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NEWS FROM THE AO DEVELOPMENT INSTITUTE (ADI)

Three-dimensional statistical shape analysis—a useful tool for developing a new type of orbital implant?

What is the average three-dimensional (3-D) shape of the orbit? Is size related to shape? Is there a relevant difference between the left and the right orbit or between different individuals? If so, can it be categorized? In replying to these questions we aim to improve the quality in the repair of complex orbital fractures (COF).

Clinical background

The repair of COF is still a clinical challenge as limited access and visibility make exposure difficult and correct implant-shaping and -positioning is not easy to achieve. Within this fracture pattern the posterior medial wall and orbital floor is an area of special importance where inadequate reconstruction leads to serious functional and cosmetic defects. Typically globe position is affected, resulting in visual impairment and posttraumatic enophthalmos. In order to improve and facilitate the repair of COF, an anatomically preshaped implant which could be perfectly positioned using active intraoperative navigation would be desirable.

In order to achieve this, a more detailed 3-D specification of the anatomy of the bony orbit is necessary. Our objective is to introduce a method for the 3-D statistical assessment of normal orbital shape and its variability. Therefore, with the support of the AO Research Fund, a collaboration between the AO Development Institute (ADI) in Davos, the Konrad Zuse Zentrum für Informationstechnik Berlin (ZIB), and clinicians has been established.

3-D statistical shape analysis

To build statistical orbital models (Fig 1) 3-D triangulated shapes have first to be extracted from the CT data by an expert, using manual, semi-automated segmentation tools. In a second step the expert determines anatomically meaningful patches or regions on the orbits. Patch boundaries are constructed by specifying characteristic anatomical landmarks. Finally the computer determines the corresponding points and produces a statistical model, based on principal component analysis. Such a model contains all shapes of the sample set and enables users to visualize in 3-D the mean shape and its most important variations (Fig 2 and Fig 3).

Conclusions

We describe a method to capture patterns of shape variability, providing a useful and powerful tool to assess the variations of the bony orbit. In order to render the variability of a statistical model, it can be visualized, animated or quantified in different ways (Fig 3). Our experience is that among different pathways the methodology may vary, firstly according to the definition of the number and distribution of suitable anatomical landmarks and secondly, depending whether only shape, or shape and size play an important role.

The method is applicable to many medical problems and disciplines. In technical terms it may be adopted to automate the task of image segmentation or to generate virtual templates. As illustrated in Fig 4, several orbital shapes can be produced by rapid prototyping. It may help the clinician to better describe and understand the difference between pathological and normal shape conditions as observed in trauma surgery or craniomaxillofacial deformities. Further it may help to improve analysis, planning, and simulation of surgical procedures.

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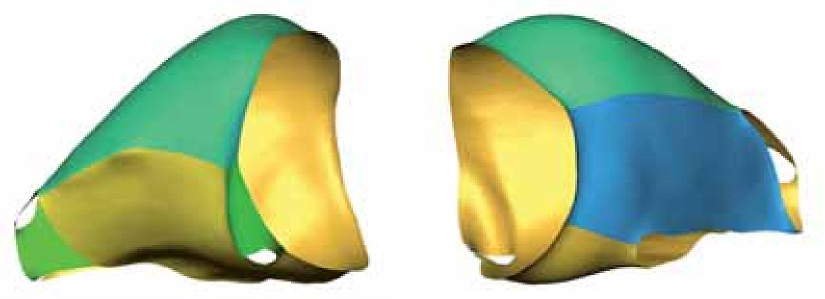

Fig 1 Statistical shape model of a left orbit with patches.

Fig 2 Three shape variations of the orbit, generated from the statistical model.

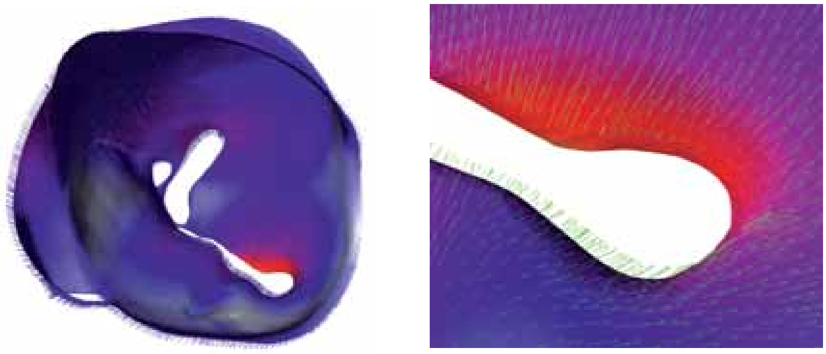

Fig 3 Visualization of shape variation by colormaps or distance vector fields.

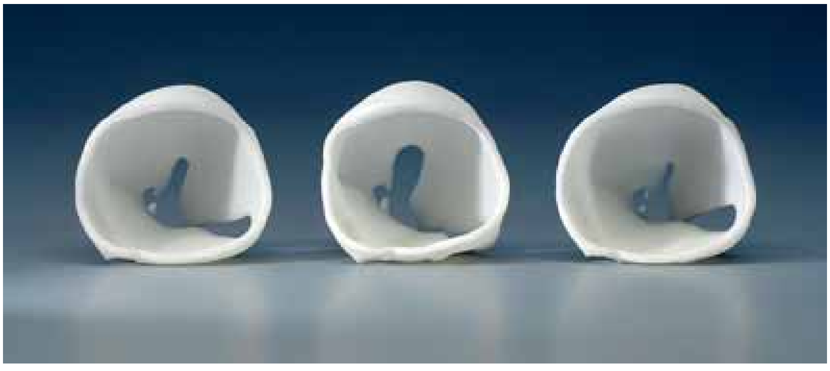

Fig 4 Illustration of shape variability using rapid prototyping.