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The use of modern imaging techniques in the diagnosis and treatment planning of patients with orbital floor fractures

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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Summary

Background: Ocular motility impairment associated with orbital trauma may have several causes and manifest with various clinical symptoms. In some cases orbital reconstructive surgery can be very challenging and the results are often unsatisfactory. The use of modern imaging techniques aids proper diagnosis and surgical planning.

Case Report: The authors present the case of a 29-year-old male who sustained trauma to the left orbit. Orthoptic examination revealed limited supra- and infraduction of the left eye. The patient reported diplopia in upgaze and downgaze with primary position spared. Dynamic magnetic resonance imaging (dMRI) was performed, which revealed restriction of the left inferior rectus muscle in its central section. A patient-specific anatomical model was prepared on the basis of 3-dimensional computed tomography (CT) study of the intact orbit, which was used to prepare a custom pre-bent titanium mesh implant. The patient underwent reconstructive surgery of the orbital floor.

Conclusions: Modern imaging techniques such as dMRI and 3-dimensional CT reconstruction allow us to better understand the pathophysiology of orbital floor fractures and to precisely plan surgical treatment.

key words: **orbital fracture • magnetic resonance • orbital implants • computer models**

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Background

Orbital trauma, in particular fractures of the lower wall, produce numerous symptoms such as enophthalmos, infraorbital hypoesthesia and periorbital ecchymosis [1]; however, the most important sign is diplopia [2]. This results from limitation of the eye's motility on the affected side, which is caused by tissue entrapment in the fracture fissure or inferior rectus muscle paresis [3]. In some cases both of these mechanisms are coexistent [4]. Establishing a correct diagnosis only on the basis of the clinical picture in such patients is very problematic and demanding for an ophthalmologist-strabologist. The use of modern imaging techniques such as dynamic magnetic resonance imaging (dMRI) can aid this process. Correct classification of the existing ocular motility disorders helps to establish an effective treatment plan. The treatment method of choice in cases of tissue restriction that results in significant diplopia is reconstructive surgery using alloplastic materials [5,6]. In some patients this procedure can be very challenging and the results are unpredictable. This is mostly due to late intervention and fracture complexity, as well as technical problems such as narrow operating field and the intricate process of manually forming, fitting and aligning orbital implants [7]. Using specialized software and rapid prototyping technology it is possible to create patient-specific anatomical models of the bony orbits (8). Patient computed tomography (CT) images of an undamaged orbit are converted into a 3-D model which is then mirrored onto the contralateral side. This effectively creates a virtual model that represents the pre-morbid anatomy of the traumatized orbit. Next, using a photopolymer rapid prototyping technique, a physical model is built which serves as a template to shape and form titanium mesh into a custom implant. By utilizing such pre-formed (prior to surgery) implants, the procedure becomes less challenging for the surgeon and results in shorter operating times with less trauma to the orbital contents and better functional results [6,7].

Case Report

A 29-year-old male, who had sustained trauma to the left orbit during a basketball game 1 month earlier, was referred due to troublesome diplopia. Symptoms had persisted since the incident and were accompanied by visible limitation of eye rotation on the affected side. After initial physical examination, which did not reveal any other abnormal signs, a CT scan was performed. This showed a left orbital floor fracture without significant tissue herniation; however, the inferior rectus muscle was situated directly over the fracture fissure (Figure 1). The patient was referred to the Department of Binocular Vision Pathophysiology and Strabismus to determine the nature of the ocular motility impairment.

Orthoptic examination revealed limited supra- and infraduction of the left eye. The patient reported diplopia in upgaze and downgaze with primary position spared. Prismatic cover-test for distance was 0Δ with 0.5Δ right-sided hypertropia (RHT) in primary position, but in upgaze it was 4Δ with 16Δ RHT and in downgaze 2Δ with 10Δ left-sided hypertropia (LHT). Detailed examination on a major amblyoscope in 9 gaze positions showed that vertical deviation increased when the affected (left) eye was abducted. Subsequently, a Hess chart was plotted (Figure 2A). The clinical picture presented by the patient led to the conclusion that the cause of ocular motility limitation was a combination of paresis (limited depression) and restriction (limited elevation) of the left inferior rectus muscle. Due to the fact that this diagnosis was uncertain, the patient was referred for a dMRI of the extraocular muscles.

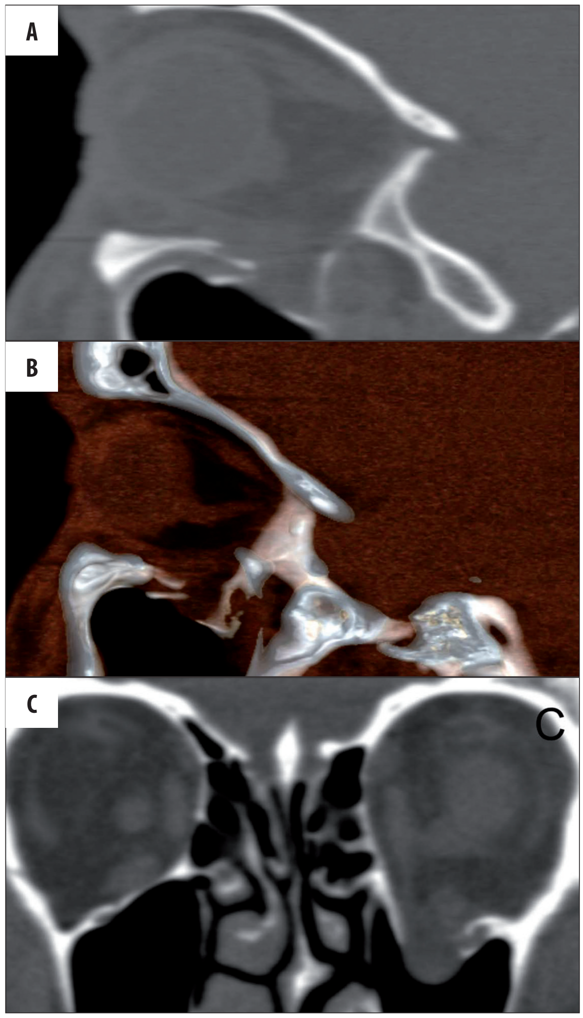

Figure 1. Computed tomography of the orbits. (**A**) Sagittal scan of the left, fractured orbit. (**B**) Three-demensional image reconstruction with sagittal plain cut. (**C**) Coronal scan. Fracture of lower orbital wall with soft tissue herniated into the maxillary sinus.

dMRI consists of a number of short sequences during which the patient fixates on consecutive points placed in different positions of gaze [9]. The sequence lasts 13 seconds per gaze position in order to prevent blinking artifacts (T2-dependent images). The extraocular muscles are visualized in coronal and sagittal planes. Measurements of selected muscles including shape, sectional area and volume are than obtained by means of image processing software.

In then particular patient the dMRI was focused on the action of the left inferior rectus muscle (1.5T MRI, Siemens Avanto). It exhibited a sudden increase in its cross-sectional area when measured in the coronal plane on slices representing the central part of the muscle body. Additionally,

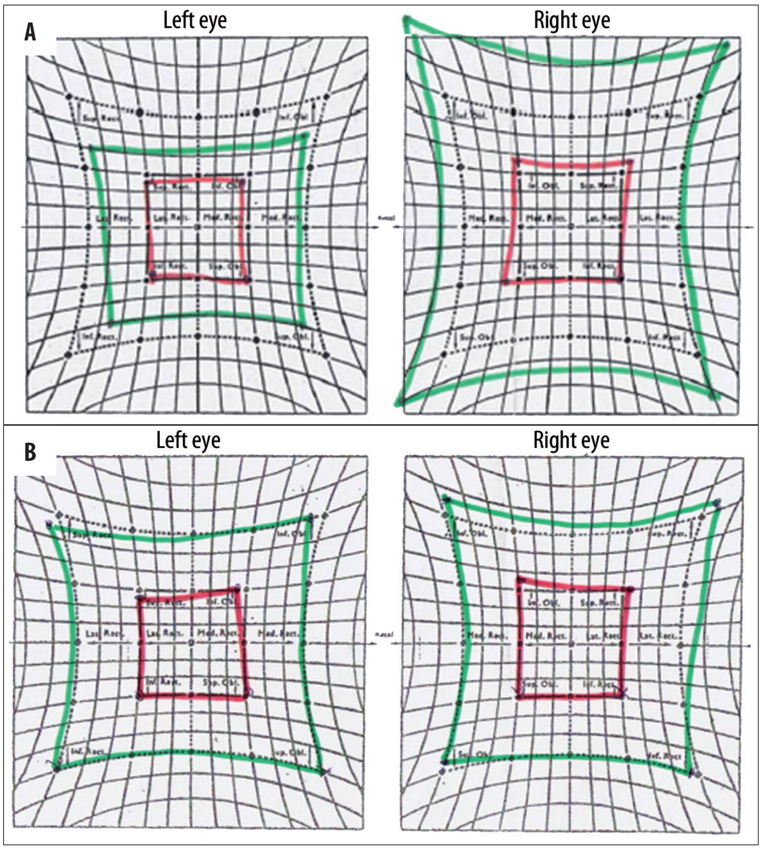

Figure 2. Hess chart plotted before reconstructive surgery. Hess chart plotted after reconstructive surgery.

on the sagittal scans the site of restriction was clearly visible, especially during 30° upgaze (Figure 3). These findings were consistent with theoretical considerations suggesting that in certain cases of limited depression and elevation the former does not result from muscle paresis but from its restriction in its central section. In such patients the effective contractile force of the inferior rectus is reduced because only its anterior part is capable of rotating the globe [10].

Due to the fact that a restrictive factor was found to be responsible for ocular motility impairment, the patient was qualified for orbital reconstructive surgery. The surgery was performed under general anesthesia. The left lower orbital wall was reached by transconjunctival approach and herniated tissues were reduced. The implanted alloplastic material was titanium mesh and rapid-prototyping was implemented to create an individual anatomical model. This was built on the basis of a 3-dimensional multislice computed tomography (MSCT) scan of the intact orbit (GE Lightspeed VCT). Titanium mesh 0.4 mm in thickness [KLS Martin Group, Germany] was shaped and cut to size using the anatomical model to achieve a 3-D shape that best fitted the contours of the orbit (floor) (Figure 4).

The orthoptic examination 2 weeks after surgery revealed a large improvement in ocular ductions of the left eye. The patient reported diplopia only in peripheral upgaze. Postoperative prismatic cover-test for distance was 2Δ with no vertical deviation in primary position. Accordingly, in upgaze it was 4Δ with 5Δ RHT and in downgaze 0Δ, and no vertical deviation was present. The plotted Hess chart exhibited only slight restriction of the left inferior rectus (Figure 2B).

Discussion

Orbital fractures result from direct trauma to the orbital rim (buckling theory) or the mechanism of blow-out when the force is applied to the globe (hydraulic theory) [11]. When the defect occurs in the lower wall it may produce symptoms associated with entrapment of the soft tissues and thus restriction of eye motility. This eventually leads to facial skin dysesthesia, enophthalmos, and diplopia, which is most bothersome for the patient [1,2,5]. Generally there are 3 types of patients with ocular motility impairment after or following orbital floor fracture [4]. The first group consists of subjects with hypotropia of the eye on the affected side, thought to consist of cases of pure restriction of the inferior rectus muscle localized in its anterior part. The second type of patient has hypertropia of the eye on the affected side, a deviation associated with either paresis or restriction localized posteriorly in the muscle cone [10]. The third type consists of cases with a combination of the above disorders that exhibit diplopia in upgaze and downgaze, with the primary position spared; such patients pose a great challenge for both the ophthalmologist and the maxilla-facial surgeon. The decision whether to perform reconstructive surgery or to observe the patient and see if the paresis resolves is difficult and must be made on an individual basis. Magnetic resonance imaging, in particular dMRI, aids this process. Analysis of inferior rectus entrapment in the course of orbital floor fractures by means of MRI has been performed by several authors. Totsuka [12] found that restriction of inferior rectus action is sometimes caused by the surrounding tissue and not the muscle itself. Nevertheless, the muscle in the area where it is pulled down

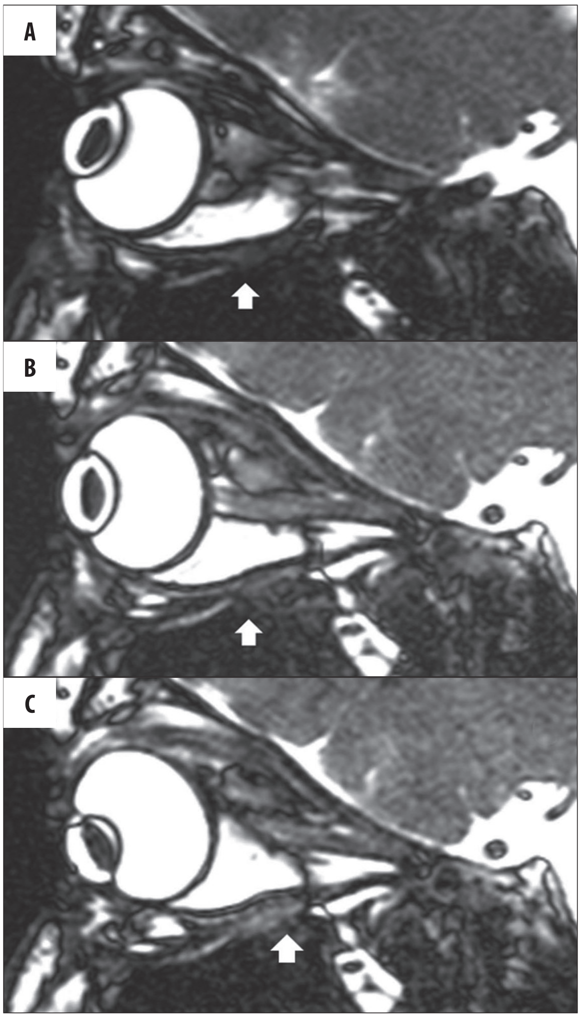

Figure 3. Magnetic Resonance sagittal scans of the fractured orbit (T2-dependet images). Lack of signal in the area of bone tissue. Part of the inferior rectus muscle has been displaced into the maxillary sinus. Arrow indicates the zone of tissue entrapment. (**A**) 30° upgaze, (**B**) Primary position, (**C**) 30° downgaze.

by the soft tissue has a distorted shape and its cross-sectional area is enlarged [13].

In cases of documented tissue restriction and associated diplopia, reconstructive surgery is indicated [5]. The outcome appears to be dependent on surgical timing, fracture size, and preoperative vertical deviation value [1,2,4]. Successful resolution of diplopia is achieved in 17–52% of cases, depending on the study and method of evaluation [2].

In search of better results, surgeons have used different kinds of alloplastic materials and proposed different techniques. One of the most recent advances is a method using rapid-prototyping and custom titanium mesh implants [6,8]. The rationale for using this technique was the fact that the complex anatomy of the orbit makes the process of shaping and cutting the bone graft intraoperatively very difficult, and it is almost impossible to achieve a 'true-to-original' 3-D shape. This resulted in poor outcomes due to intraoperative trauma of the inferior rectus muscle [11]

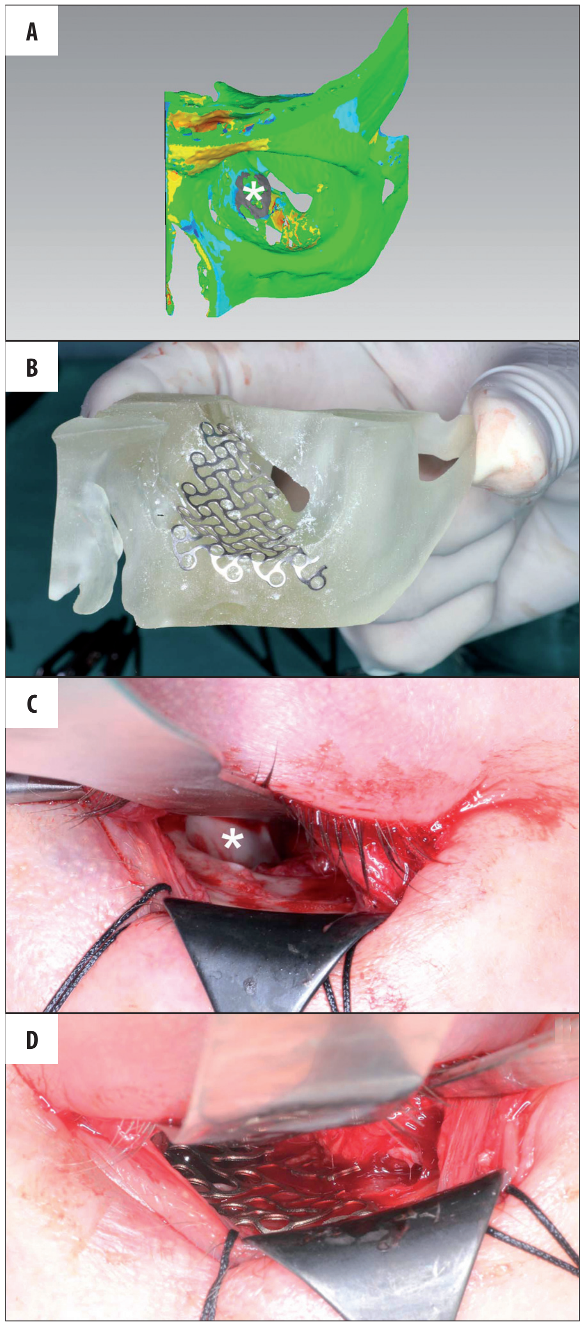

Figure 4. Modeling and application of custom implant. (**A**) Virtual model undergoing symmetry analysis. Green color indicates left-right symmetrical surfaces within tolerance ±1 mm. Asterix indicates the most unsymmetrical region of orbital wall, area of destruction [dark grey color indicates that points are not within the range of symmetry]. (**B**) Rapid prototyping anatomical model in the operating theatre. Model created using the mirroring technique, represents the original "pre-morbid" shape of the injured lower orbital wall. Custom implant (0.4 mm titanium mesh) formed on the basis of the re-established anatomical relations. (**C**) Intra-operative view showing a transconjunctival approach. Trapdoor type fracture and the depressed lower orbital wall can be seen after reduction of herniated inferior rectus muscle [asterix] (**D**) Custom implant located within the orbit and covering the bone defect in the lower orbital wall. It is stabilized by screws that are fixed to the lower orbital margin.

and incomplete reconstruction of the bony defect [7]. Pre- or intraoperative titanium mesh shortens operating times, and decreases the number of attempts required to position the implant in the orbital cavity and assess its shape and fit. This significantly reduces the risk of inferior rectus damage [6]. As the implant is tailored to the shape of the orbit, the whole area of bony defect can be covered with the mesh. All of the above factors influence the long-term results, which are better than in the standard method [14].

Conclusions

Modern imaging techniques such as dMRI and CT 3-dimensional reconstruction allow us to better understand the pathophysiology of orbital floor fractures and to correctly plan surgical treatment. Thanks to these new technologies, the process of orbital floor reconstructions can be significantly improved.

References:

1. Chi MJ, Ku M, Shin KH et al: An analysis of 733 surgically treated blow-out fractures. Ophthalmologica, 2009; 224: 167–75
2. Biesman BS, Hornblass A, Lisman R et al: Diplopia after surgical repair of orbital floor fractures. Ophthalmol Plast Reconstr Surg, 1996; 12: 9–16
3. Kushner BJ: Paresis and restriction of the inferior rectus muscle after orbital floor fracture. Am J Ophthalmol, 1982; 94: 81–86
4. Gosse EM, Ferguson AW, Lymburn EG et al: Blow-out fractures: Patterns of ocular motility and effect of surgical repair. Br J Oral Maxillofac Surg, 2010; 48: 40–43
5. Harris GJ: Orbital blow-out fractures: surgical timing and technique. Eye, 2006; 20: 1207–12
6. Kozakiewicz M, Elgalal M, Loba P et al: Clinical application of 3D pre-bent titanium implants for orbital floor fractures. J Craniomaxillofac Surg, 2009; 37: 229–34
7. Metzger MC, Schön R, Weyer N, Rafii A: Anatomical 3-dimensional pre-bent titanium implant for orbital floor fractures. Ophthalmology, 2006; 113: 1863–68
8. Elgalal M, Kozakiewicz M, Loba P et al: Patient specific implants, designed using Rapid Prototyping and diagnostic imaging, for the repair of orbital fractures. Med Sci Monit, 2010; 16(Suppl.1): 75–79
9. Tian S, Nishida Y, Isberg B, Lennerstrand G: MRI measurements of normal extraocular muscles and other orbital structures. Graefe's Arch Clin Exp Ophthalmol, 2000; 238: 393–404
10. Lerman S: Blowout fracture of the orbit. Diagnosis and treatment. Br J Ophthal, 1970; 54: 90–98
11. Hosal BM, Beatty RL: Diplopia and enophthalmos after surgical repair of blow-out fracture. Orbit, 2002; 21: 27–33
12. Totsuka NKR: Kinematic magnetic resonance imaging of orbital blow-out fracture with restricted ocular movement. Orbit, 1997; 16: 75–83
13. Tonami H, Yamamoto I, Matsuda M et al: Orbital fractures: surface coil MR imaging. Radiology, 1991; 179: 789–94
14. Kozakiewicz M, Elgalal M, Loba P et al: Treatment with individual orbital wall implants in humans – 1-year ophthalmologic evaluation. J Craniomaxillofac Surg, 2011; 39(1): 30–36