence of isolated wall fractures, the orbital floor and roof were predominantly concerned. The bottom wall was the most frequently impaired wall and fragments of the bone were dislocated into the maxillary sinus. Not uncommonly periorbital fat tissue and/or the inferior rectus muscle were prolapsed into the sinus. This is consistent with other studies such as the findings of Kühnel et al. and Tan Baser et al. [3, 7].

Additionally, Stam et al. reported that roof fractures occur more often isolated than in combination with other facial fractures. In the majority of cases the roof fracture was dislocated downward [29]. Associating the isolated orbital wall fracture with multiple facial fragments, it depends on the type of injury mechanism. In road traffic accidents, for example, the risk of suffering from multiple fractures is higher than in physical assault. The offender usually targets the prominent points of the face as nose, temple or cheek. Kühnel et al. stated that trauma to the lateral face happens more often than to the midface. Vehicle accidents are here the executive cause as in our study [3]. In summary, we highlighted the etiologies and incidences of osseous traumata of the orbit. Orbital wall fractures can provoke other severe concomitant damage to the eye.

5.2 Soft tissue traumata of the orbit

Injuries of orbital soft tissue structures following eye traumata may occur as a result of blunt or penetrating injuries, burns or chemicals. In worst case the damage can lead to blindness. Sharp objects such as foreign bodies are less frequent than contusion injuries. In our retrospective study we specifically looked at injuries to the ocular globe and lens, the extraocular muscles, the optic nerve and orbital vessels, which were caused by traumata. 9.5% out of 1,061 midface CT scans illustrated injuries to the soft tissue structures. Just 0.3% showed an isolated trauma to the orbital contents without any damage to the osseous bones.

The numerous reasons of visual loss or even blindness are penetrating injuries of the globe, visual nerve or its pathway. Visual loss due to midfacial fractures is a seldom occasion. It ranges between 0.3% and 3.5% in different studies as Septa et al. declared [16].

5.2.1 Ocular globe and lens

23.8% of 101 identified altered soft tissue traumata of the orbit presented with an unshaped and conspicuous globe. 6.9% (N = 7) were identified by two longtime experienced radiologists as (partially) ruptured as they showed a change of globe contour, wall irregularity and the presence of intraocular air. A dislocated or destroyed lens confirmed the diagnosis and a fast and reliable diagnosis of a ruptured globe is essential to avoid further complications such as vision loss, posttraumatic enophthalmitis, abscess or meningitis. Yuan et al. stated in their paper that CT imaging detects a globe rupture with a certainty of 81% [19]. In our findings, five out of seven globe ruptures were associated with orbital fractures. In 80% of the cases all four walls were affected. A traumatic lens dislocation without a ruptured globe is possible, too. Lee et al. analyzed diagnostic modalities for confirming a dislocated lens. They stated that point-of-care ultrasound is an accomplished choice in confirming a dislocated lens [30]. However, ultrasound is contraindicated when having the suspicion of a ruptured globe as it can spark extravasation of colloidal fluidity. A CT scan of the orbit is the alternative and safest choice.

5.2.2 Extraocular muscles

Considering traumata to the extraocular muscles with the consequence of ocular motility disturbance, we identified 45 extrusions of ocular muscles, eight penetrations by osseous fragments and one by foreign body out of 101 soft tissue traumata. The major causes of ocular motility disturbance and diplopia after a trauma are listed by Chen et al.: orbital wall fractures, paralysis of oculomotor nerves or the extrusion of the muscle due to enlaced structures [31]. In agreement with our findings, tissue edema and hemorrhages either intramuscular or in fat tissue are accountable for the displacement of ocular muscles.

Laceration of an ocular muscle caused by a bone fragment or foreign body can induce severe motility disturbances. At suspicion of a ruptured extraocular muscle early diagnostic should be sought. CT is therefore mandatory to visualize the damage to the muscle and to allow the surgical approach. Traumatic ruptures frequently correlate with major orbital injury. If CT imaging does not reveal any rupture of orbital muscle in spite of clinical symptoms as strabismus and diplopia, MRI will be a valuable method. Thus, further potential sequelae can be avoided [31]. Chen et al. pointed out that in a majority of cases the ruptured muscle can be detected at or near the annular tendon insertion [31]. A direct injury to the ocular muscle elicited by a foreign body was once found in our study.

5.2.3 Optic nerve

In our study we evaluated the morphology and the shape of the visual nerve. We asserted that traumatic injuries to the nerve are mostly associated with fractures of the orbital walls and skull. Commonly, the injuries represented with concomitants such as periorbital hematoma and/or edema. In case of globe movement by concussive forces, the nerve can compensate by his extra length. Trauma to the midface can cause damage to the optic nerve due to different mechanisms. Most commonly, impairment indirectly damages the visual nerve by shearing forces. The patient may suffer from deficiency in vision, visual field or color perception. Another mechanism is the direct trauma to the nerve by bone fragments or sharp objects such as projectiles. It may result in nerve avulsion and/or traumatic optic neuropathy [32].

In a computer modelling study, Cirovic et al. researched the mechanism of damage to the optic nerve. They considered two principal means: the tremendous rotation of the nerve in relation to the globe and secondly the increasing IOP of the globe deformation which we also studied in our research [33]. Luxenberger et al. differentiated the type of mechanism by means of the various segments of the visual nerve. They reported that direct damage to the nerve specifically concerns the intraocular and intraorbital portions. A blunt trauma more often affected the intracranial segment, subdivided in pars intracanalicularis and pars intracranialis [20]. Anatomically, the most affected part of the optic nerve is where the nerve passes through the optic canal [20]. In our analysis we noticed a correlation between involving damage of the optic canal and an altered morphology of the visual nerve in the CT images. As Lee et al. illustrated, the impairment of the optic nerve occurs in microscopic levels. Contusion necrosis or disruption of the nerve fibers may result which conclude immediately in loss of vision [32]. On the one hand, Lee et al. described a damage of the optic nerve in 0.5-5% of closed head trauma. On the other hand, they stated that the severity of the trauma does not consistently correlate with the degree of damage [32]. A rare complication of ocular traumata is the direct avulsion of the optic nerve. In our cases, we recorded one transection by a foreign metallic body.

5.2.4 *Orbital vessels*

Severe trauma to head and orbit include violation to the vascular orbital structures. In our study we looked for posttraumatic hemorrhage due to vascular lesions within the orbit and for direct carotid-cavernous-fistulae. They predominantly result from (serious) head traumata and in rare cases spontaneously. Searching for literature about the occurrence of dCCF, we found it difficult to find reliable data. Aguiar et al. illustrated in their paper from 2017 the endovascular treatment of carotid-cavernous vascular lesions [34]. They described 10/39 patients with a dCCF. Nine from ten were caused by a traumatic brain injury. A similar study about endovascular treatment of CCF defined 10/60 patients with dCCF [35]. In our findings, we identified ten CT images of traumata to the midface with prominent ophthalmic veins, which indicates the possibility of a dCCF. Other characteristics, such as exopthalmus, orbital edema and enlarged extraocular muscles strengthen the diagnosis. In six of 101 CT images the posttraumatic CCF was confirmed. Gathering from the references dCCF are rare. For that reason it poses a challenge to clinician and radiologist to diagnose them in minimum time. Data from different literature showed identical clinical manifestations of dCCF as pulsatile proptosis, diplopia, chemosis and vascular murmur, which should raise attention to clinician and ophthalmologist [34, 35]. Aguiar et al. highlighted in their study that it is important to identify and confirm the suspect of dCCF. A CT scan of the skull is required as first line imaging. Further diagnostic instruments, such as ultrasound or DSA, should be considered to avoid further complications such as poor vision [34].

6. Summary

In our retrospective study we researched for possible injuries to the eye and orbit in patients who suffered from polytrauma. We assessed 6,000 patients with severe trauma, who were treated at the Unfallkrankenhaus Berlin (UKB) between February 2006 and August 2014. Out of them, 1,061 maxillofacial CT scans were performed additionally to a whole-body scan as further injuries to eye and/or orbit could clinically not be excluded. We used a systemic diagnostic workup to examine the frequency and severity of a trauma to osseous and soft tissue structures of the orbit. For the assessment of the bony orbital walls we included the detection of a fracture gap, a rough dislocation of bony fragments as well as the detonation of osseous sutures between facial bones. Concerning the orbital soft tissue structures we looked at injuries of the ocular globe including the lens, extraocular muscles, optic nerve and orbital vessels. Complementary, we collected clinical data of eye examinations of our patients by using the medical information system (MIS) software medico. We appraised the ophthalmic diagnostic findings based on three criteria: the intraocular pressure (IOP), the vision and eye movements and recorded whether surgery or conservative treatment was conducted.

Out of 1,061 maxillofacial CT images, 811 were excluded. 668 patients did not have a trauma to the midface and 143 patients only showed fractures of the nose and/or jaw. The remaining 250 patients revealed traumata to the orbit: 149 CT scans showed fractures of the orbital cavity without participation of soft tissue structures. Three patients presented with pure soft tissue traumata to the eye and 98 scans displayed combined injuries of bones and orbital soft tissue structures. The right orbit was concerned in 35.6%, the left orbit in 32.8% and both orbits in 31.6% of cases. The prevailing type of fracture was the single wall fracture, followed by two- and three-walled fractures. In the majority of cases the orbital roof, floor or lateral wall were concerned. Besides blow-out fractures, we detected characteristic fractures as the tripod fracture and Le Fort 2°. Regarding the soft tissue traumata of 101 CT scans, we detected an unshaped vitreous body in 23.8% and a (partially) ruptured globe in 6.9%. The ocular lens was dislocated in six cases (5.9%). A foreign body pre-orbital and within the conus was found three times. Considering the extraocular muscles, we discovered that 44.6% of muscles were dislocated. In 7.9% extraocular muscles were pierced by bone, in one case the muscle was pierced by a foreign body. Searching for structural alterations of the optic nerve, 12.9% of 101 scans presented an elongated optic nerve and 9.9% revealed an altered morphology. One nerve was transected by a metallic foreign body. Upon closer inspection of orbital vessels, we detected 9.9% prominent ophthalmic veins and 5.9% posttraumatic dCCF

out of 101 CT scans. The results of the clinical eye examinations showed that 19.2% of the collective of 250 patients presented with an increased IOP. 4.8% of 250 patients had a reduced or lost vision and 10% of patients had suffered from a limited ocular movement after trauma to the midface.

In conclusion, approximately 9.5% from 1,061 polytrauma patients presented with associated orbital injuries. Ocular injuries are not often given immediate concern as patients with life-threatening conditions need to be stabilized first. Undetected serious eye injuries might lead to a reduced or lost vision, which could result in severe limitations of quality of life. The results of our study speak in favor for early ophthalmological consultations and radiological imaging. Diagnostic and treatment of possible orbital injuries should be remembered in a polytrauma patient.

7. Literature

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8. Eidesstaatliche Erklärung

Hiermit erkläre ich, dass ich die vorliegende Dissertation selbständig erfasst und keine anderen als die angegebenen Hilfsmittel benutzt habe.

Die Dissertation ist bisher keiner anderen Fakultät, keiner anderen wissenschaftlichen Einrichtung vorgelegt worden.

Ich erkläre, dass ich bisher kein Promotionsverfahren erfolglos beendet habe und dass eine Aberkennung eines bereits erworbenen Doktorgrades nicht vorliegt.

Datum Unterschrift

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