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Clinical Paper
Trauma

Individually preformed titanium mesh implants for a true-to-original repair of orbital fractures

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Abstract. The purpose of this investigation is to present the results using preoperatively-formed titanium mesh implants for a true-to-original primary repair of extensive orbital floor and medial wall fractures.

Individually preformed implants were used to repair extensive orbital floor injuries in 19 patients at the University Hospital, Freiburg. The form of the orbital floor and walls was analysed by preoperative diagnostic CT scan data. The form of the virtual reconstructed orbit was transformed into a model of the orbital cavity by a template machine.

Postoperative imaging by or CT scan verified the exact 3D reconstruction of the orbital cavity 'true to original'. None of the patients demonstrated diplopia or enophthalmos postoperatively. Using individually preformed titanium mesh implants, the accuracy of the 3D orbital reconstruction was within a range of 1 mm.

The reconstruction using preformed implants proved to be less time consuming, more precise and less invasive, compared to 'free hand' efforts, for the repair of orbital injuries using titanium mesh and calvarial grafts.

Key words: individual preformed mesh; orbital fracture; reconstruction; navigation aided procedure; osteosynthesis template; computer-assisted surgery.

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In craniofacial trauma, the involvement of orbital structures is noted in up to 40% of cases[17]. Fractures of the orbital cavity occur mainly medial to the infraorbital groove and canal. Orbital floor fractures are regularly combined with fractures of the medial wall, because of a limited bone thickness in this area[3,30,34].

Post-traumatic orbital deformities caused by incorrect reconstruction of orbital dimensions are severe complications causing enophthalmos, diplopia and visual acuity disturbance[30]. In about 8.5% of patients treated with orbital injuries a volume excess which leads to enophthalmos is noted, especially when the deep orbital cone is affected[8,30]. To prevent such complications, immediate repair of orbital injuries with the restoration of pre-injury anatomy is indicated in extensive orbital floor and medial wall fractures[15]. Due to the complex orbital anatomy, precise 3D reconstruction of orbital injuries remains challenging.

Secondary orbital reconstruction is indicated when primary repair was not performed or when the result of primary repair is not satisfying. The identification of anatomic landmarks in secondary orbital reconstruction is even more challenging because of scarring and defects of the orbit. Often more than one operative procedure is needed to achieve an acceptable result[14,36,42]. Good results have been reported following one step orbital reconstruction and secondary orbital reconstruction using computer-assisted methods[10,51].

To achieve satisfying results in primary orbital reconstruction, 3D reconstruction of the orbital floor and orbital walls is mandatory[15,38]. The exact reconstruction of the complex 3D anatomy of the orbital cavity with an individually S-shaped craniocaudal rise of the orbital floor, and a retrobulbar bulge formed by the posterior aspect of the medial orbital wall and orbital floor remains a challenge for the reconstructive surgeon.

Depending on the defect localization and size, materials with varying rigidity have been recommended for the repair of orbital injuries. The use of autologous and alloplastic materials, except titanium, and calvarian bone grafts has been tempered by complications, such as foreign body reactions, resorption, displacement and late enophthalmus[2,6,23,31,47]. A true-to-original reconstruction of the demanding 3D anatomy of the orbital walls is, however, rarely achieved[9,41,43].

Using bulky calvarian bone grafts or free-hand-bend titanium mesh, precise 3D reconstructions of the retrobulbar bulge are generally not achieved. Orbital reconstruction procedures, especially for the correction and prevention of enophthalmus deformity, therefore aim at a reduction of an enlarged orbital volume, rather than a true-to-original reconstruction of the orbital cavity[9,41,43].

Preoperative planning and intraoperative computer-assisted control helped to improve results in craniomaxillofacial reconstructive surgery by using modern imaging techniques for diagnostics and associated technologies (i.e. stereolithographic models)[1,5,7,10,16,18,19,26,37]. In orbital reconstruction, however, intraoperative computer-assisted control of the correct placement of calvarial grafts or bending and adaptation of titanium mesh implants can be time consuming[10].

Individually prefabricated titanium implants using computer-assisted design and manufacturing (CAD/CAM) are already used in reconstructive surgery of cranial vault defects[40]. A method of individual preforming of titanium mesh implants based on a virtual ideal orbital reconstruction has been described previously[32]. The results of primary orbital reconstruction using preoperatively individually formed orbital implants, and intraoperative computer-assisted control of exact placement of the implants are demonstrated.

Methods

During August 2004 and July 2005 orbital reconstruction using individually preformed titanium mesh implants for the primary repair of orbital injuries was performed in 19 patients using a new technique described previously[32]. Only orbital floor and wall defects larger than 15 mm in diameter were repaired using preformed implants, due to the danger of late enophthalmus after resorption of the foils. Smaller defects were repaired by resorbable foils, such as PDS, Ethisorb (Ethicon, Norderstedt, Germany) (in 12 patients, but not included in the evaluation of this study). Extensive defects (defect size larger than 15 mm) of the orbital floor were repaired in eight patients, combined orbital floor and medial orbital wall injuries in seven patients, and dislocated zygomatic complex fractures in combination with involvement of the orbital floor were repaired in four patients. Preoperatively, the precise form of the orbital floor and walls was evaluated using diagnostic CT or Cone-beam scan data (Fig. 1). The ideal form of the injured orbital cavity was recalculated using the mirror image of the unaffected side[10]. The virtually reconstructed orbital form was then transformed into a model by a template machine as described previously[32,33]. The exact outline of the orbital defect was marked on the ideal orbital model. Manually the individual titanium mesh (Synthes, Paoli, USA) was then adjusted and 3D bending was performed. The preformed implants were inserted via transconjunctival incision without lateral canthotomy in all 19 patients. Marking of anatomical landmarks facilitated the precise intraoperative placement of the implants. Following the subperiosteal insertion of implants into the orbital cavity the exact localization of the implant was controlled by computer-assisted means (Voxim software, IVS Solution, Germany) before the implants were fixed with 1.0 or 1.3 titanium microscrews (Synthes, Paoli, USA) (Fig. 2a and b).

The results of orbital reconstruction by individually preformed titanium mesh implants were evaluated by image fusion of postoperative CT data and preoperative virtual planning of the 'ideal' orbital cavity (Voxim, IVS Solution, Germany). These two datasets were evaluated in axial, coronal and sagittal views. Depending on the individual size of implants different numbers of measurement points were taken for the evaluation of the image fusion[33].

Results

Intraoperative bending and adjustment of the preformed implants was not needed. Marking of anatomical landmarks facilitated the precise and quick placement of the implants. The insertion of the preformed titanium mesh implants using the transconjunctival approach was less time-consuming compared to orbital repair using unprepared titanium mesh, because the on-site bending and cutting to size was not necessary. Repetitive trial fitting of the titanium mesh was, therefore, avoided and the procedure was less traumatic to the periorbital tissues. Following

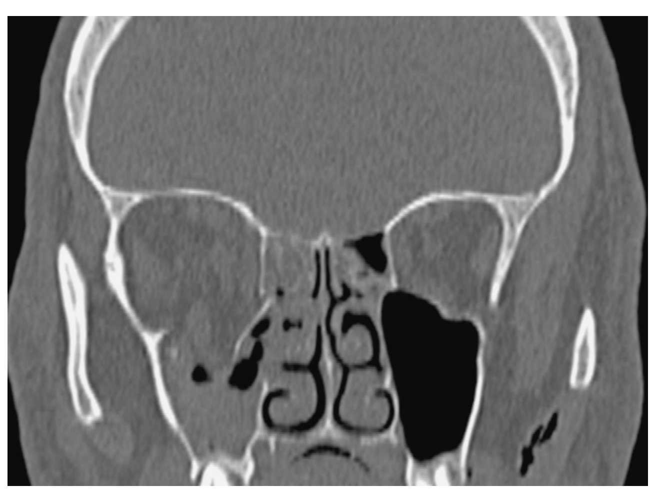

Fig. 1. Coronal reconstruction of computer tomography demonstrates extensive orbital floor fracture. The orbital volume is enlarged and periorbital soft tissue dislocated into the maxillary sinus.