Computer-Aided Planning and Reconstruction of Cranial 3D Implants

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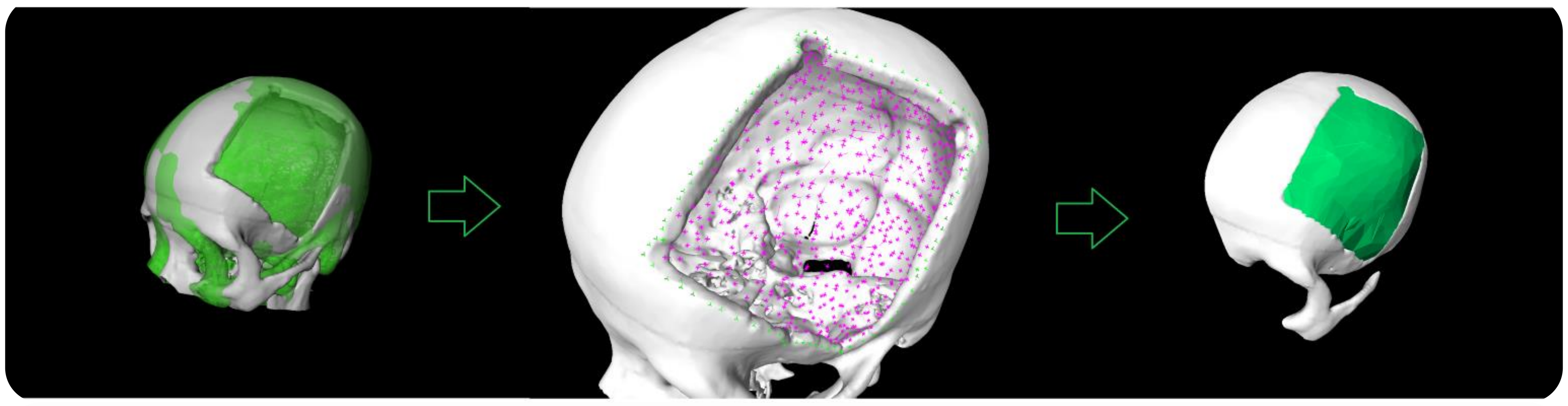
Purpose

Cranioplasty is among the oldest surgical procedures and trauma, infections, tumors and compression caused by brain edema are some of the reasons for the removal of bone[1]. However, the reconstruction becomes difficult, if the defect is large and located in the fronto-orbital region, which is an area requiring aesthetic considerations. Thus, good preoperative evaluation, surgical planning and preparation, and accurate restoration of the anatomical contours are mandatory for a satisfactory outcome [2]. Computer-aided planning of cranial 3D implants has gained importance during the last decade due to the limited time in clinical routine, especially in emergency cases and to avoid complications[3]. But, state-of-the-art techniques are still quiet time consuming due to a low level approach. Generally speaking, CT scans are used to design an implant, often using non-medical software, which is not really appropriate. As a result, neurosurgeons spend hours with tedious low level operations on polygonal meshes for designing a satisfactory 3D implant. Commercial implant modeling software[4], like MIMICS, Biobuild or 3D-Doctor, is not always available, but if it is, using such software can be very complex. In this paper, an alternative software allowing fast, semi-automatic planning of cranial 3D implants under MeVisLab[5,6] is presented.

Methods

The introduced method uses non-defected areas of the patient's skull as a template for generating an aesthetic looking and well-fitting implant. This is accomplished by mirroring the skull itself and fitting it – at least partly – manually into the defected area. By further marking the defect's boundaries and the surface of the mirrored template in the defected area, the implant's shape is defined. Similar methods have been proposed before[7], however our approach enhances the template with automatic application of Laplacian smoothing and Delaunay triangulation, giving the implant a better fitting shape.

Figure 1 – Overall planning workflow, left: original skull (white) and mirrored skull (green), middle: marker cloud with edge (green) and surface (magenta) markers, right: final implant.



Results

Skull mirroring, marker setting and the smoothing was integrated into a user-friendly planning prototype, which was found easy to use and much faster than the non-medical modelling software applications used by our clinical partners. The planning of a 3D implant with our prototype took a new user less than thirty minutes, while the first author was even able to obtain a similar result in about twelve minutes. in Figure 2. another clinical, more complex, case is shown. Summarized, the proposed software tool enables surgeons to generate a well-fitting implant which is able to be generated within several minutes, also improving the user's experience and reducing time consumption, compared to the other methods. Yet, the software was not tested in clinical trials but with the mentioned advantages the tool could be an alternative to commercial software not available at a clinic.

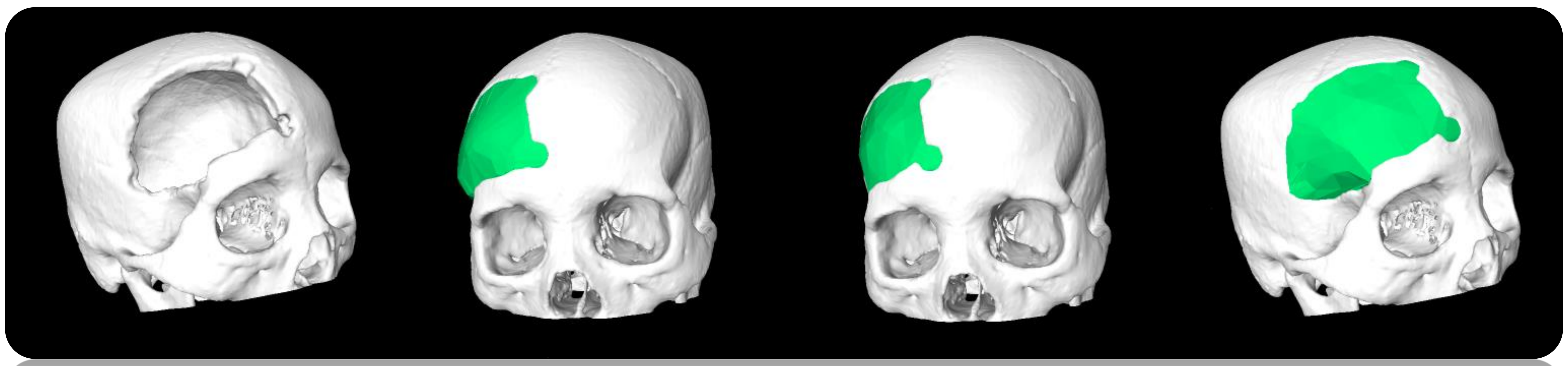


Figure 2 - Result of a clinical case with a large and more complex cranial defect on right-front side (left). Due to the complex form the unsmoothed implant (middle-left) results in a well-fitting but not aesthetic looking result. However, applying the smoothing algorithm results in a more suitable form (right and middle-right).

Conclusion

In this publication, the semi-automatic planning of cranial 3D Implants under MeVisLab has been introduced. As a result, we demonstrated that MeVisLab could be an alternative to complex commercial planning software which may also not be available in a clinic. Since pure mirroring is not sufficient for an implant, because human heads are in general too asymmetric, the user can perform afterwards Laplacian smoothing, followed by Delaunay triangulation for generating an aesthetic looking and well-fitting implant. Finally, our software prototype allows to save the designed 3D model of the implant as a STL-file for 3D printing. The 3D printed implant can be used for further pre-interventional planning or even as the real implant for the patient[8]. Further, there are several areas for future work, for example a comparison with commercial and open-source[9] software.

Video Tutorial: https://www.youtube.com/watch?v=8epxE8pUMPk

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