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Custom wave-shaped CAD/CAM orbital wall implants for the management of post-enucleation socket syndrome

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ABSTRACT

The satisfactory management of post-enucleation socket syndrome is a major challenge. In addition to enophthalmos and hypophthalmos, the appearance of the supratarsal fold is frequently unsatisfactory. Using a combination of orbital volume reduction by means of custom wave-shaped CAD/CAM implants (1), the implantation of a dermis-fat graft (2), and the fitting of an acrylic eye prosthesis (3), an algorithm has been developed that has led to considerable long-term improvements.

10 patients have already been treated by this method. The most important step is the reduction of orbital volume by means of custom wave-shaped CAD/CAM implants. These move the intraorbital soft tissue in an anterior and cranial direction. This considerably reduces the required volume of additional dermis-fat grafts, which are always subject to resorption. The use of an acrylic eye prosthesis facilitates the aesthetic and functional correction of this condition and exerts less pressure on the lower eyelid due to its low weight.

The method presented here leads to stable and aesthetically pleasing results with a minimum risk of complications. One problem is the exact predictability of the necessary orbital volume reduction by the custom wave-shaped CAD/CAM implants. Further studies and a larger number of cases are required to address this problem.

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1. Introduction

Management of post-enucleation socket syndrome (PESS) with a view to achieving aesthetically satisfactory long-term results is a major challenge in general, and particularly in cases of secondary reconstruction, for example after infection and/or the extrusion of implants such as silicone implants or hydroxyapatite implants. The appearance of the supratarsal fold, in particular, is often unsatisfactory (Kim et al., 2014).

On account of the fluid boundaries between maxillofacial surgery, oculoplastic surgery, and ophthalmology, an interdisciplinary approach has to be recommended. In addition to the expertise of maxillofacial surgeons and oculoplastic surgeons, skilled and experienced ophthalmologists are required because only their work,

namely the production of a realistic artificial eye, can complete the task begun by surgeons (Shah et al., 2014).

PESS develops after enucleation or evisceration of the eyeball (Tyers and Collin, 2001). Reasons for enucleation include tumors (e.g. retinoblastoma, choroidal melanoma) and trauma. In some cases, infections may also necessitate such surgery (Kord Valeshabad et al., 2014). In addition to enophthalmos and deep superior sulcus deformity, these patients frequently exhibit ptosis or eyelid retraction and hypophthalmos (Tyers and Collin, 2001). This typical physical appearance is the result of a volume deficit of the intraorbital tissues and a constant bony orbital volume. In some cases, namely after non-reconstructed orbital wall fractures or defects, bony orbital volume even increases.

As a result, there are two basic surgical approaches:

- (1) increase the volume of intraorbital tissues, or
- (2) reduce the bony orbital volume.

The first approach usually involves implanting mostly spherical implants that imitate the former eyeball, such as

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silicone balls, hydroxyapatite implants, or dermis-fat grafts, into the remaining intraorbital tissue. Another option is the injection of autologous fat or alloplastic fillers into the orbit (Adenis et al., 1999; Tyers and Collin, 2001; Hardy et al., 2007; da Silva et al., 2008; Goiato et al., 2010; Buchanan et al., 2012).

While dermis-fat grafts, autologous fat, and absorbable fillers are subject to resorption and must therefore usually be reinjected (Guberina et al., 1983; Starks and Freitag, 2018), the other implants are occasionally dislocated, exposed, or infected, in which cases removal may be necessary (Tyers and Collin 2001; Hardy et al., 2007; Wang et al., 2009; Buchanan et al., 2012).

The second approach, namely the reduction of bony orbital volume, can be achieved by inserting autologous bone grafts, such as outer table calvarial grafts or avascular iliac crest transplants, or alloplastic implants, such as titanium mesh, MEDPOR implants, or silicone implants, into the orbit near the orbital walls (Hardy et al., 2007; Rana et al., 2012). Transplanted bone, however, may be resorbed. By contrast, alloplastic implants such as titanium mesh, MEDPOR, and silicone implants have the advantage of having good form and volume stability, but MEDPOR and silicone implants have the disadvantage of not being radiopaque.

The establishment and continuous development of computer-assisted surgery in the field of cranio-maxillofacial surgery, and the new possibilities offered by using selective laser melting (SLM) to produce custom titanium implants, have resulted in new therapeutic approaches (Wilde and Schramm, 2016).

Custom titanium meshes, which are additively built using SLM, have proven effective in particular for the reconstruction of post-traumatic orbital wall defects (Zimmerer et al., 2016; Wilde and Schramm, 2016). For this reason, an obvious approach is to employ this additional technology to manage PESS.

The primary objective of this study was to describe in detail the workflow developed to manage PESS by means of custom wave-shaped CAD/CAM orbital wall implants. The secondary objective was to present clinical findings and pitfalls for a cohort of 10 patients.

2. Case report

The following algorithm was used to manage PESS:

1. Orbital volume reduction with custom wave-shaped CAD/CAM implants.
2. Additive implantation of a dermis-fat graft in the residual anterior orbital tissue.
3. Fitting of an acrylic artificial eye.

2.1. Technical report: step by step planning and treatment

2.1.1. Preparation and computer-assisted planning

1. Clinical examination, photographic documentation (Fig. 1a, b). An impression is taken of the maxilla in order to produce a so-called navigation splint for intraoperative referencing and navigation (Fig. 1c).
2. CT scan of the facial skeleton and reconstruction in 1 mm layers. During the CT, the patient wears the navigation splint.
3. Computer planning with iPlan CMF 3.0 software (Brainlab®, Munich, Germany).
 - a) DICOM files from the CT scan are loaded.
 - b) The data set is oriented to the natural head position (NHP) in all three planes (Frankfurt plane, transverse plane, and frontal plane).

- c) Reference points are defined and marked for intraoperative navigation.
 - d) Atlas-based autosegmentation of the affected and unaffected orbits is carried out with iPlan CMF 3.0 software. Virtual orbital models of the right and left orbits are created with iPlan CMF 3.0 software for further reconstruction planning (Fig. 1d).
 - e) Depending on the initial finding, either the unaffected side is mirrored to the affected side (for example, in the case of untreated orbital wall fractures), or planning continues with segmentation of the affected side (for example, in the case of intact bony orbits).
 - f) 3D deformation of the segmentation of the orbit using the Smart Shaper software tool. The segmentation of the orbit is deformed in such a way that the orbit attains the shape it should have after a patient-specific, wave-shaped implant is inserted. Orbital volume is thus reduced. The middle orbit height (cranial–caudal) and the middle orbit length (anterior–posterior) in the sagittal view serve as an orientation for volume reduction by the wave-shaped implant (Fig. 1e).
 - g) The desired extent of the custom orbital implants is marked using marker points (Fig. 1e).
 - h) The CT DICOM data and the Brainlab xBrain file are uploaded to a secure FTP server of our partner company (in this case, KLS-Martin®, Tuttlingen, Germany).
 - i) A medical engineer of the partner company then designs two custom wave-shaped implants using proprietary CAD software and computer planning data from the hospital.
 - j) An STL file of the orbital implants is transferred back via the secure FTP server.
 - k) The STL file of the orbital implants is downloaded and loaded into iPlan CMF software. As the coordinate system of the STL file corresponds with the plan in iPlan CMF, the orbital implants can be immediately positioned correctly in iPlan CMF in accordance with planning (Fig. 1f).
 - l) Implants are checked and, if necessary, adapted by 3D deformation in iPlan CMF.
 - m) The corrected implants are saved in a new xBrain file and transferred to the medical engineer via the secure FTP server.
 - n) The medical engineer modifies the design of the orbital implants and returns the STL file.
 - o) The new STL file of the orbital implants is downloaded and loaded into iPlan CMF, where the design is checked (Fig. 1f).
 - p) The design is either approved or modified as described above until the surgeon approves it.
4. The partner company produces the titanium orbital implants by means of laser melting and sends them to the hospital (Fig. 1g).
 5. The implants are sterilized.

2.1.2. Surgery

1. The patient is positioned on the operating table with a carbon head rest to allow intraoperative 3D imaging.
2. The skull reference array of the navigation system is attached to the calvaria, and the navigation splint is attached to the maxilla.
3. The navigation system is used to reference the patient.
4. Transconjunctival access to the orbital floor. An incision is made in the conjunctival scar and not in the fornix, as is the case with orbital wall fractures.
5. Dissection and exposure of the orbit from anterior to posterior as well as from lateral to medial to the posterior third of the orbit. In the case of an existing, untreated orbital wall

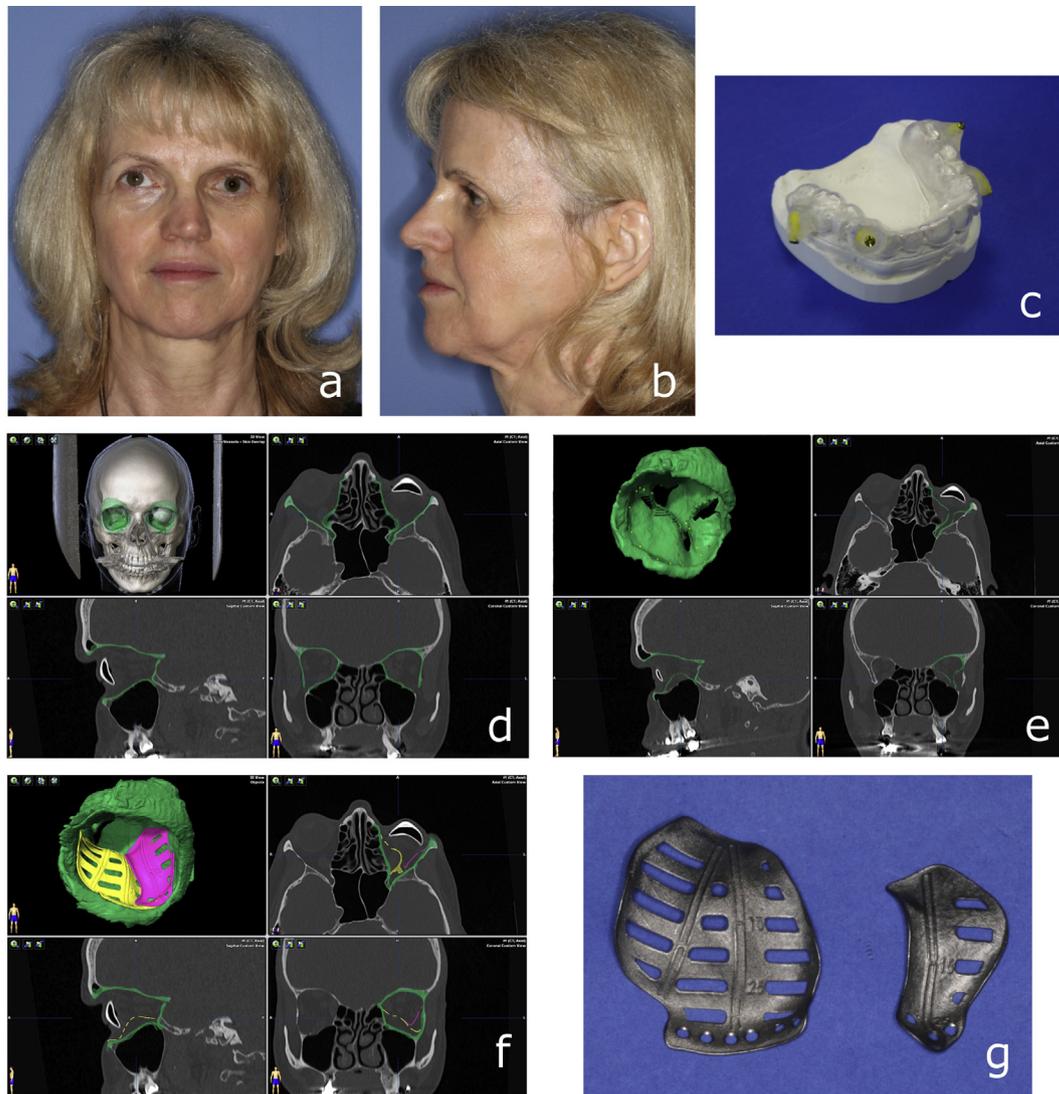


Fig. 1. Planning steps: (a) Preoperative frontal view. (b) Preoperative lateral view left. (c) Navigation splint. (d) Multiplanar view of atlas-based autosegmentation of affected and unaffected orbits using iPlan CMF 3.0 software (Brainlab®, Munich, Germany). Creation of virtual models of the orbits for further reconstruction planning. (e) 3D deformation of the segmented orbit using the Smart Shaper software tool. The segmented orbit is deformed in such a way that it obtains the desired shape to be achieved with the implantation of the custom wave-shaped implant. This typically results in a reduction in orbital volume. (f) Design of two custom wave-shaped implants. The STL files of the orbital implants are imported into iPlan CMF 3.0 software in order to assess the design in multiplanar view. (g) Custom wave-shaped implants are manufactured by selective laser melting (large = medial implant, small = lateral implant).

fracture, lateral, posterior, and medial edges for the implant are identified and exposed.

6. The medial wave-shaped implant is implanted first and positioned to allow for the best fit. The implant is fixated to the posterior infraorbital rim with 1 or 2 screws (Ø 1.5 mm, length 4 mm). The position is checked using intraoperative navigation and, if required, the position is changed.
7. The second lateral wave-shaped implant is attached (Fig. 2a). The position is again checked using the navigation system (Fig. 2b).
8. An intraoperative check for enophthalmos is carried out, as is a check of the degree to which the orbit is filled.
9. Depending on the degree to which the orbit is filled, a spindle-shaped dermis-fat graft is taken from the cranial lateral flank to the iliac crest. Dermis with the lowest possible amount of fat must be used in order to minimize postoperative shrinkage of the graft (Fig. 2c).
10. The dermis-fat graft is implanted and fixated in the remaining anterior orbital tissue in order to maximize filling

of the eye socket. The conjunctiva is then closed with absorbable 6-0 suture (Fig. 2d).

11. Intraoperative imaging is performed by a 3D C-arm (Fig. 2e), and DICOM data are imported into the iPlan CMF software. Images are fused with preoperative planning CT and computer planning in order to assess reconstruction (Fig. 2f).
12. The largest possible Illig shell is inserted to re-form the fornix at an early stage.
13. After the skull reference array and the navigation splint are removed, surgery ends.

2.1.3. Postoperative procedure

1. Sufficient analgesia is provided (e.g. 600 mg ibuprofen three times a day as basic medication, tilidine 50/4, if required, or, additionally, 15 mg piritramide s.c., if required).

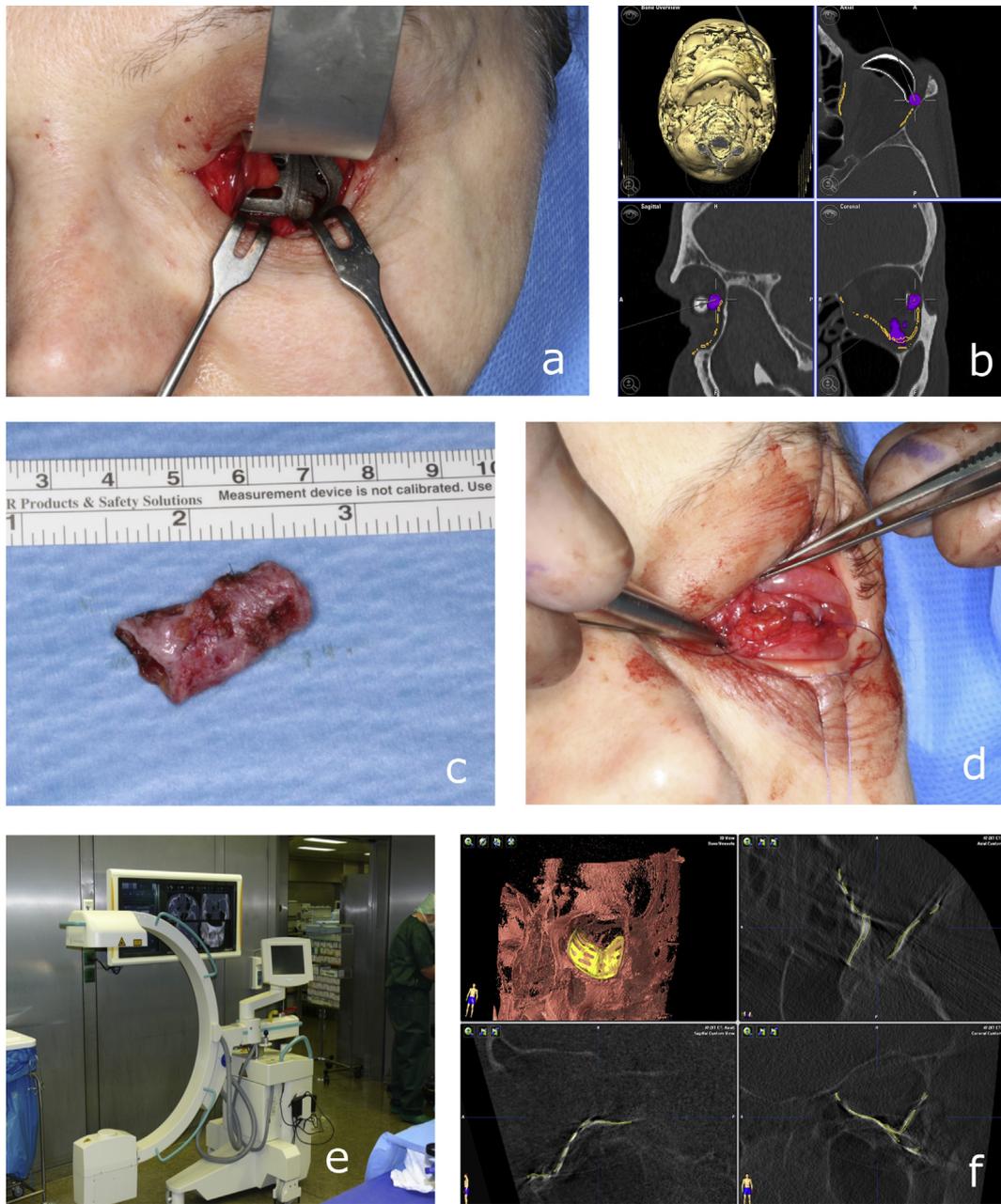


Fig. 2. Operation: (a) Implantation of the wave-shaped implants via a transconjunctival approach. (b) The navigation system (Brainlab®, Munich, Germany) is used to assess the position of the implant in a multiplanar view. The orange area represents the desired implant position according to computer planning. The purple areas show the position of the pointer on the implant surface and indirectly show the position of the implants in the orbit. If the purple areas correspond with the computer planning (orange area), the implants are in the correct position. (c) Dermis-fat graft from the lateral cranial flank to the iliac crest. (d) Implantation and fixation of the dermis fat graft in the remaining anterior orbital tissue to maximize the filling of the orbit. (e) Intraoperative imaging by a 3D C-arm (Ziehm®, Nuernberg, Germany). (f) DICOM import of the 3D C-arm data set into the iPlan CMF software. Image fusion with computer planning for intraoperative assessment in the multiplanar view. The implant position corresponds with computer planning (yellow area).

2. The patient is discharged from hospital with the Illig shell after acute pain symptoms have subsided (approximately 5 days \pm 2 days).
3. After approximately 2–3 weeks, an impression is taken of the eye socket using alginate, and a custom acrylic conformer, which is as large as possible, is produced to re-form the fornix for the artificial eye to be made by an ocularist (Fig. 3a, b).
4. After 5–6 weeks, a custom acrylic artificial eye is fabricated and fitted (Fig. 3c).
5. Further postoperative follow-ups are conducted after 12 weeks, 6 months, and 12 months (Fig. 3d, e).
6. Optional aesthetic improvements can be made no earlier than 6–9 months after surgery. These include:
 - eyelid corrections
 - blepharoplasty — if necessary, contralateral
 - modifications of the artificial eye
 - changes to eyeglasses, if required, with positive or negative lenses on the enophthalmic side.

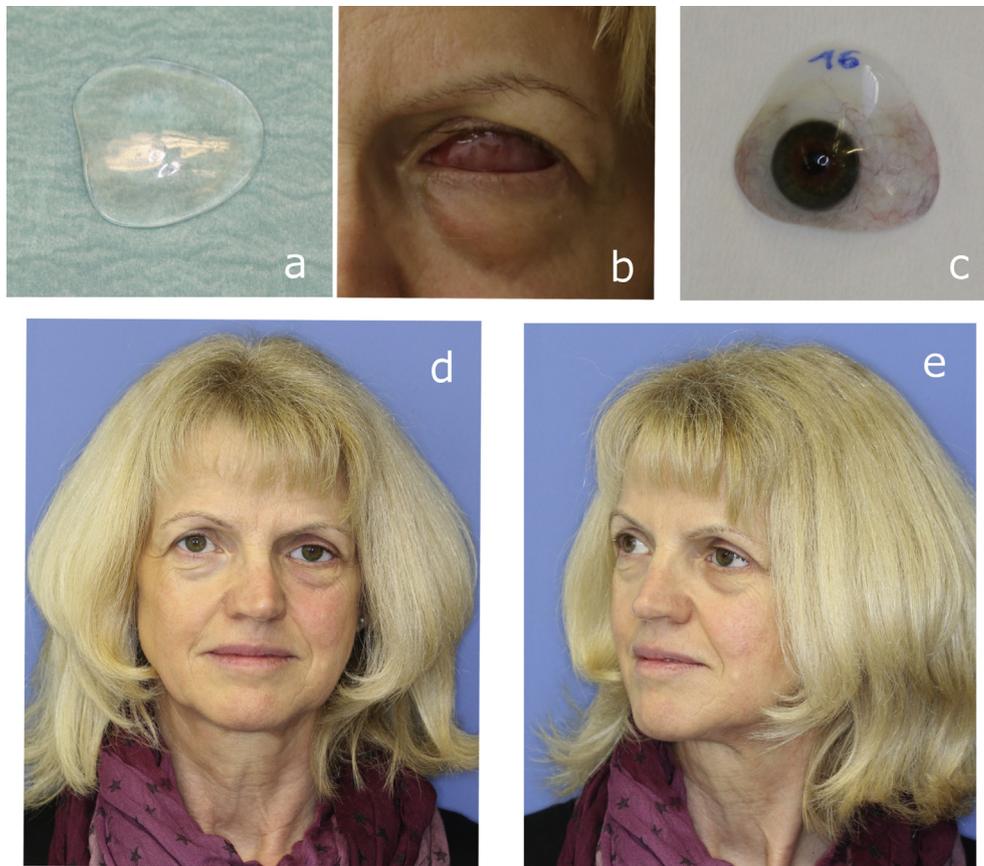


Fig. 3. Postoperative care: (a and b) Production and insertion of a large custom acrylic conformer to shape the fornix (approximately 2–3 weeks after the operation). (c) After 5–6 weeks, a custom acrylic artificial eye is fabricated and fitted. (d) Frontal view 10 months after the operation. (e) Lateral view.

2.2. Case series

Since this method was introduced in our hospital in 2015, 10 patients have been treated in the manner described above. Patient data are shown in [Table 1](#).

2.2.1. Clinical aspects

Aesthetics were markedly improved in all 10 patients. To date, no patient has experienced an exposed implant or an infection.

In one case, revision surgery in the area of the operated orbit was performed 8 months after the first operation on account of undercorrection and an unsatisfactory aesthetic result. The implants from the first operation were removed and replaced with custom wave-shaped implants of a different size, which resulted in greater orbital volume reduction ([Table 1](#), patient 4). This specific

case concerned an injury from the Iraq war, which was caused by an improvised explosive device (IED). Multiple operations had therefore been performed in several hospitals in Iraq and Germany before the first operation took place in our hospital. This was the only patient who required a lateral canthotomy to enlarge transconjunctival access for the placement of the wave-shaped implant. The reason for this was that, due to heavy scarring of midface, orbits and eyelids, the elasticity of the lower lid was severely limited and thus the risk of iatrogenic lid laceration was too great.

Implants were placed by way of an isolated, transconjunctival approach without lateral canthotomy in all other nine patients.

In one patient, surgeons realized during the operation that the orbit was not sufficiently filled. They therefore cut and formed by hand two standard fan-shaped titanium meshes and placed them on top of the custom wave-shaped implants. This reduced the

Table 1
Case series patient characteristics (♂ = male, ♀ = female).

	Gender	Reason for enucleation	Dermis-fat graft (yes/no)	Revision necessary (yes/no)	Secondary lid correction (yes/no)
1	♂	Trauma	Yes	No	No
2	♀	Infection	No	No	No
3	♀	Trauma	Yes	No	Yes
4	♂	Trauma	Yes	Yes	Yes
5	♀	Retinoblastoma	Yes	No	No
6	♀	Trauma	Yes	No	No
7	♂	Trauma	Yes	No	No
8	♂	Trauma	Yes	No	No
9	♂	Trauma	Yes	No	Yes
10	♀	Trauma	Yes	No	No

orbital volume more than originally planned (Table 1, patient 7). This case required revision surgery as a result of complex, multiple trauma to the frontal bone, the right orbit, and the right midface, caused by the explosion of a gasoline stove.

An oculoplastic surgeon performed secondary eyelid corrections in three of the ten patients to further improve aesthetics (Table 1).

2.2.2. Analysis of the workflow

Preparatory measures such as photographic documentation (frontal, lateral, cranial, caudal), production of a navigation splint, non-contrast-enhanced multislice computed tomography, and reconstruction of the data in 1 mm layers are routine clinical procedures and therefore do not require separate analysis (Schramm et al., 1999, 2007).

Computer-assisted planning

The iPlan CMF 3.0 software (Brainlab®, Munich, Germany) allowed us to conduct ‘atlas-based’ autosegmentation of surgically relevant regions, such as the orbits, in combination with the uncomplicated and rapid manipulation of the segmented region and computer models. This made it possible to effectively and quickly plan orbital volume reduction by the surgeon (Fig. 1d, e). The required time depended on the complexity of the case. When we were dealing with an isolated orbit, the time required for the first step of computer planning involving the segmentation and deformation of the orbit for the purpose of volume reduction with a custom wave-shaped implant took approximately 30–45 min, including data transfer to the partner company (in this case KLS Martin®, Tuttlingen, Germany) via the FTP server.

A medical engineer from the partner company then proposed a design for each implant on the basis of the data he received. He transferred this design in STL format to us via the FTP server. Each wave-shaped implant was then imported into the iPlanCMF 3.0 software (Fig. 1f). A decisive advantage here was that the implants could be seen in their planned position in the orbit after they were imported. Corrections to the design in terms of size and shape were easily carried out using the iPlan CMF 3.0 software manipulation tools. The time required varied from case to case and depended on the stage of planning, with more time required for the first correction of the design than for the second or third.

In the beginning, it was often necessary for the surgeon to lend more support to the medical engineer of the partner company, and to discuss the design of the implant either by telephone or web meeting. After the first four or five cases, communication with the medical engineer about the design of the implants became less complicated. In the end, only one to two corrections were usually required for the final design. After the design was approved by the surgeon, 3–5 working days passed before the implants arrived at the hospital by mail.

Surgery

Registration of the patient for intraoperative navigation and the import of the preoperative plan into the navigation system are routine procedures in navigational surgery. After the transconjunctival approach, the insertion of the wave-shaped implants proved to be more difficult and thus more time-consuming compared with, for example, the flat orbital meshes used for orbital wall reconstruction. Nevertheless, the wave-shaped implants were inserted as planned into the eye sockets in all 10 cases.

The high degree of manufacturing precision made the wave-shaped implants easy to place in all cases. Positioning was so clear that the navigation system was not needed for the intraoperative arranging of the implants. In no case was it necessary to change the position of an implant. The navigation system did, however, allow intraoperative and radiation-free monitoring of the

implant position. Furthermore, it proved to be helpful in cases where orbital reconstruction had not yet been carried out (Fig. 2b).

Intraoperative imaging with a 3D C-arm was easily performed by the surgeon without additional assistance. Approximately 10 min passed from the adjustment of the device to the intraoperative evaluation of the achieved result. By fusing the intraoperative 3D data set and the preoperative plan in the iPlan CMF software, we were able to compare exactly the implant position with the preoperative planning (Fig. 2e, f).

The visual and palpatory assessment of orbital filling after implantation of the wave-shaped implants strongly depends on the surgeon's experience and is almost exclusively based on subjective criteria. In nine of the 10 cases, a dermis-fat graft was added (Fig. 2c, d). In all nine of these cases, the dermis-fat graft was easily harvested from the patient's flank without complications.

Postsurgical care and fitting of the artificial eye

After surgery, all patients complained of severe pain and pressure symptoms in the region of the operated eye. Pain was considerably greater than that experienced after, for example, anatomical orbital reconstruction following an orbital wall fracture. Severe pain continued for approximately 3–5 days. Pain was manageable in all cases using a combination of 600 mg ibuprofen three times a day as basic medication and 50/4 mg tilidine as necessary. In individual cases, an additional subcutaneous administration of 15 mg piritramide was necessary for 1–2 days for anesthetization purposes. The average hospital stay was 4.8 days. A large plastic conformer was placed in the socket by the ocularist after approximately 14–21 days in order to shape the fornix (Fig. 3a, b). The definitive acrylic artificial eye was inserted 5–6 weeks after the operation (Fig. 3c).

3. Discussion

In our experience, the procedure presented here to manage PESS leads to stable and aesthetically pleasing long-term outcomes.

The focus of the treatment concept presented in this study is on the long-term reduction of orbital volume through the implantation of custom wave-shaped CAD/CAM implants. The special wave design of the titanium mesh (Fig. 1f, g) not only reduces the orbital volume but also helps shift the residual soft tissue in the eye socket in the anterior and cranial directions. This addresses the basic problem of PESS without increasing the risk of dislocation, implant exposition, and infection because the implants, as in orbital wall fracture treatment, are placed below the periorbita and fixated in the region of the infraorbital rim with at least two screws per implant, to prevent them from moving out of position. In addition, a thick layer of soft tissue is formed anterior to the implants. With respect to the material used, i.e. titanium, no complications are to be expected. Titanium is now a well-established material for mesh implants used in the treatment of orbital wall fractures (Metzger et al., 2006; Yi et al., 2012; Zimmerer et al., 2016). Virtually no complications due to titanium have been described (de Graaf et al., 2018; Furrer et al., 2018). In our experience, this also applies to custom CAD/CAM titanium implants produced by selective laser melting.

There is legitimate concern about implant exposure and infection in patients who have undergone radiotherapy. This problem occurs, for example, in patients who have lost an eye due to retinoblastoma and who received radiation therapy after enucleation. There was one patient in our cohort who had been treated for a retinoblastoma with adjuvant radiotherapy (Table 1, patient 5). She exhibited delayed wound healing in the conjunctiva but not implant exposure. Nevertheless, physicians should be aware of this risk in these special cases.

The largest unsolved problem of the method presented here is the planning of the necessary orbital volume reduction by means of custom CAD/CAM wave-shaped orbital implants. Volume reduction was based on the middle orbit height (cranial–caudal) and the middle orbit length (anterior–posterior) in the sagittal view (Fig. 1e, f). These measurements, however, are based solely on our experience in planning wave-shaped implants. Furthermore, planning was based exclusively on the bony situation of the eye socket and did not take into account the degree to which the orbit was filled with soft tissue prior to the operation. Smart new ideas and additional studies are necessary to better calculate the required orbital volume reduction prior to the operation, and thus better predict the outcome.

In order to counter this problem in our method, we decided intraoperatively to implant an additional dermis-fat graft into the anterior region of the orbital residual soft tissue to further improve orbital filling in nine out of 10 cases. On account of the expected shrinkage, we attempted to keep the fat content of the transplant in relation to the dermis content as low as possible. Nevertheless, shrinkage cannot be calculated or predicted (Kuzmanović Elabjer et al., 2010). Thus, the larger the dermis-fat graft, the greater the risk of a recurrence of PESS. We are of the opinion that PESS should be managed primarily through orbital volume reduction with wave-shaped implants. The use of dermis-fat grafts should be kept to a minimum or, if possible, avoided.

In addition to the two established wave-shaped implants in the orbital floor region and the medial and lateral orbital wall, we believe that a third wave-shaped implant could be placed in a lateral-cranial position in the orbit. This remains only a theoretical consideration at the moment. We have no clinical experience with such an implant.

It is also possible to use standard titanium meshes to reduce the orbital volume instead of the selective laser-melted CAD/CAM wave-shaped implants (Rana et al., 2012). A further possibility is to pre-bend meshes into a wave shape on a patient-specific orbit model. This method was used in our hospital before selective laser-melted CAD/CAM titanium meshes became available. The advantage of the laser-melted CAD/CAM wave-shaped implants compared with the hand-bent standard titanium meshes is their significantly higher dimensional stability. As a result, they do not bend out of shape when they are placed in the orbit, unlike the standard titanium meshes. Furthermore, the laser-melted CAD/CAM wave-shaped implants do not have sharp edges or corners. They are thus considerably easier to place compared with the hand-bent standard titanium meshes, which are cut with metal shears, because they are less likely to catch in soft tissue, which is thus less traumatized. Such soft tissue traumatization can lead to local tissue necrosis, which can lead to shrinkage and volume reduction of the intraorbital soft tissue.

The workflow presented here involves not only CAD/CAM wave-shaped implants, but also navigation and intraoperative imaging. Both are an integral part of computer-assisted surgery of the mid-face and orbit (Schramm et al., 2006; Wilde and Schramm, 2014).

It is our experience, however, that navigation has become less significant since the introduction of custom CAD/CAM implants. The precision of the custom implants and their nearly perfect fit make navigation to the correct position less necessary. Navigation can, however, help to guide orientation in difficult surgical sites, in particular for less experienced surgeons.

Intraoperative imaging, for example with a 3D C-arm, continues to be important and highly useful, even when custom implants are used. This applies more to a seeing eye than to PESS, where blindness is no longer a risk. Intraoperative radiological imaging, in combination with the possibility of image fusion with the preoperative plan, allows the surgeon to immediately assess the surgical

procedure in the operating room. In addition, postoperative imaging is not required after intraoperative 3D imaging in most cases (Wilde et al., 2013; Wilde and Schramm, 2014).

The question may arise as to why intraoperative imaging with ionizing radiation is a good idea when radiation-free navigation can be used for intraoperative visualization. At first glance, this question appears to be justified. But if we consider the precision of navigation systems and the information they provide, for example, about the entire implant or a complex reconstruction, navigation systems are clearly inferior to intraoperative imaging with respect to the information they provide, reliability and documentation (Schramm et al., 2007).

The acrylic artificial eyes used in the method presented here have an advantage over glass eyes in that they can be better customized; material can be selectively added to acrylic eyes by polymerization (e.g. the eye can be thickened in the region of the supratarsal fold) and also removed mechanically. Furthermore, it is easier to custom-paint an acrylic eye and thus make it match the companion eye (Goiato et al., 2014; Cevik et al., 2012). An additional advantage of acrylic eyes is their markedly reduced weight compared with glass eyes. As a result, undue tension on the eyelids is relieved and increased laxity is prevented.

A final issue is the relatively high price of custom CAD/CAM implants compared with traditional PESS management methods. For this reason, the method presented here will not be the treatment of choice in most centers at this point in time, and will be used primarily for complicated revision surgery. Nevertheless, we believe that the procedure presented here can save costs because the use of custom implants reduces operation times, while good long-term results may allow the avoidance of possible revision, thus reducing long-term costs (Shippert, 2005; Abbott et al., 2011; Heufelder et al., 2017).

4. Conclusion

The presented method for the management of PESS appears to offer predictable, stable, and aesthetically pleasing results, with a minimum risk of complications. An important unresolved problem is the assessment of required orbital volume reduction by wave-shaped implants during digital planning. Further thought and studies are required to resolve this issue.

Ethical Standards

All procedures performed in this paper involving human participants were in accordance with the 1964 Helsinki declaration and all patients gave informed consent before the procedures.

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Conflict of interest

All authors declare that they have no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jcms.2019.06.015>.

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