

Surgical Treatment of Solitary Orbital Wall Fractures

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Learning Objectives

- Support the surgical decision-making in the treatment of orbital fractures with a focus on timing, biomaterials, and approach.
- Master the surgical skills for predictable dissection and reconstruction of the orbit by using the anatomical landmarks.

- Improve basic knowledge about the advantages of virtual treatment planning, navigation, and intraoperative imaging.
- Know when to reconstruct the orbit with patient-specific implants.

Introduction

Fractures of the orbit are relatively common in maxillofacial trauma. They can occur in isolation or involve concomitant skeletal structures as well. There is variation in fracture complexity due to the amount of energy transfer, and clinical presentation can be heterogenous due to soft-tissue involvement. Proper physiological assessment, a full radiological description of the fracture configuration, and orthoptic evaluation form the foundation for decision-making and thereby predictable clinical outcomes [1–6].

The surgeon must combine this information with evidence-based indications for surgery, appropriate timing, knowledge of the different approaches, biomaterials, and advanced technologies. This can be a challenging task, and there is ongoing debate about the optimal management of orbital fractures in facial trauma care. The diversity in training and surgical skills adds a confounding component, since many surgical

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specialities manage orbital fractures [6, 7]. In addition, there is a lack of high-quality studies defining the standards of care for the optimal treatment of orbital fractures. The controversies on surgical indication are discussed in Chap. 9; this chapter describes the process after the indication for surgery has been established.

Surgical Decision-Making and Operative Procedure

The goals of surgical treatment of an orbital fracture are clear: the globe needs to be repositioned and the orbital volume restored, in order to recover the ocular function (Fig. 10.1). Although these goals are related to the orbital contents, the restoration of the orbital contour is the first and probably the most predictable step in orbital reconstruction [1].

The shape of the bony orbit and the intricate architecture of the soft tissue pose surgical challenges. Orbital reconstruction is performed in a confined space close to vital and delicate structures, with a limited overview. This presents a risk of iatrogenic damage and surgical complications [1]. Detailed planning and adequate expo-

sure of the orbital floor and the medial wall are necessary to avoid complications. Considerations on timing [4–6, 8], biomaterials [4, 6], virtual surgical planning [9, 10], preformed or custom plates (patient-specific implants, PSIs) [10], approach [6, 8], navigation [9, 10], and intraoperative imaging [9] will be discussed in the following paragraphs.

Timing

The literature evidence on ideal timing of the surgical intervention is contradictory and difficult to interpret. Timing of surgery can be differentiated between immediate (<24 h), early (<2 weeks), and delayed treatment (2–6 weeks). Reconstruction after 6 weeks is not considered primary treatment any more, as the soft tissue and bone behave as a revision case [6]. Except for threatening visual emergencies and (pediatric) trapdoor fractures (Chaps. 12 and 13), all indications for surgery are relative [4, 6].

Several surveys on surgical decision-making on orbital fractures indicate that surgeons generally prefer to operate within 2 weeks after the injury [7]. The rationale behind early surgery is that the fracture is more easily accessible [2, 6]. There is less iatrogenic damage, because of the absence of fibrosis, and fewer adhesions in the orbital soft tissue are present. However, there is currently insufficient proof that postponing surgery harms the outcome. As clinical signs and symptoms may change in the days or weeks after trauma, a more delayed approach might influence the type and choice of treatment. The scientific rationale for these timing recommendations is vague considered that some indications for surgery will not always occur (enophthalmos) or will resolve spontaneously over time (diplopia) [5].

From a practical perspective, the surgical approach is easiest performed after ecchymosis and swelling has resolved, which is generally after 4–14 days. The additional time could be used for (virtual) treatment planning and, if indicated, fabrication of a PSI [2, 6, 10].

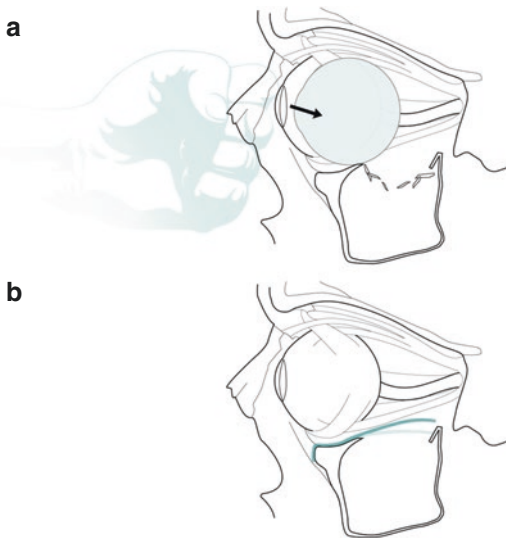


Fig. 10.1 Orbital defect (a) and reconstruction of the affected orbital walls by an orbital implant (b)

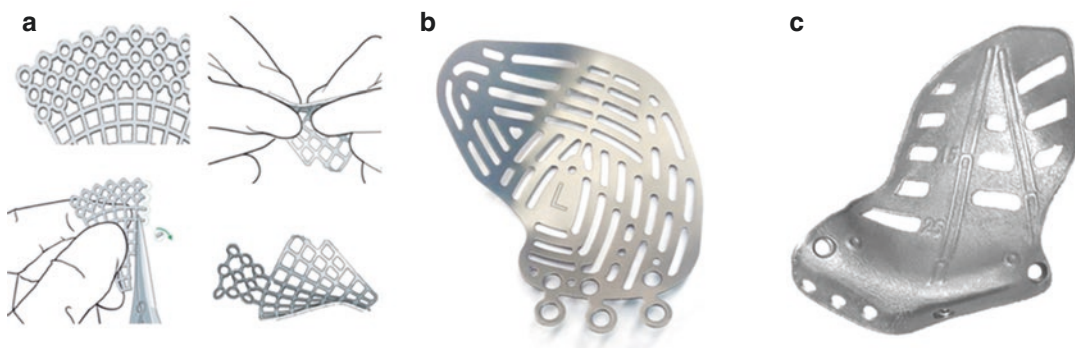


Fig. 10.2 Orbital implant options: flat (a), preformed (b), patient specific implant (c)

Biomaterials

A wide variety of implant materials have been used to reconstruct orbital wall fractures. Implant materials must have specific characteristics to achieve adequate reconstruction of the pretraumatized anatomy and correction of enophthalmos or diplopia. The ideal reconstruction material has perfect architecture or contouring abilities to restore volume and shape, is biocompatible, facilitates drainage of fluids, has no donor site morbidity, is radiopaque, is stable and allows fixation, and is readily available at reasonable cost [3, 11]. Based on their excellent biocompatibility, autologous bone grafts used to be the gold standard. The main disadvantages of autologous bone grafts are donor site morbidity, unpredictable resorption rate (up to 86%), and difficulties in shaping the graft. These drawbacks inspired the development of alloplastic materials that are currently considered the gold standard for reconstruction. Titanium in specific adheres to most of the abovementioned demands and is widely used, either as preformed orbital reconstruction plates, patient-specific implants, or flat titanium meshes for intraoperative moulding (Fig. 10.2).

Virtual 3D Planning and Implant Choice

Since orbital reconstruction is performed in a confined space with a limited overview, a computer-assisted surgery (CAS) workflow can

be of great added value. The first steps in this CAS workflow are generation of the virtual patient model and advanced diagnostics to support diagnosis and indication (Chap. 9). The virtual planning is performed after surgery is indicated, but it utilizes the information already obtained in the advanced diagnostics process. The unaffected mirrored orbit that had been positioned over the affected orbit for obtaining detailed insight into the extent and displacement of the fracture is used as the target anatomy for reconstruction (Fig. 10.3).

The next step is to select an implant that can mimic this target anatomy as closely as possible [12–15]. A virtual model of an implant with a predefined shape, such as a preformed implant, can be imported in dedicated virtual planning software. The 3D model of the implant can be positioned in the virtual patient: the contours of the implant are shown in the 3D model and the multiplanar views. The patient model provides information on existing anatomical structures; visualization of the mirrored orbit's overlay adds the desired reconstruction information to the multiplanar views (Fig. 10.4).

Several positions of the implant may be tested to find the optimal position of the implant. Different aspects are considered to evaluate the position of the implant in the virtual surgical planning. Apart from reconstructing the orbital contour as accurately as possible, it is important that the implant covers the orbital defect, is sufficiently supported by existing bony structures (e.g., support on the dorsal ledge, bony support at

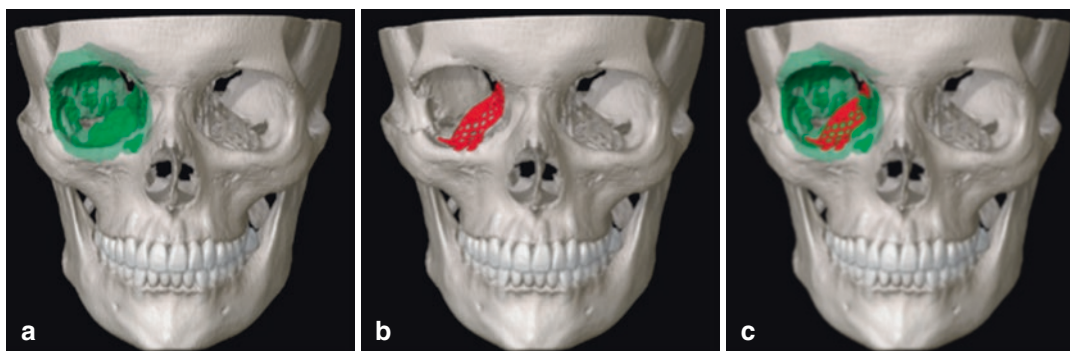


Fig. 10.3 Virtual surgical planning. The mirrored orbital contour is considered the target anatomy for reconstruction (a). A virtual model of the implant is imported and positioned in the orbit of the patient (b). The mirrored

model can be visualized in the positioning process and serves as a blueprint for the target anatomy the implant should reconstruct (c)

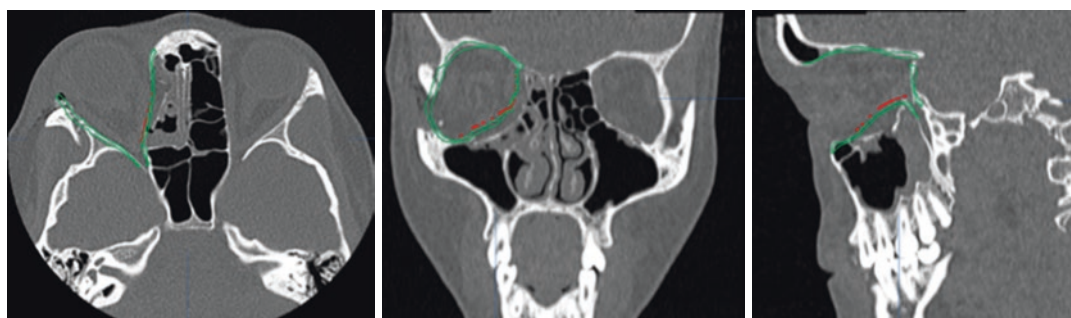


Fig. 10.4 Visualization of the implant model and mirrored orbit in the multiplanar views. The implant follows the mirrored contour nicely, has support on the posterior ledge, and can be fixated on the infraorbital rim

the medial tip of the implant), and allows fixation at the infraorbital rim [16–18]. The planning process may be repeated for preformed implants of different sizes or from different manufacturers, and the implants may be virtually trimmed at predefined locations to evaluate if a reduced size of the implant still meets the positioning requirements. These options ensure that the possibilities of preformed implant reconstruction can be thoroughly evaluated. The optimal implant positioned in the ideal position may be considered the end point of the virtual surgical planning in case of a preformed implant [12, 16, 19].

Preformed or PSI

Preformed titanium implants can provide an adequate reconstruction in the majority of orbital reconstructions. Their predefined shape, which allows virtual surgical planning, is frequently based on the shape of the average orbit and thus provides a satisfactory resemblance to the majority of orbits. The aforementioned trimming at predefined locations increases their fitting potential. In limited cases, an optimal fit cannot be achieved using a preformed implant (Fig. 10.5). An inaccurate virtual fit of preformed implants



Fig. 10.5 Example of an incorrect fit of a preformed implant. Although the largest implant size was chosen in this example, the implant does not reach the OPPB. The

lack of posterior support led to the decision to use a patient-specific implant

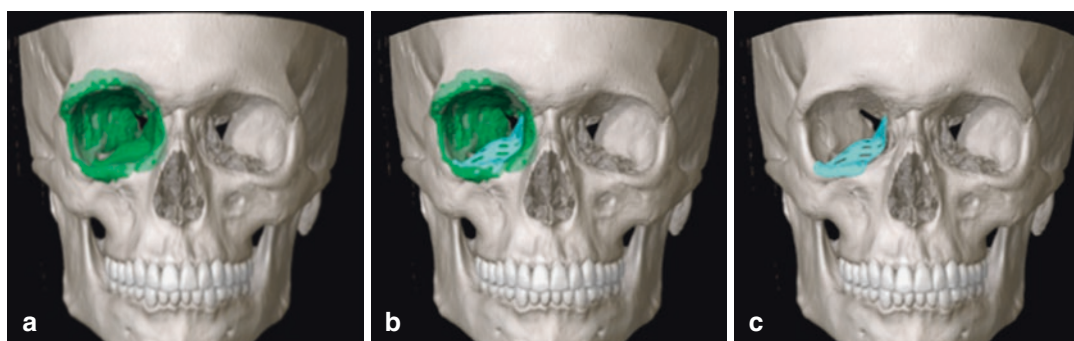


Fig. 10.6 Design of a patient-specific implant. The advanced diagnostics information (a) is the basis for designing a patient-specific implant (b). Several virtual

prototypes may be designed before the virtual planning is completed (c) and the final design can be produced

may lead to the decision to use a patient-specific implant (PSI), but a PSI may also be indicated because of clinical considerations such as a need for overcorrecting the volume of the orbit.

The advanced diagnostics information that is utilized in PSI cases is identical to the information used in virtual surgical planning of a preformed implant. The virtual surgical planning process and result differ in a PSI reconstruction; information about anatomical boundaries of the fracture and optimal reconstruction shape is exported from the virtual planning software. Design software is used to model an implant that meets the requirements on defect coverage and reconstruction of the pre-traumatized anatomy

(Fig. 10.6). Prototypes of the implant can be imported into the virtual surgical planning to verify their fit and evaluate the necessity of alterations to the design. If the virtual planner and surgeon are satisfied with the implant design, the virtual model of the PSI may be sent to a manufacturer for fabricating the physical implant in titanium using laser sintering.

A PSI offers enhanced possibilities to tailor the implant's shape to the patient's anatomy (Fig. 10.7). Support on existing bony ledges and an extension over the orbital rim provide feedback on implant positioning to assure that the planned position is reached. The implant's shape can be adjusted to meet the clinical needs of the



Fig. 10.7 Tailoring the implant to the patient's anatomy and fracture specifics. Compared to the preformed implant, the patient-specific implant exhibits an improved

fit on the infraorbital rim. The patient-specific implant is supported by the OPPB, and an overcorrection is embedded in the implant's design

patient as well: an overcorrection in volume or rim height may be embedded to resolve enophthalmos or hypoglobus [14]. Although patient specific implants offer improved positioning and clinical outcome compared to preformed implants, the high cost and logistical demands prohibit their widespread use. Considering these restrictions, the use of PSIs is currently the gold standard only in complex or secondary reconstruction of the orbit [20].

Surgical Technique

Approach

The surgical access to the orbit has undergone a true evolution over the last few decades. In the early nineties, the coronal approach, which was used in neurosurgery, became the working horse in orbital surgery; it was often combined with a skin incision in the lower eyelid. Drawbacks like scar visibility and surgical invasiveness of this extensive procedure have driven the development of more cosmetic incisions around the orbit that deliver at least equivalent but often better surgical access. Widely used approaches to restore the orbital boundaries after an orbital wall fracture are a transconjunctival, subtarsal, or subciliary approach. In the last decade, the transconjunctival incision has gained popularity and has become the standard approach for orbital reconstruction.

The transconjunctival approach has no visible scarring, as it is covered by the lower eyelid. A

good exposure can be established and the risk of complications, such as entropion, is relatively low. In theory, two modifications can be used: the preseptal and the retroseptal route. The preseptal route has the advantage that the fat prolapse is limited compared to the retroseptal route. The drawback is that the preseptal route theoretically has a higher chance of postoperative entropion. A modification of the retroseptal route, which partly alleviates the fat prolapse, is explained below.

The approach starts by placing two non-resorbable sutures, one around the inferior rectus muscle and the other on the inferior tarsal plate of the lower eyelid. The first suture is used to raise the globe, so that the upper eyelid can provide protection during surgery. The other one allows the lower eyelid to be everted more easily using the Desmarres retractor. The conjunctiva is stretched and incised with a diathermy or scalpel. The incision should be started approximately four millimetres from the fornix and run from the caruncle to the lateral ligament. The inferior orbital rim should be palpated as a target for the approach. Next, the diathermy can be used to explore the retroseptal loose connective tissue down to the periosteum while keeping tension on the eyelid. The Desmarres retractor is reversed for retaining the lower eyelid, and the periosteum is incised to gain access to the orbital cavity.

A major advantage of the transconjunctival approach is that the medial wall can be exposed with a medial transcaruncular extension and exposure of the floor and rim can be improved

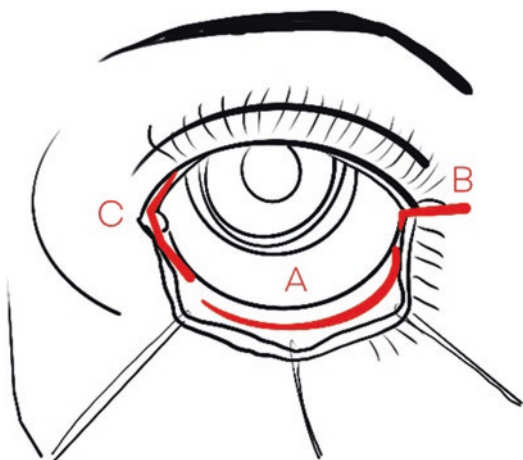


Fig. 10.8 Transconjunctival approach (a), lateral extensions (canthotomy/cantholysis) (b); medial extension (transcaruncular)

with a lateral canthotomy or, if necessary, a cantholysis (Fig. 10.8). For the lateral canthotomy, the existing incision can be expanded by stripping the lower part of the lateral canthal tendon, followed by an incision of approximately 1 cm through a natural skin crease. By extending the incision medially through the caruncle, the medial wall up to the roof of the orbit can be reached. The anatomy in this region is complex, with the Horner muscle, medial rectus muscle, and lacrimal drainage system. The incision towards the medial wall must therefore be made through the fibrous part of the caruncle.

Dissection of the Orbit

After subperiosteal access is gained at the inferior orbital rim, the dissection starts laterally. The relatively solid bone of the sphenozygomatic region is intact in most patients, which allows the surgeon to develop the surgical plane relatively easy. The next step is identifying the inferior orbital fissure (Fig. 10.4). The contents may be cauterized by bipolar diathermy. This fissure can be followed to the posterior orbit. On the medial side of the posterior part of the inferior orbital fissure, a ledge may be identified, which is formed by the orbital process of the palatine bone (OPPB). This ledge, or OPPB, consists of relatively solid bone and remains intact in most cases. For that reason, the OPPB is one of the

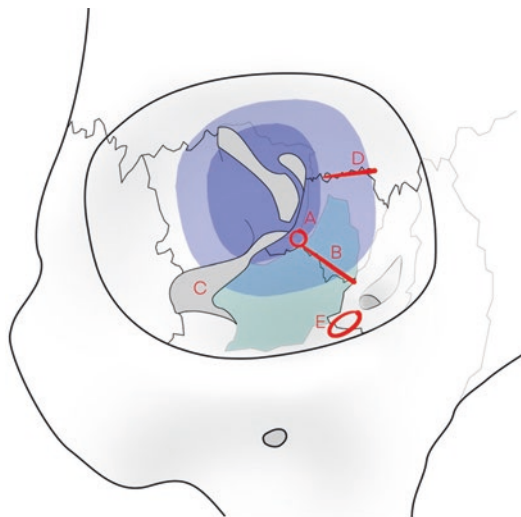


Fig. 10.9 Landmarks in the orbit for orbital reconstruction: medial strut (a), orbital process of palatine bone/keyzone (b), inferior orbital fissure (c), superior strut (d), attachment of inferior oblique muscle (e)

main pillars of the orbital reconstruction [21]. Beat Hammer identified this region as key zone and Jaquéry also incorporated this structure in his classification [22]. The location is visualized in Fig. 10.9.

The next steps are medial dissection and finding a way around the fracture. The bony structures in the anterior third of the orbit may be used for this, provided these are unaffected by the fracture. Medial traction is usually enough to mobilize the tissues bulged through the defect. A meticulous dissection with a periosteal elevator is required to find the medial border of the defect. This border can be followed to the OPPB. The medial wall can be extremely thin and can easily be damaged by the exploration of the orbit. Nevertheless, the medial strut, which forms the boundary between the orbital floor and medial wall, is relatively rigid. This region can be identified as a white line when it is intact (Fig. 10.4). In two-wall defects, the medial strut may also be dislocated; a more cranial dissection is advised, and a transcaruncular extension of the transconjunctival incision can be helpful. The orbital contents should be handled very gently. If the orbital contents are released from the fracture gap, it is best to remove remaining sharp edges.

Polydioxanone (PDS) or neuro patties can be used to bundle the contents and keep the soft tissue away during insertion of the reconstruction material.

The aforementioned principles can also be used in case of a trapdoor fracture, but gentle pressure is enough to release the entrapped tissues in most cases. Besides removal of the sharp edges, no further action is necessary.

Relevant Surgical Landmarks Related to the Reconstruction

The globe and the ocular muscles receive ligamental support from the periorbital, which contains a network of connective tissue septa, surrounded by fat. The ligaments are attached to the orbital walls, as described by Koornneef [23]. Unfortunately, the structural integrity of the orbital septae may be compromised as a result of trauma and will certainly be (further) disrupted due to the approach and surgical dissection. Although orbital surgery requires meticulous dissection skills, it remains almost impossible to predictably redress all the soft tissue in the correct position and original dimension. Even after the release of the disrupted or entrapped orbital contents, a certain amount of disturbed soft tissue anatomy, scarring, and fibrosis can definitely be expected.

A properly positioned implant can restore the comminuted bony structures and volume of the orbit. It creates a solid fundament to facilitate free movement of the globe. The orbital implant must be gently inserted between the bone and the soft tissues. The implants require support at the anterior, posterior, lateral, or medial boundaries to obtain a stable position. Several strategic landmarks are fundamental for restoring the appropriate anatomical relations. The orbital process forms the important posterior ledge to dock the implant on. In large two-wall defects, the rotational freedom of the orbital implant is increasing and additional support on the superior strut (border of medial wall and orbital roof) can be of added value to prevent rotational outliers in implant position [24] (Fig. 10.10).

Although the focus lies on the posterior landmarks, the position of the anterior rim is of equal

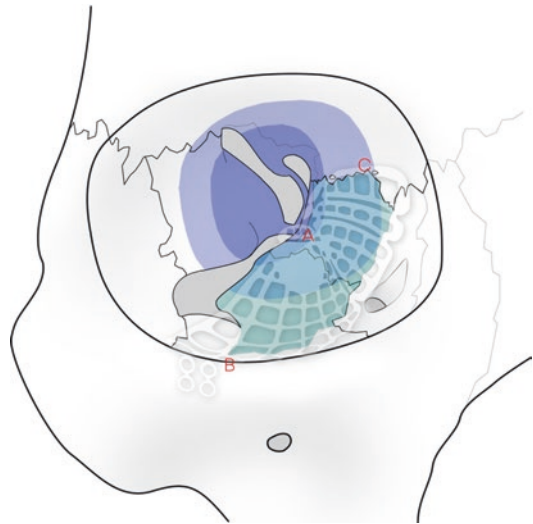


Fig. 10.10 Implant support: ledge (a), anterior rim (b), medial wall/superior strut (c)

importance. In impure blow-out fractures with concomitant facial fractures (ZMC, NOE of Le Fort II/III), the vertical position of the globe is mostly determined by the position of the anterior rim. Suboptimal repositioning of the ZMC automatically leads to a poor position of the orbital implant, especially since the rim is required for fixating the orbital implant anteriorly. This is one of the reasons that the facial pillars must be restored anatomically before the orbit is reconstructed. A more caudally positioned rim will lead to a suboptimal implant position, an increase of orbital volume, and potential enophthalmos or hypoglobus.

Intraoperative Navigation and Imaging

The ideal implant position has been determined during the virtual surgical planning: the goal for the surgeon is to position the implant as close as possible to the planned position during surgery. Because of the confined space and protruding soft tissue, a visual assessment of the implant position is infeasible and realization of the planned position is difficult. The possibility to consult the planning aids the surgeon during reconstruction by creating artificial anatomical landmarks for evaluating the implant position. In the computer-assisted surgery workflow, addi-

tional technology may be introduced that can transfer the preoperative planning to the intraoperative setting and provide more sophisticated feedback on implant positioning. Surgical navigation and intraoperative imaging are effective intraoperative technologies in orbital reconstruction; these techniques will be explained in more detail in the following paragraphs.

Navigation

Many people will associate the term navigation with the route guidance in a car. The navigation system tracks the location of the car using GPS, knows the destination, and provides feedback to the driver on the position of the car in relation to the destination. Surgical navigation is a comparable technique, but the working principle is different, as is explained below. Surgical navigation can provide visual and quantitative feedback on the realized implant position with respect to the planned position. Although surgical navigation is an expensive and logistically complex technique, it has shown to improve predictability of orbital reconstruction significantly [25–27].

The navigation system is constituted of the following components: an infrared camera, a

patient reference frame, a surgical navigation pointer, and a computer system plus screen (Fig. 10.11). The patient reference frame has reflective marker spheres attached, which allow the camera to detect the position of the frame. The patient reference frame is rigidly attached to the patient's cranium to track the position of the patient within the operation room. Similarly, the navigation instrument has markers attached to track its position. It is essential that the line-of-sight between the camera and the reflective spheres is not blocked, since this would hamper detection of the frame or instrument. The ultimate goal is to visualize the position of the instrument within the virtual planning, but this requires a registration procedure.

The registration procedure establishes relationship between the physical position of the patient and the virtual surgical planning. Registration relies on identifying similarities between the physical patient and the surgical planning. Reference points are generally utilized in facial traumatology. These points are identified in the virtual planning and indicated on the patient. Easy and reproducible identification of these points in the virtual planning and on the

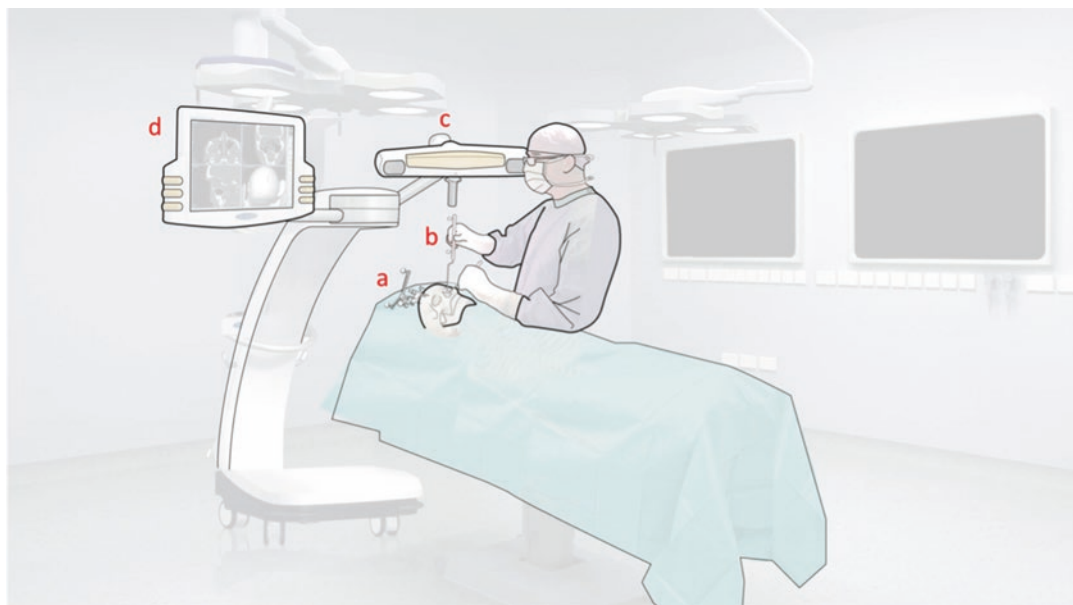


Fig. 10.11 Surgical navigation system with its different components. (a) patient reference frame, (b) surgical instrument, (c) camera, (d) screen

patient is essential for an accurate match, which heavily affects the accuracy of the subsequent navigation feedback. Since anatomical landmarks don't meet these indication requirements, the reference points should be artificially created. Bone-anchored titanium screws may be inserted intra-orally or in pre-existent wounds [28]. The screws need to be dispersed as much as possible to ensure a good registration result.

A less invasive method is the use of a dental occlusal splint that embeds the markers [29], but this may require additional imaging (radiation exposure) to the patient since the splint may not be present in the initial computed tomography (CT). A virtual dental registration splint can be obtained by fusing an intraoral scan with the CT; the splint can be 3D printed and used to indicate the registration points on the patient during surgery [30, 31]. This method decreases the radiation exposure, but it does require specific hardware and software. The navigation error yielded by all registration approaches discussed is below 2 mm in the orbital region [28–30]. The decision for a registration method can be made on an individual basis and depends on patient and hospital characteristics.

After the registration procedure, the surgeon can use the navigation to compare the realized implant position to the planned position with the navigation pointer. If the navigation pointer is positioned in the patient, the screen will show the location of the tip of the pointer in the multiplanar view (sagittal, coronal, and axial slices) and in the 3D model of the preoperative CT scan. When the pointer is moved, the view is changed to the slices of the new position. Visualization of the planned implant contour in the multiplanar views helps the surgeon to assess if the planned implant position has been obtained. The reconstructed contour can be evaluated by moving the pointer along the implant, but it is more effective to use predefined marker points on the implant [32]. These marker points can be indicated in the virtual surgical planning, allowing the system to compute the difference in planned and realized marker positions. This approach provides quanti-

tative feedback and gives the surgeon an indication on the direction of repositioning.

Even though navigation provides the surgeon with relatively precise information on the implant position, there is some residual error. The most important source of error is the registration procedure. The surgical outcome of orbital surgery should always be validated with a radiological control. This radiological control used to be performed postoperatively. Technological advancements have made cone-beam computed tomography (CBCT) scanners available in different (mobile) setups to facilitate intraoperative imaging [17]. Since the image quality of the mobile CBCT scanners is sufficient, the need for postoperative imaging is eliminated.

Implant positioning can be evaluated on the intraoperative scan for defect coverage and bony support. The intraoperative imaging can also be fused with the virtual surgical planning to provide more thorough feedback on the obtained implant position. The literature has shown that if the implant is positioned without navigation, the surgeon will alter the position of the implant in half of the cases based on intraoperative imaging. Intraoperative imaging significantly improves the implant positioning [33], reduces the need for secondary interventions, and saves operation time [17].

Computer-Assisted Evaluation

Evaluation is an important part of the computer-assisted surgery workflow. The intraoperative or postoperative imaging can be fused with the preoperative 3D planning, which allows objective assessment of the surgical result. The deviation of the final implant position can be quantified and expressed as rotations and translation from the planned position. The volume difference between the unaffected and reconstructed bony orbit may also be assessed. Evaluation and quantification are very instructive and insightful for the inexperienced surgeon to identify errors in planning or surgery. This enhanced knowledge will aid in the planning and surgery of future trauma cases.

Recovery and Follow-up

Patients are hospitalized for one or two nights after orbital reconstruction, depending on postoperative pain and how self-sufficient the patient is. In the first hours after surgery, a retrobulbar hematoma may develop. This can cause compression of the optic nerve and, potentially, loss of vision. For this reason, it is essential to perform pupil function and vision assessment at least hourly in the first 4 h after surgery.

Postoperative swelling and pain, formation of a hematoma, contusion of the ocular muscles, and changes in the position of the globe and muscles generally lead to an increase or at least persistence of symptoms (diplopia and limited eye motility) in the first weeks after surgery. Intraocular swelling can lead to temporary exophthalmos or an elevated position of the globe. The patient should be prepared for this during the preoperative consultation. The patient is advised to start monocular orthoptic exercises three times a day within a few days after the orbital reconstruction to improve motility. These exercises might additionally resolve swelling or avoid early adhesions.

As discussed in the previous chapter, patients are scheduled for follow-up 2 weeks, 6 weeks, and 3 months after surgery. In this period, a significant improvement in ocular motility is often noticed as well as a decrease in diplopia. Both diplopia and motility can be confirmed with objective orthoptic measurements. Further recovery and adaptation will occur up to 1 year after surgery, with possible further subjective improvement of the symptoms.

Despite an anatomical reconstruction of the bony orbit and repositioning of the soft tissue, permanent residual diplopia and limited eye motility may occur. These could be the result of adhesions, local entrapment, or a disruption of the periorbita, the suspension system of the intraocular soft tissue. In general, severe motility restriction and diplopia in central gaze lead to residual symptoms. Enophthalmos can persist due to insufficient restoration of the orbital contours or decrease of soft-tissue volume due to atrophy. Entropion, ectropion, and increased

scleral show are complications directly related to the surgical approach. Other possible surgical complications are infraorbital nerve dysesthesia and epiphora.

A well-prepared and performed orbital reconstruction will often lead to a significant improvement of the initial complaints. The globe position will be restored in most cases if the reconstructed orbital wall contours resemble the pretraumatized contours. These contours will form the fundament for redressing of the soft-tissues in order to facilitate ocular motility and diminish the diplopia. A clinical example of clinical improvement after surgical reconstruction is presented in the clinical example.

Clinical Example of Surgical Treatment of a Blow-out Fracture

A 21-year-old female was referred to the department of oral and maxillofacial surgery with a dislocated orbital floor and medial wall fracture (class III), combined with a lateral wall fracture on the right side (Figs. 10.12a–c and 10.13a–c).

Her main clinical problem was a limited elevation with diplopia at elevation and depression, and an evident step at the frontozygomatic suture. There was no significant enophthalmos (Hertel 18/19). Orthoptic evaluation objectified the limited ocular motility at elevation (31° OD / 40° OS) and depression (40° OD / 51° OS), with a binocular single vision (BSV) score of 38/100 points (severe diplopia). The patient was scheduled for early orbital reconstruction with VSP and surgical navigation because of the severe diplopia and dislocated lateral wall.

In the multiplanar reconstructions of the CT scan, the amount of dislocation of the orbital walls can be easily assessed (Figs. 10.14 and 10.15). The DICOM data was imported into the Brainlab software. The advanced diagnostics, with segmentation of the unaffected orbit and mirroring to the affected orbit, are visualized in Figs. 10.15 and 10.16. Several preformed implants were assessed in the virtual surgical planning; the implant of choice at the optimal position is shown in Fig. 10.17a, b. The addi-



Fig. 10.12 (a–c) Clinical appearance at first presentation, (a) en face, (b) submental, (c) elevation

tional screw holes or extensions can be cut beforehand to prevent unnecessary intraoperative implant adjustments.

The orbital defect is reconstructed with a preformed orbital implant. The implant position was controlled with the help of surgical navigation and verified using intraoperative imaging (Fig. 10.18a–c). Superimposition of

the intraoperative CBCT scan on the virtual surgical planning enabled direct comparison between planned position and actual result (Fig. 10.19).

The patient was discharged from the hospital 1 day after surgery. She continued her studies 2 weeks after the reconstruction. Normal ocular motility was restored directly after surgery. The

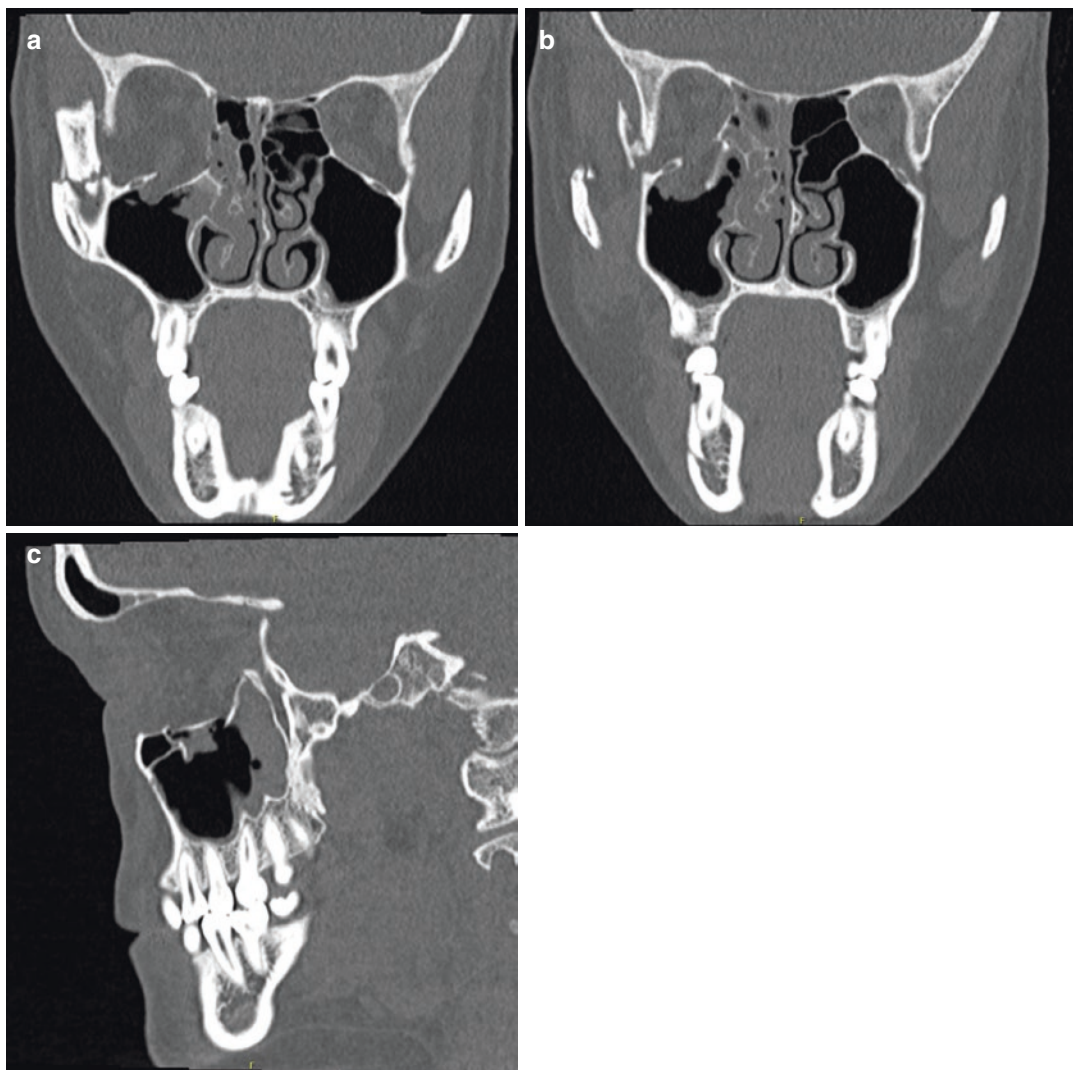


Fig. 10.13 Coronal (a, b) and sagittal (c) views of the CT scan at first presentation

diplopia dissolved in 3 months. During the follow-up of 12 months, no enophthalmos occurred (Fig. 10.20a–c). Figure 10.21a–d shows the

improvement of the BSV over time. The patient was satisfied with the recovery of her ocular function and the excellent clinical result.

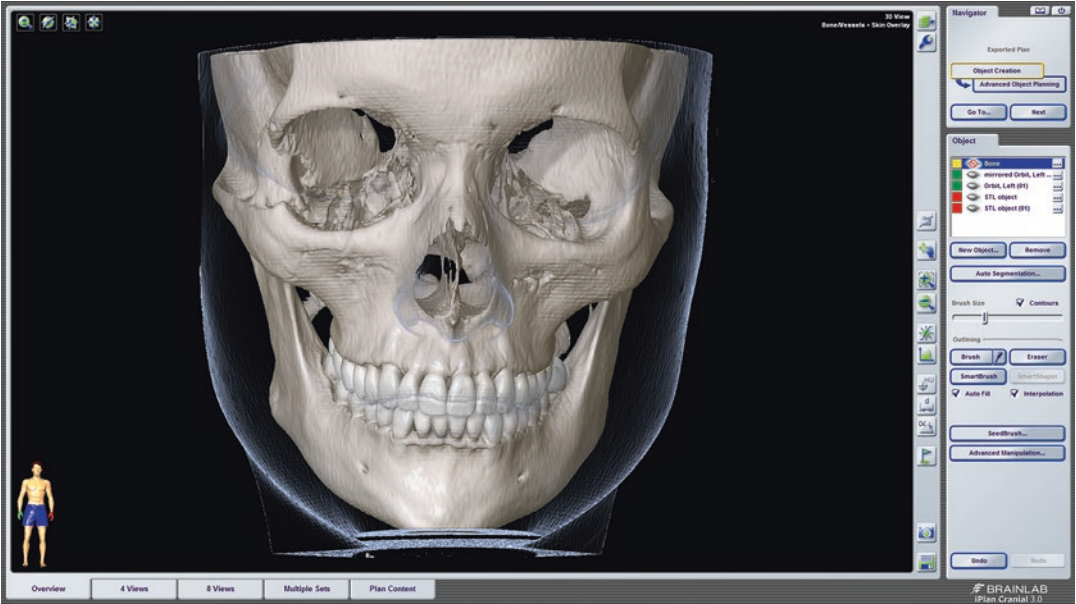


Fig. 10.14 The amount of dislocation of the orbital walls can be easily assessed during the preoperative planning

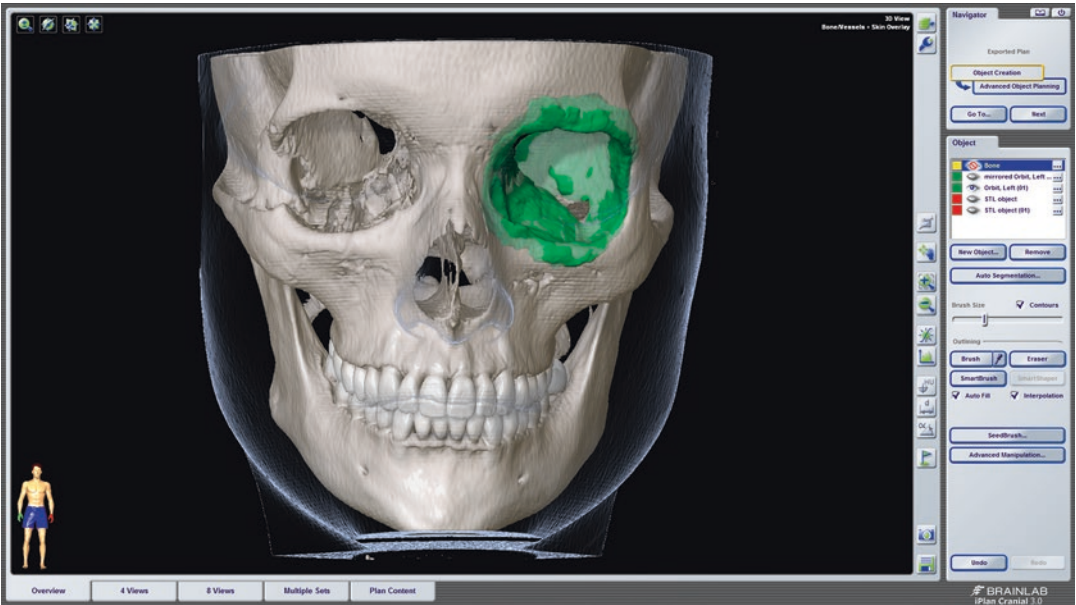


Fig. 10.15 Segmentation of the unaffected side

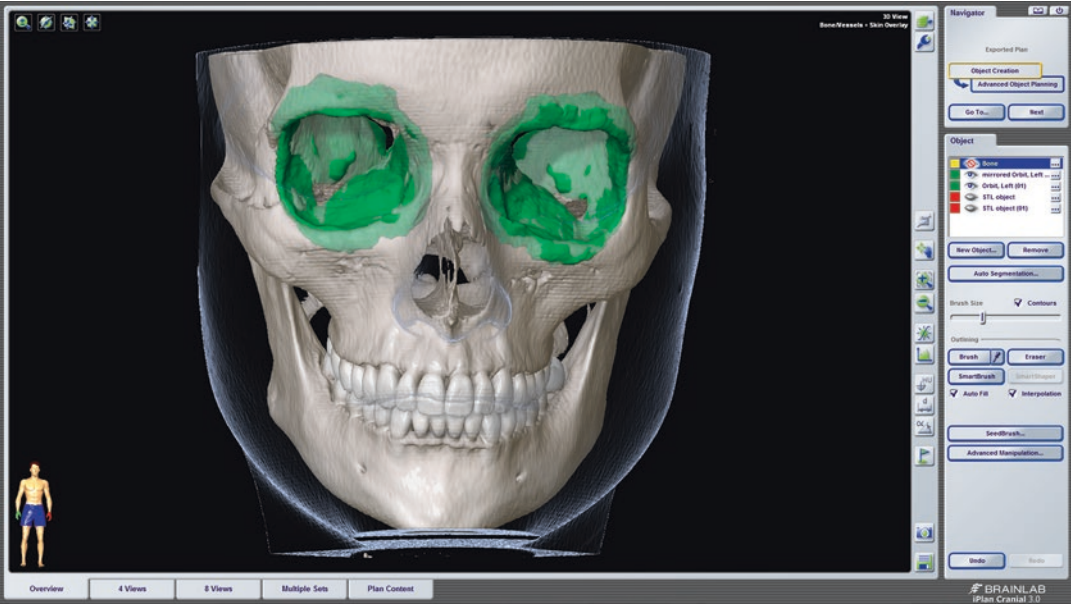


Fig. 10.16 Mirrored to the contralateral side to mimic the pre-traumatized anatomy

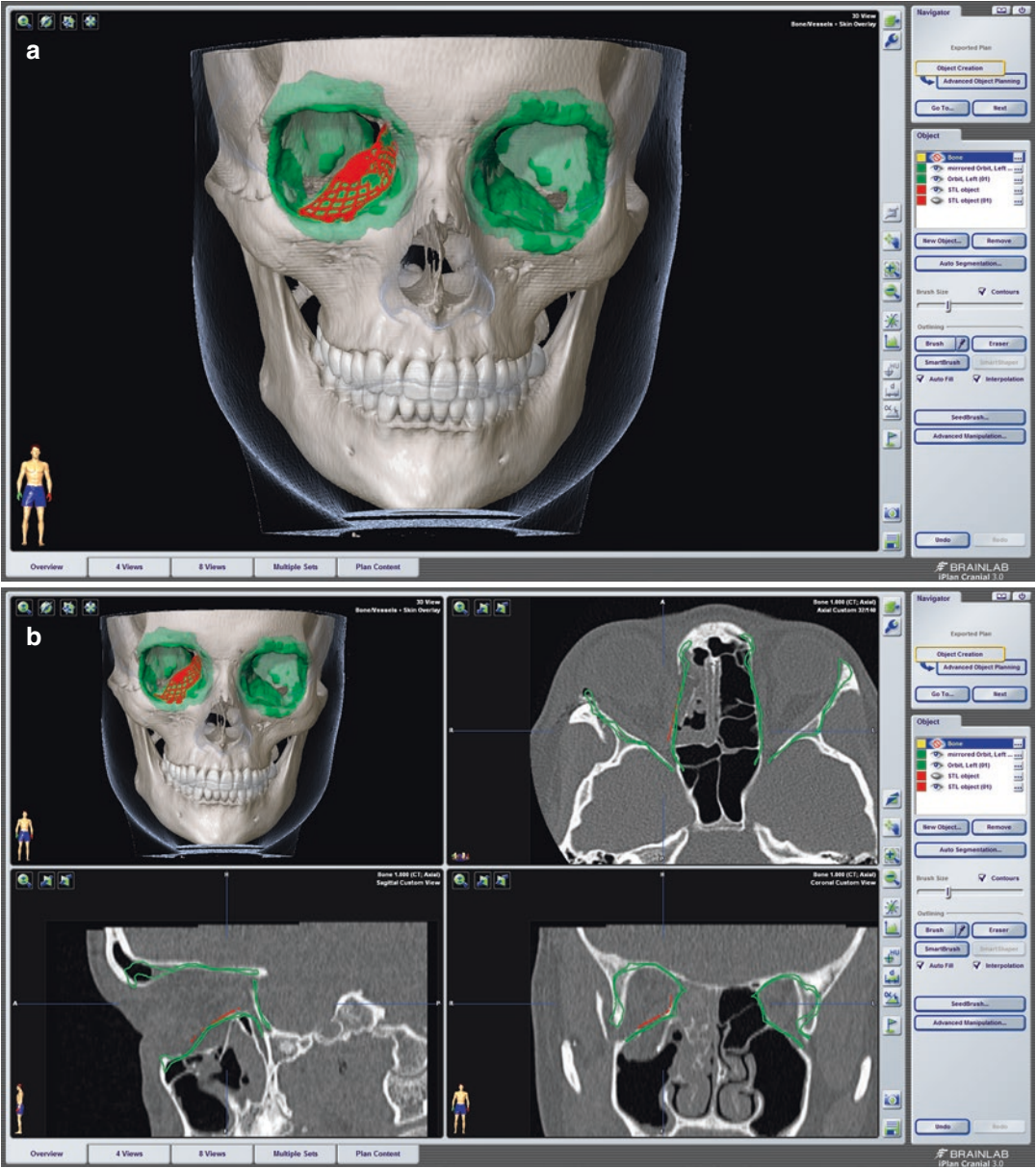
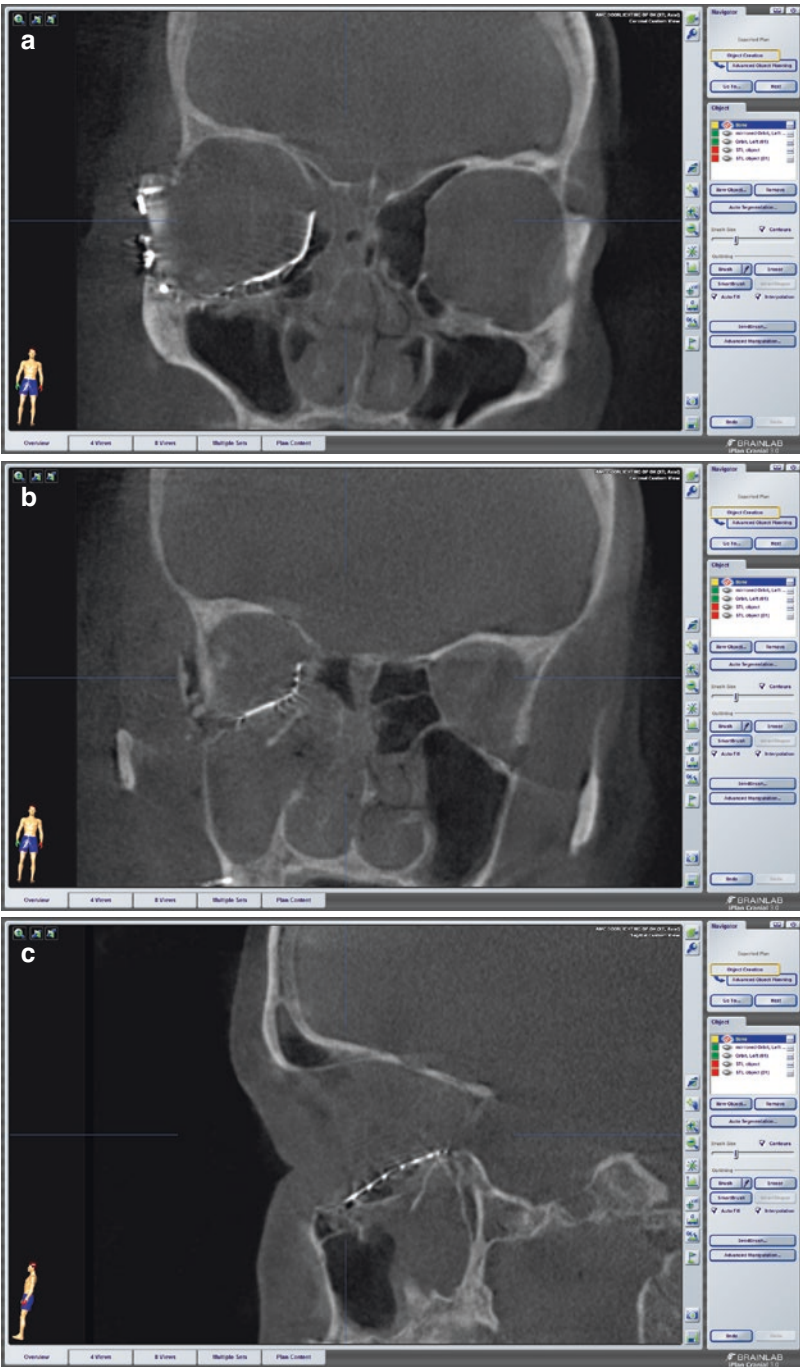


Fig. 10.17 (a, b) The STL file of the best fitting implant imported into the software

Fig. 10.18 (a–c)
Intraoperative imaging
for quality control



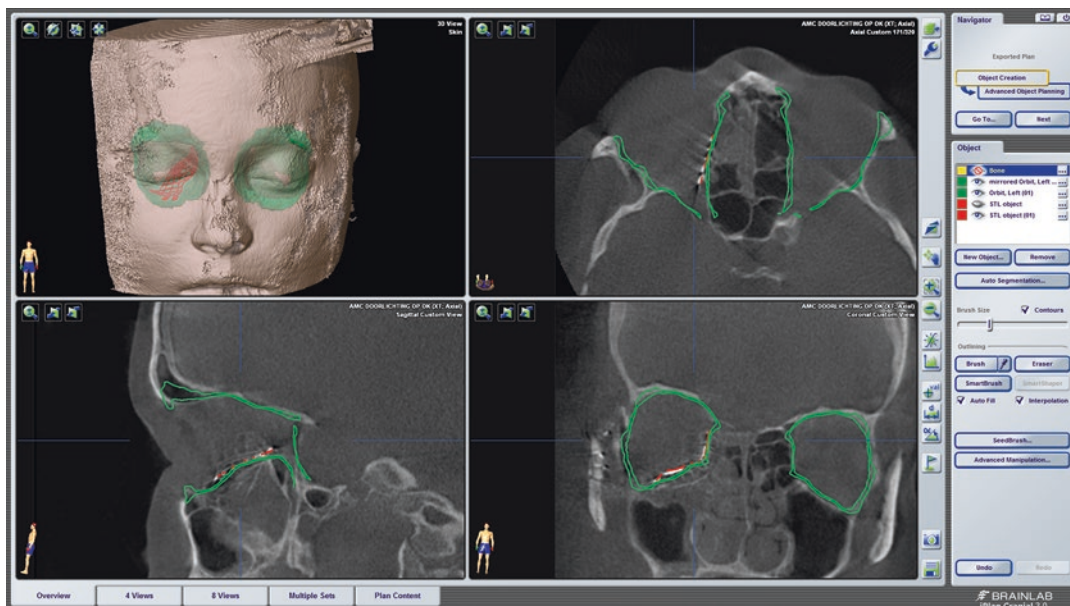


Fig. 10.19 Superimposition of the intraoperative imaging on the virtual surgical planning, which allows one-to-one comparison of the planned and obtained implant position

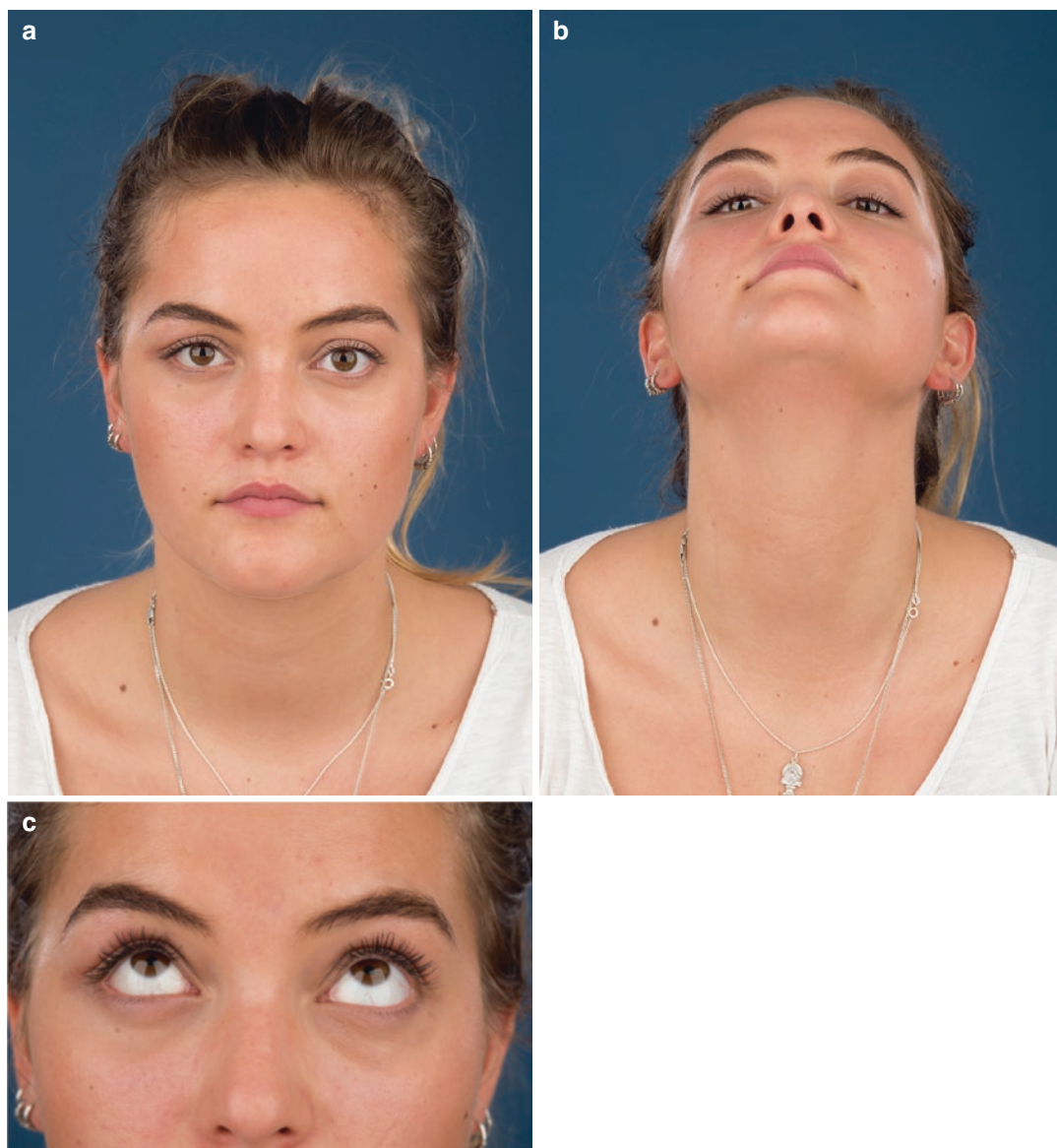


Fig. 10.20 (a–c) Clinical result 1 year after surgery, (a) en face, (b) submental, (c) elevation

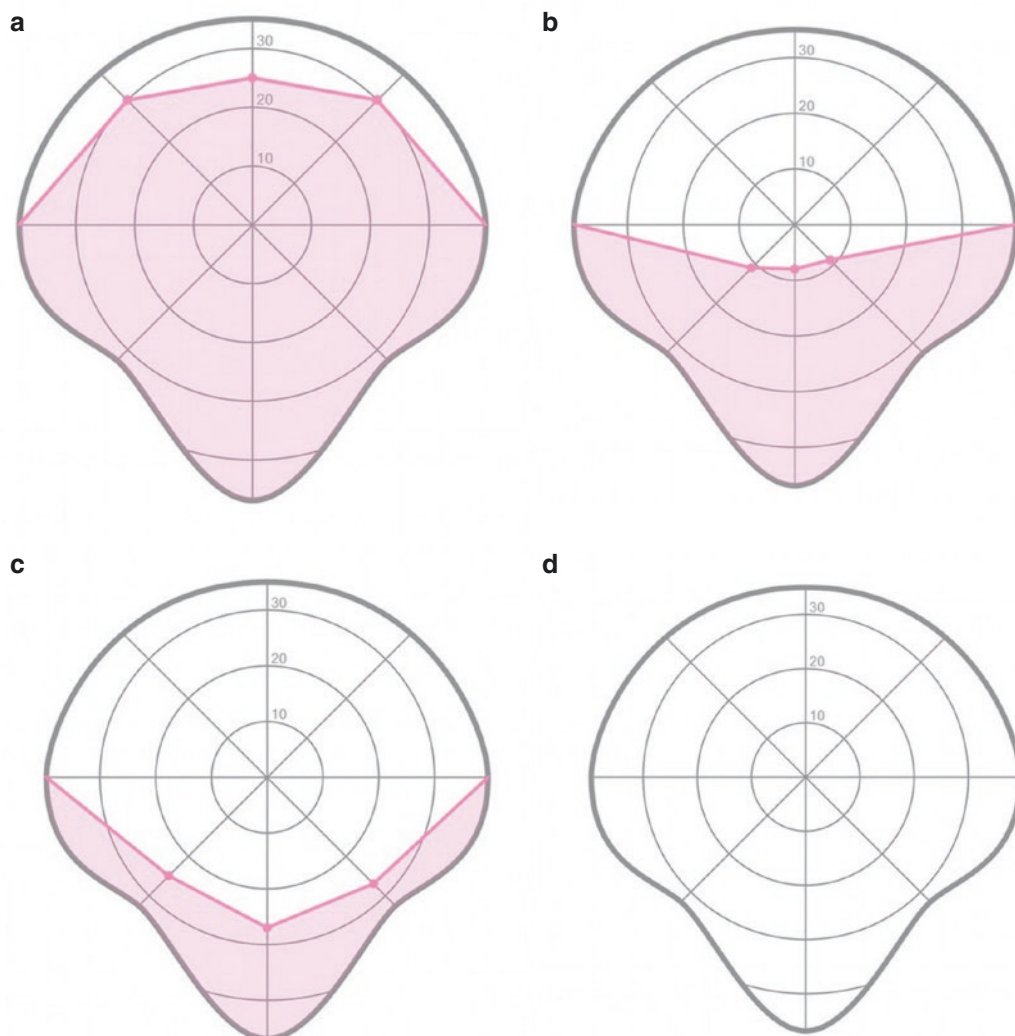


Fig. 10.21 (a–d) Binocular single vision (BSV) (a) preoperative, (b) 2 weeks after surgery, (c) 6 weeks after surgery, (d) 1 year after surgery

Conclusion

Orbital wall reconstruction can be a complex procedure with variable results. The limited overview, keyhole access and, in complex cases, loss of anatomical references are all challenges that need to be overcome to reconstruct the orbit adequately. Proper clinical decision-making forms

the fundament of treatment. The orbital implant positioning should be as accurate and reliable as possible and add to bulb position, ocular movements, soft-tissue volumes, and esthetic outcome. Although meticulous dissection skills of an experienced surgeon are mandatory, a wide range of medical technology can help improve the quality and predictability of treatment further.

References

1. Dubois L, Steenen SA, Gooris PJ, Mourits MP, Becking AG. Controversies in orbital reconstruction-I. Defect-driven orbital reconstruction: a systematic review. *Int J Oral Maxillofac Surg.* 2015;44(3):308–15.
2. Dubois L, Steenen SA, Gooris PJ, Mourits MP, Becking AG. Controversies in orbital reconstruction-II. Timing of post-traumatic orbital reconstruction: a systematic review. *Int J Oral Maxillofac Surg.* 2015;44(4):433–40.
3. Dubois L, Steenen SA, Gooris PJ, Bos RR, Becking AG. Controversies in orbital reconstruction-III. Biomaterials for orbital reconstruction: a review with clinical recommendations. *Int J Oral Maxillofac Surg.* 2016;45(1):41–50.
4. Dubois L, Dillon J, Jansen J, Becking AG. Ongoing debate in clinical decision making in orbital fractures: indications, timing, and biomaterials. *Atlas Oral Maxillofac Surg Clin North Am.* 2021;29(1):29–39.
5. Jansen J, Dubois L, Maal TJJ, Mourits MP, Jellema HM, Neomagus P, et al. A nonsurgical approach with repeated orthoptic evaluation is justified for most blow-out fractures. *J Craniomaxillofac Surg.* 2020;48(6):560–8.
6. Holmes S. Primary orbital fracture repair. *Atlas Oral Maxillofac Surg Clin North Am.* 2021;29(1):51–77.
7. Christensen BJ, Zaid W. Inaugural survey on practice patterns of orbital floor fractures for American oral and maxillofacial surgeons. *J Oral Maxillofac Surg.* 2016;74(1):105–22.
8. Gooris PJJ, Jansen J, Bergsma JE, Dubois L. Evidence-based decision making in orbital fractures: implementation of a clinical protocol. *Atlas Oral Maxillofac Surg Clin North Am.* 2021;29(1):109–27.
9. Schreurs R, Becking AG, Jansen J, Dubois L. Advanced concepts of orbital reconstruction: a unique attempt to scientifically evaluate individual techniques in reconstruction of large orbital defects. *Atlas Oral Maxillofac Surg Clin North Am.* 2021;29(1):151–62.
10. Gander T, Essig H, Metzler P, Lindhorst D, Dubois L, Rücker M, et al. Patient specific implants (PSI) in reconstruction of orbital floor and wall fractures. *J Craniomaxillofac Surg.* 2015;43(1):126–30.
11. Jansen J. Advanced concepts in orbital wall fractures—virtual surgical planning, intraoperative imaging and clinical management. Amsterdam: University of Amsterdam; 2020.
12. Mahoney NR, Peng MY, Merbs SL, Grant MP. Virtual fitting, selection, and cutting of preformed anatomic orbital implants. *Ophthalmic Plast Reconstr Surg.* 2017;33(3):196–201.
13. Rana M, Chui CH, Wagner M, Zimmerer R, Rana M, Gellrich NC. Increasing the accuracy of orbital reconstruction with selective laser-melted patient-specific implants combined with intraoperative navigation. *J Oral Maxillofac Surg.* 2015;73(6):1113–8.
14. Kärkkäinen M, Wilkman T, Mesimäki K, Snäll J. Primary reconstruction of orbital fractures using patient-specific titanium milled implants: the Helsinki protocol. *Br J Oral Maxillofac Surg.* 2018;56(9):791–6.
15. Scolozzi P. Applications of 3D orbital computer-assisted surgery (CAS). *J Stomatol Oral Maxillofac Surg.* 2017;118(4):217–23.
16. Bittermann G, Metzger MC, Schlager S, Lagrèze WA, Gross N, Cornelius CP, et al. Orbital reconstruction: prefabricated implants, data transfer, and revision surgery. *Facial Plast Surg.* 2014;30(5):554–60.
17. Wilde F, Schramm A. Intraoperative imaging in orbital and midface reconstruction. *Facial Plast Surg.* 2014;30(5):545–53.
18. Rana M, Holtmann H, Rana M, Kanatas AN, Singh DD, Sproll CK, et al. Primary orbital reconstruction with selective laser melted core patient-specific implants: overview of 100 patients. *Br J Oral Maxillofac Surg.* 2019;57(8):782–7.
19. Jansen J, Schreurs R, Dubois L, Maal TJJ, Gooris PJJ, Becking AG. The advantages of advanced computer-assisted diagnostics and three-dimensional preoperative planning on implant position in orbital reconstruction. *J Craniomaxillofac Surg.* 2018;46(4):715–21.
20. Schlittler F, Vig N, Burkhard JP, Lieger O, Michel C, Holmes S. What are the limitations of the non-patient-specific implant in titanium reconstruction of the orbit? *Br J Oral Maxillofac Surg.* 2020;58(9):e80–e5.
21. Gooris PJJ, Muller BS, Dubois L, Bergsma JE, Mensink G, van den Ham MFE, et al. Finding the ledge: sagittal analysis of bony landmarks of the orbit. *J Oral Maxillofac Surg.* 2017;75(12):2613–27.
22. Jaquiéry C, Aepli C, Cornelius P, Palmowsky A, Kunz C, Hammer B. Reconstruction of orbital wall defects: critical review of 72 patients. *Int J Oral Maxillofac Surg.* 2007;36(3):193–9.
23. Koornneef L. New insights in the human orbital connective tissue. Result of a new anatomical approach. *Arch Ophthalmol.* 1977;95(7):1269–73.
24. Sabelis JF, Youssef SALY, Hoefnagels FWA, Becking AG, Schreurs R, Dubois L. A technical note on multi-wall orbital reconstructions with patient-specific implants. *J Craniofac Surg.* 2021;33:991.
25. Dubois L, Schreurs R, Jansen J, Maal TJ, Essig H, Gooris PJ, et al. Predictability in orbital reconstruction: a human cadaver study. Part II: navigation-assisted orbital reconstruction. *J Craniomaxillofac Surg.* 2015;43(10):2042–9.
26. Zavattero E, Ramieri G, Roccia F, Gerbino G. Comparison of the outcomes of complex orbital fracture repair with and without a surgical navigation system: a prospective cohort study with historical controls. *Plast Reconstr Surg.* 2017;139(4):957–65.
27. Cai EZ, Koh YP, Hing EC, Low JR, Shen JY, Wong HC, et al. Computer-assisted navigational surgery improves outcomes in orbital reconstructive surgery. *J Craniofac Surg.* 2012;23(5):1567–73.

28. Luebbers HT, Messmer P, Obwegeser JA, Zwahlen RA, Kikinis R, Graetz KW, et al. Comparison of different registration methods for surgical navigation in cranio-maxillofacial surgery. *J Craniomaxillofac Surg.* 2008;36(2):109–16.
29. Venosta D, Sun Y, Matthews F, Kruse AL, Lanzer M, Gander T, et al. Evaluation of two dental registration-splint techniques for surgical navigation in cranio-maxillofacial surgery. *J Craniomaxillofac Surg.* 2014;42(5):448–53.
30. Schreurs R, Baan F, Klop C, Dubois L, Beenen LFM, Habets P, et al. Virtual splint registration for electromagnetic and optical navigation in orbital and craniofacial surgery. *Sci Rep.* 2021;11(1):10406.
31. Zeller AN, Zimmerer RM, Springhetti S, Tavassol F, Rahlf B, Neuhaus MT, et al. CAD/CAM-based referencing aids to reduce preoperative radiation exposure for intraoperative navigation. *Int J Med Robot.* 2021;17(3):e2241.
32. Dubois L, Essig H, Schreurs R, Jansen J, Maal TJ, Gooris PJ, et al. Predictability in orbital reconstruction. A human cadaver study, part III: implant-oriented navigation for optimized reconstruction. *J Craniomaxillofac Surg.* 2015;43(10):2050–6.
33. Jansen J, Schreurs R, Dubois L, Maal TJJ, Gooris PJJ, Becking AG. Intraoperative imaging in orbital reconstruction: how does it affect the position of the implant? *Br J Oral Maxillofac Surg.* 2020;58(7):801–6.

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