

# Current Strategies in Post-traumatic Orbital Reconstruction

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**Abstract** Posttraumatic orbital reconstruction is one of the most fascinating fields in reconstructive craniomaxillofacial surgery. Hardly any other field in craniomaxillofacial surgery has changed so much in terms of diagnostics, biomaterial selection for reconstruction, surgical techniques including approaches and quality control. In particular, in the field of reconstructive orbital surgery all advances in modern medical treatment are summarized and represented. Reconstructive orbital surgery thus became the medical field spearheading all reconstructive surgical specialties in terms of use of DICOM-data, computer assistance, change towards patient-specific solutions and establishing digital workflows for adequate quality control during all phases of treatment, i.e. pre-, intra- and post-operative. With this paper, this evolutionary process shall be demonstrated as well as display the spirit of change that was necessary to optimize reconstructive orbital surgery and to improve medical care in all areas of reconstruction. Finally, reconstructive orbital surgery could prove to be a highly foreseeable field nowadays, thus giving the next generation of CMF-surgeons a huge opportunity to drive this topic further into the future.

**Keywords** Orbital reconstruction · Computer-assistance · Orbital surgery · Quality control

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When I was asked to write a paper on orbital surgery, it directly met my interest because it was a chance to look back at our craniomaxillofacial surgery speciality, and I realized that indeed orbital surgery has somehow become my interest and accompanied my academic and surgical career over the last 30 years. So, it is time to look backward and identify today's more systematic achievements and to look into the future.

Looking backward somehow orbital surgery was something like an inter-speciality no-man's-land where only randomly one or the other from the fields of maxillofacial surgery, ENT, plastic surgery, oculoplastic surgery, or general surgery stepped in systematically; the majority did it—of course in best intention—without really knowing what they did: comparable to performing bimaxillary orthognathic surgery without model planning and without splints.

On the other hand, development of orbital surgery is linked to academic teaching platforms and networks like the Arbeitsgemeinschaft für Osteosynthesefragen (AO), who—through AOCMF—contributed significantly over more than the last 20 years in advancing the field of orbital reconstructive surgery and helped to stimulate the knowledge transfer within the key players of the specialties mentioned above.

With this paper, I want to give special respect to surgeons I heard about (Paul Tessier), surgeons I learned from through multiple international meetings (i.e., Joe Gruss, Paul Manson) and people I was happy to work with and learn and develop together (Rainer Schmelzeisen, Beat Hammer, Alexander Schramm, Majeed Rana and my former teams at the University Hospital in Bochum and Freiburg and the current team at Hannover Medical School). And if I would be asked to relate some special tips in orbital surgery to one of the persons, I would relate

“form stable biomaterial” to Joe Gruss [2], “orbital volume restoration” to Paul Manson, the posterior third of the orbit being the orbital “key area” [10, 11], and “inside plating of the lateral orbital wall” and “medial canthal ligament repair in the Hammer-technique” to Beat Hammer [8], “innovations in analyzing and computer-assistance” to Rainer Schmelzeisen [6]. So, each of them contributed to give the bigger picture of orbital reconstruction.

Over the last 30 years, I fostered my personal experience in orbital surgery and I have to conclude that probably everything had its glory and justification and its specific time; however, looking backward—other than in nearly all other subspecialty fields of CMF surgery, i.e., cleft-lip and palate repair, orthognathic surgery, tumor surgery—most advanced changes occurred in management of trauma and especially in orbital surgery: this accounts for diagnostics [21], the surgery itself approaches [4] material for reconstruction [22], intraoperative evaluation [18], and the postoperative management.

At the starting of my career, post-traumatic orbital surgery was more or less regarded as a “yes” or “no” decision, whereas today the specific extent of the intraorbital defect(s) and deformity can be defined and quantified preoperatively [9] and directly correlated with the clinical findings and features.

This was not and still is not possible and cannot be adequately handled by a Water’s view radiograph because due to its technique a sagittal information is not given at all and even the proper evaluation of the orbital walls—apart from a “hanging drop-sign” on the orbital floor into the maxillary sinus especially for an evaluation of the medial and lateral wall as well as the orbital roof, is inappropriate. Probably one could nicely compare it to the progress in air traffic, where the flying principles stay the same however the technology clearly progressed as did the standards, planning, safety, and quality measures, etc. The posterior third of the orbit was clearly a “no-man’s-land,” and this was due to the fact that our teachers were trained based on two dimensions only. So, there was no clear assessment based on 3D-imaging with all of today’s knowledge with aligning the data set in the correct coordinate system according to the specific patient, to look at the oblique sagittal view of each orbit [23]. From this, we learned that the safe way to dissect the orbit is to safely expose the posterior ledge via the lateral orbital route [8].

So, according to today’s radiological standard, 2D imaging does not play a role anymore to indicate or stay away from post-traumatic primary or secondary orbital reconstruction. I don’t only say “not play a role,” I would better like to say—in memory of John Lennon “Let it be”!

Probably out of this “defensive” diagnostic approach in imaging with the limitations of 2D, the widespread use of

bioresorbables or “soft” materials for reconstruction of the orbital walls could develop because you did not clearly see before surgery however intraoperatively you saw and felt a lot, but we did not really explore the orbit adequately since there was no individual preoperative anatomic familiarity with the patient’s specific situation furthermore, by placing non-radiopaque materials in the orbit we could not really postoperatively evaluate what we did and achieved with our reconstruction, this is why I would call that period of orbital reconstruction “cloudy times” (by the way for those, who still favor bioresorbables in orbital reconstruction, the “cloudy times” remain stable!) and the reconstructive orbital surgery was often accompanied by myths and believes, i.e., fat atrophy as an excuse for inappropriate anatomic repair or contour loss over time in case of bioresorbable implants used for orbital reconstruction. This luckily has stepped up today to another level of evidence by using 3D imaging as a standard pre- and postoperative diagnostic method [19].

By the way evidence-based medicine should not only scientific-wise be reduced by creating metaanalyses out of digital libraries but used prospectively in a responsible way in our own clinical cases, so that we can create even individual patient-specific evidence before and after! And this is exactly why 3D imaging had to step in.

Thirty years ago, the standard approach I was taught for the orbital floor was the subciliary, transpalpebral, or infraorbital approach, all being transfacial approaches. The approach for the lateral orbit and the zygomatico-frontal suture had been the lateral eyebrow incision. The approach for the medial orbital wall was the Kilian incision or the coronal approach. Today—thanks to the inter-speciality knowledge exchange, the clear recommendation is to go for invisible incisions in reconstructive orbital surgery, avoiding any harm to the palpebral and periorbital structures, i.e., transconjunctivally in the inferior fornix with or without medial extension to expose the orbital floor, lower part of the lateral orbit and the medial orbit including the inferior orbital rim [14]. The retroseptal transconjunctival approach should be bow-shaped parallel to the retracted lower eyelid margin and placed minimum at a 10-mm distance to the lower eyelid margin. The incision is transconjunctival only first, and then the scissors are directed anterior to the inferior oblique muscle and aim directly posterior to the inferior orbital rim, where the periosteum is incised later (Fig. 1).

The recommended incision for the orbital roof respectively the upper part of the lateral orbit is the upper lateral blepharoplasty incision; in major orbital roof reconstructions a coronal flap might still be justified [7].

Whatever incision is selected, it is to give the appropriate exposure and overview to identify the individual extent of the orbital deformity and to reconstruct the inner

**Fig. 1** Transconjunctival approach (a–c) with final exposure of the infraorbital rim and the orbital floor (d)



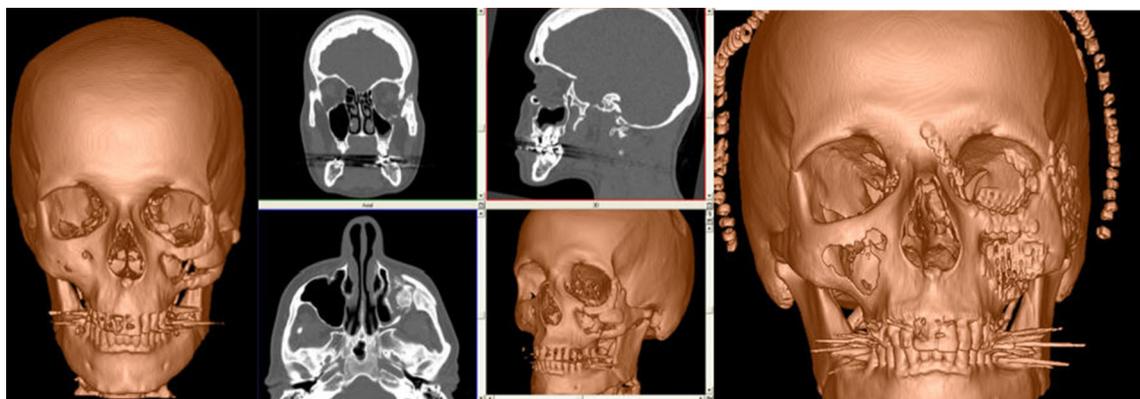
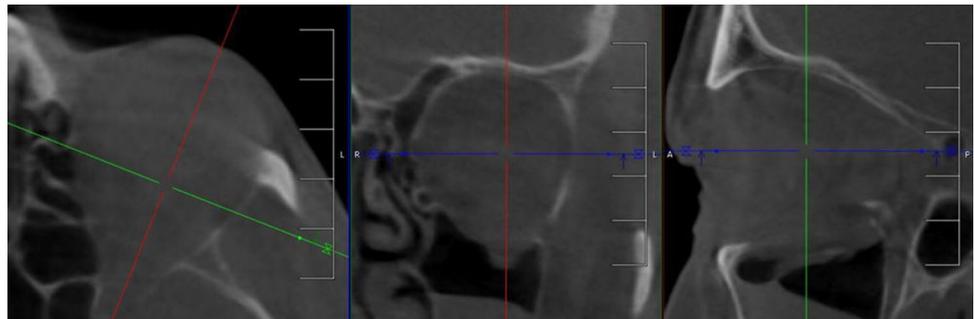
and outer orbit, if needed, in a safe and predictable way. Above this, any unfavorable interference with eyelid structures has to be avoided. This is why over the past 20 years I completely shifted to the above mentioned retroseptal transconjunctival approach, which unfortunately has not been accepted by all surgeons yet.

As mentioned before, diagnostics moved up from 2D over selected images gained out of a CT or MRI dataset up to today’s interactive use of the full DICOM dataset ideally acquired in one volume dataset with gantry put to zero, the patient lying in a neutral position with a minimum slice thickness of 1 mm in a soft tissue window. The latter protocol allows using today’s diagnostic preoperative datasets as a key part for a digital workflow from the surgery-based diagnostics to a possible patient-specific implant fabrication, intraoperative navigation [16] and intra- and postoperative image fusion of post-op datasets [12, 13]. In addition to a CT dataset and in selected cases

MRI, cone beam tomography (CBCT) [19] has entered the field of congenital and acquired orbital deformities. Remember, today 3D imaging should be regarded as a standard before taking a patient to reconstructive orbital surgery.

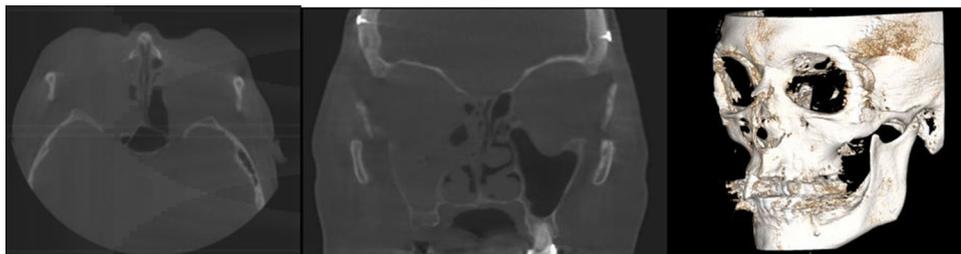
Whatever dataset or combination of datasets is used together with clinical assessment and judgment, these data should be available as freely usable DICOM data ideally independent of specific viewer software. Every reconstructive surgeon should be able to use these DICOM data to correctly analyze the deformity preoperatively, identify the individual symmetry, quantify the need for reconstruction and have a sound idea of which type of biomaterial should be used, where to place and how to fix it and whether or not to correct true to original (this accounts especially for decreasing an enlarged orbital volume in primary trauma cases) or where to overcorrect (this accounts especially for secondary post-traumatic orbital

**Fig. 2** A two-wall orbital defect (orbital floor and medial orbital wall) prior to surgery and before reconstruction (axial, coronal and oblique sagittal view)

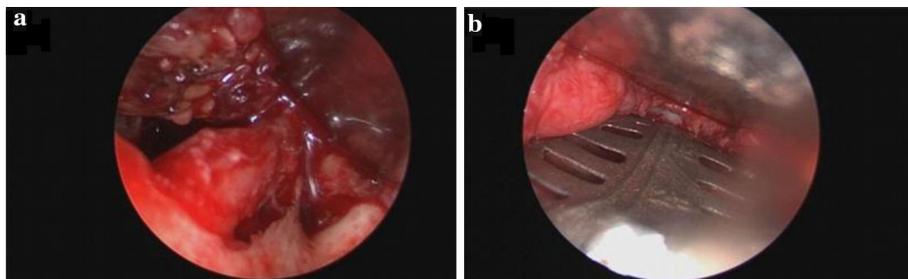


**Fig. 3** Secondary orbital reconstruction before correction and following corrective surgery

**Fig. 4** A case of Graves' disease with bilateral orbital decompressive procedures by a selective removal of orbital wall respectively selective outwarding of bilateral orbital wall



**Fig. 5** Endoscopic view of the posterior ledge after exposure (a) and subsequently the implant after appropriate positioning on the posterior ledge (b)



reconstructions [6]) or where to even under correct (this accounts especially for decompressive procedures, i.e., in Graves' disease with surgical need for orbital volume enlargement [17]). To provide this knowledge in analyzing 3D datasets, the CMF surgeon should be trained to confidently use analyzing software apart from the legal role the radiologist has to play with the radiological report setup, execute and evaluate the proper treatment plan (Figs. 2, 3, 4).

Looking backward the tendency to use non-specific orbital implants or even soft or biodegradable material was historically much higher than today where I personally tend to divide the corrective need for the orbital walls into two main-scenarios that are:

Either there is an *indication to recontour the bony orbit*, then I decide for a form stable material that is bone, metallic or ceramic biomaterial. Different ways allow for contouring an orbital implant, i.e., ideally pre-fabricated and manufactured as a patient-specific implant. Alternatively, a biomodel averaged or individualized can be used to individually preform a non-preformed biomaterial [15]; alternatively, an averaged shaped biomaterial can be used. However, the experienced reconstructive orbital surgeon can perform an “eminence-based” reconstruction even with non-preformed biomaterials just out of experience.

Or there is *no need for recontouring the orbital walls*, then I would even refrain from using larger implants and stay away from extended explorations of the orbit. However, to decide this, you better should have an inside view by 3D radiology.

The latter decision is supported even intraoperatively by modern technology, i.e., intraoperative imaging. We use intraoperative 3D C-Arm (Ziehm Vario 3D, Ziehm Vision,

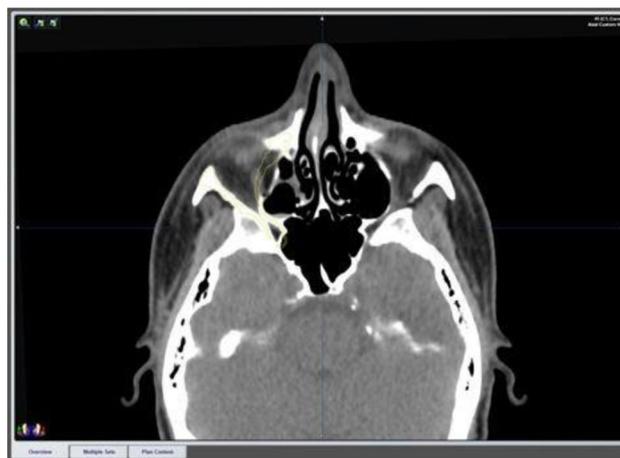
Nürnberg, Germany) technology to evaluate the orbital contours at the end of surgery, i.e., before the patient is extubated: In case for corrective needs, we could proceed and revise the orbital walls of interest or even adjust the position of orbital implants [18].

About the materials used for orbital reconstruction there could be an extra and extensive debate [5]:

To pacify this often very emotionally driven discussion: I would like to mention one premise in reconstructive orbital surgery that is:

1. “You have to prove that you have been there.”
2. “Make sure your reconstructed contour stays.”

*To fulfill the No. 1 premise* This allows dividing the group into materials that are either radiopaque or



**Fig. 6** Postero-medial bulge whose integrity has a great impact on orbital volume shifts. On the right side is defect with the preoperative planning in yellow

radiolucent. Alternatively, endoscopy could create intraoperative evidence to verify the extent of dissection and the position of the implant at the posterior ledge. Furthermore, endoscopy could clarify whether dissection meets the implant dimensions or not (Fig. 5).

*To fulfill the No. 2 premise* The biomaterial formed should be stable; this is not the case in biodegradation where—in the best case—the surgically achieved reconstruction would be re-established with the contour changing via biodegradation [3]. Clearly, the 1:1 remodeling of an orbital wall that has been reconstructed with a biodegradable biomaterial remains an unpredictable hope [20]. This might be insignificant in so-called small orbital wall defects, but, to be honest, nobody really knows, what is a small and a non-small orbital defect; this again shows different significance depending on where the defect in the orbit is located. Basically, there is hardly a 1 cm in diameter orbital wall defect that needs contour repair as long as the periorbit remains intact. This accounts especially for the anterior and medial third of the orbit; a similar defect in the posterior third of the orbit might be much more volume-wise relevant [7, 10] (Fig. 6: postero-medial bulge).

In my hands, the radio-opacity together with the stability of form are the clear criteria to choose the adequate biomaterial for today's orbital reconstruction.

So, how should we approach analyzing wise a 3D dataset for decision making in reconstructive orbital surgery?

After uploading the individual 3D data set, it has to be aligned according to the individual planes of symmetry, i.e., Frankfort horizontal plane and the median sagittal plane.

Axial, coronal and oblique sagittal cuts have to be symmetrically analyzed in an intraindividual side-to-side comparison [23]. Contour loss or defects have to be identified and measured. Anatomical landmarks are the transition zone between medial orbital wall and floor, posteromedial bulge, the posterior ledge, the entrance to the optic canal. The unharmed lateral orbital wall shows the linear projection of the lateral wall to the orbital rim; the intact orbital floor shows the more or less pronounced lazy S-shape of the orbital floor in the oblique sagittal view. The latter indicates as well the length of a potential orbital floor implant—no matter which kind of biomaterial is used. To avoid any interference of an orbital implant—no matter which biomaterial—the tip of the implant from the floor and from the medial orbital wall should be pointed away from the optic canal. First of all, the “1-cm rule” should be applied—if possible—i.e., the implant should stay away around 1 cm from the entrance of the bony optic canal. The implant overcorrection away from the optic canal leads to a more lazy S-shaped implant in the posterior

orbital third for the medio-sagittal plane and to a certain convexity of the medial orbital wall replacement. Both design information lead to less likeliness of negative interference with intraorbital soft tissue structures. Fixation of the orbital implant becomes another controversy; however, in my personal experience, there is—absolutely—no reason to exclude fixation “on” or “over” the bony inferior orbital rim. Here Ed Ellis III always sees a danger to negative effects once the orbital implant is covering the inferior orbital rim; I personally have not run in a single case, where the fixation over, inside or outside the orbital rim mattered. Yes, in case the hardware was too bulky, the periosteum not taken off appropriately or the implant fixation inadequate, but these are clearly surgeon's related mistakes; luckily the orbital rim itself does not care. In most cases, one screw fixation should be enough to take control of the orbital implant position. There are voices that tend to limit the area of fixation of orbital implants posterior to the infraorbital rim—well, there will be always a voice somewhere, but not always does a voice from somewhere make sense. So, it should be left to a scientific study to proof or not to proof the limited area of bony fixation. I personally only see a reason to fix an orbital implant if it is form stable.

One prospective study that nicely shows the benefits of modern technologies applied to the field of post-traumatic orbital reconstruction is the Orbital3 study conducted through AOCMF (AOCID, Davos, Switzerland) [22]. It compared the standard preformed orbital implants with CAD-based- and non-CAD-based individualized orbital implants in primary cases of post-traumatic orbital floor and/or medial wall reconstruction. In summary, this study proved that the more individualized the specific orbital implant is and the more the position of this implant can be intraoperatively controlled (navigational surgery) the better the anatomic reconstruction will be in terms of orbital volume. Limitations of such clinical prospective orbital studies always will be the individual experience of the



**Fig. 7** A functionalized patient-specific orbital implant, as described below

surgeon, the possible affection of the orbit and its contents due to or independent from the specific orbital trauma.

All these ideas lead in the year 2014 to the need of developing a new generation of orbital implants that are superior to any kind of implant existing on the market [13]. Together with Majeed Rana, I designed an ideal orbital implant showing different thickness topography within the area of the implant that was functionalized, i.e., we implemented functions to it by far above just recontouring an orbit (Fig. 7). The intention was to assure:

1. Proper positioning by metric info and implementing clinical relevant vectors—like the oblique sagittal and transition zone between medial wall and orbital floor into the implant design,
2. Create an objective interface for an orbital implant together with a periorbital implant versus extension of the orbital implant to the periorbital rim(s) (minimum to reconstruct or to indicate and keep the reduction around the inferior orbital rim),
3. Avoid potential pitfalls for this metric info are applied to the implant, an outer cord design guarantees a very forgiving interface to intraorbital soft tissue, i.e., no impingement of orbital soft tissues possible, an over-corrected posterior ledge in an “inverted snow shovel design (ISSD)”, defined openings allow drainage of potential orbital bleeding into the sinuses instead of creating an orbital compartment syndrome, radiation-free position control via trajectory-based navigation with the trajectories being designed into the individual implant [1],
4. To be patient specific in design
5. To be form stable and non-deformable

Our motivation to push this was due to the observation that extended dissections of the orbit in primary or even more in secondary orbital reconstructions did not do any harm to the patient but inappropriate implant shape (even due to deformation during the surgical procedure) and implant position clearly did [4, 6].

So, it took us some time to find the industrial partner, who was willing to commit himself. Unfortunately, only few industrial partner(s) for CMF surgeons understood the need for “a new and next-generation approach to implants”, which leads to benefits by far superior to only being able to recontour an orbit. Furthermore, together with this view of orbital implant design “functionalization of implants” as a global idea entered the field of reconstructive surgery and could be rolled out to most areas of CMF surgery but as well to all surgical specialties using implants for hard and soft tissue—reconstruction. However, this requires industrial partners, who are able to keep up with the pace of innovations—here I have never experienced a benefit to the surgeon when industrial partners either

entered the stock market or started global fusion with huge health care companies. Clearly, surgical innovation and determination never remained the same. Innovation and progress strongly depend on a reliable partnership which of course accounts for both directions. And it is up to powerful surgical networks to disseminate the interdisciplinary knowledge and to allow for further innovations.

Coming back to orbital reconstructive surgery, I definitely see this field as a pioneer for digital work flows, “from diagnosis to the individual implant”.

Current strategies in post-traumatic orbital reconstruction and today’s standard treatment for us in significant contour loss of orbital walls is to digitally design an implant that is custom made. However, this is still time critical as we need industrial partners to provide the implant on time. However, there is a broad variety as mentioned above to provide patient-specific implants including virtually corrected CT scans that are taken to print out biomodels only, thus allowing to preshape whatever material is available and intended to be used to reconstruct the orbit. Basically, it is amazing to see that there is hardly any material that is not accepted by the orbital environment and biology. So, it could be any licensed material and implant type including autogenous bone: calvaria split bone grafts could be adequately aligned to regain an individual patient-specific design by this method.

My personal wish is that the next generation of CMF surgeons is willing to take the challenge of developing our specialty further, using the benefits of modern 3D-imaging (which is luckily more and more available everywhere in the world) and take the advantage of digital analyzing, planning, engineering and manufacturing in a routine protocol to the benefit of patient treatment and team education. Patient specificity of treatment was and is always an issue in fields like orthognathic surgery and definitely should become an issue in reconstructive orbital surgery now and in the future.

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