Preformed Titanium Meshes: A New Standard?

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ABSTRACT

Three-dimensional reconstruction of the orbital floor is the key procedure for a primary or secondary orbital deformity. After the unaffected side is mirrored onto the affected side using the patient's computer-tomography database, the defect can be reconstructed virtually. A measurement procedure that calculates the virtually reconstructed orbital surface data is available. These data are sent to a template machine that reproduces the physical surface. A flat titanium mesh can then be adjusted preoperatively to the spatial configuration of the anatomical structures. This procedure offers optimal anatomical reconstruction of the orbital floor, especially when the deep orbital cone is affected.

KEYWORDS: Titanium mesh, virtual reconstruction, orbital cavity reconstruction

Enophthalmos, diplopia, and a disturbance in visual acuity related to the enlargement of the orbital volume are severe complications associated with post-traumatic orbital deformities for which appropriate primary reconstruction could not be achieved. The primary goal in reconstructing the internal orbital cavity is to restore the preinjury anatomy of the hard tissue. Post-traumatic complications are mainly caused by defects in the bony orbital floor rather than by changes in soft-tissue content.^{1,2}

Depending on the location and size of the defect, lyophilized dura, silastic, polyethylene or polydioxanone sheets, hydroxyapatite blocks, titanium meshes, ceramic inlays, or autogenous bone grafts are materials recommended for reconstruction. Elastic materials are often unable to withstand the static or dynamic stresses associated with large defects. These materials are also prone to foreign-body reaction, and only fibrous connective tissue remains after resorption. Autologous bone grafts are rigid and cannot be adapted to an individual's

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unique anatomy. Morbidity of the donor region also occurs. Furthermore, resorption and displacement of the implanted grafts often occur if they are not positioned and fixed precisely.

To minimize these postoperative complications and to improve correction, titanium meshes can be used to connect large orbital defects. However, adjusting to individual anatomic requirements can be time-consuming, especially if the deep orbital cone is affected or scarring makes identification of stable posterior landmarks difficult.¹

Navigation-aided procedures improve the accuracy of placing dislocated bone parts.^{3,4} The use of electronic support to reproduce the orbital floor anatomy exactly by inserting bent titanium meshes or other materials intraoperatively is still a challenge. Individually preformed grafts are necessary to close this inaccuracy gap. Their production can easily be integrated into the planning procedure.

TECHNIQUE

Virtual reconstruction is performed using three-dimensional (3D) software (Voxim, IVS Solution, Germany). Processing datasets are obtained from preoperative diagnostic computer tomography or cone-beam tomography; the latter offers a reduction in radiation dosage and easier data acquisition protocols. By selecting bone-specific Hounsfield units, it is possible to depict the skeleton and to mark the same landmarks in different views.

Marking the orbital floor of the unaffected side in separate sagittal and coronal layers results in a virtual 3D mesh with defined distances. Mirroring the unaffected side onto the affected side is a standard procedure. The distance between the marked layers, as a multiple of 0.5 mm, can be selected depending on the resolution required. The natural borders of the frontal and lateral orbital frame determine the starting layers. Setting a virtual plane under the constructed mesh provides a basis for measuring the perpendicular length between

Figure 1 Illustration of the virtual mesh for evaluating the shape of the orbital cavity. A virtual plane under the constructed mesh provides a basis for measuring the perpendicular length between corresponding points on the virtual mesh and the plane.

corresponding points on the virtual mesh and on the plane (Fig. 1). Combining the mesh grid distances and the length values produces x-, y-, and z-coordinates for each point, which are saved in a database.

The x- and y-coordinates direct a robot over a template table consisting of a perforated metal plate equipped with gliding metal cylinders. Using the z-coordinates, the machine presses the cylinders into modeling clay, which hardens after 30 minutes of exposure to air. This procedure transforms the virtual surface into a physical surface.

Figure 2 An individual three-dimensional implant for the orbital cavity shows the typical shape of the orbital floor and the medial aspect.

If required, adapting the mesh and cutting it to size are done by hand using the template table before the operation (Fig. 2). Intraoperatively, the preformed titanium mesh can be inserted and positioned using navigation-aided procedures. However, such an individually preformed mesh is automatically positioned correctly.

DISCUSSION

This procedure provides a way of producing individually preformed osteosynthesis plates for orbital floor reconstruction, which is transferable to other types of osteosynthesis plates. The use of such plates leads to optimal anatomical reconstruction of the orbital floor. Fewer manipulations of the soft tissue are necessary because fewer trials are needed to fit the plates into the orbital cavity. Concomitantly, operation time decreases. Bending should not be a problem because rigid titanium meshes can be preformed. When the diagnostic dataset is available, the production time for producing an individual template is about 1 hour. Compared with stereolithography, costs are minimal.⁵

As a result of the daily diagnostic activity of a hospital, terabytes of datasets are produced,

archived, and available as a new source of electronic data. The use of this measurement procedure creates a large amount of surface data. Because the presented devices are not available at every hospital, these data can be used for recalculating and clustering the surface of the skeleton, and for producing physical template sets or industrial preformed titanium meshes specific for age, sex, and other variables.

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