Computer-Aided Planning of Cranial 3D Implants

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Purpose

Computer-aided planning of cranial 3D implants has gained importance over the last decade due to the limited time in clinical routine, especially in emergency cases. However, state-of-the-art techniques are still very time consuming due to a low level approach. In general, CT scans are used to design an implant, often utilizing non-medical software, which is not really appropriate. Neurosurgeons spend hours with tedious low level operations on polygonal meshes for designing a satisfactory 3D implant. Commercial implant modeling software[1], like MIMICS, Biobuild or 3D-Doctor, is not always available, but if it is, using such software can be very complex. We present an alternative software allowing fast, semi-automatic planning of cranial 3D implants under MeVisLab. The method uses non-defected areas of the patient's skull as a template for generating an aesthetic looking and well-fitting implant. This is done by mirroring the skull itself and fitting it, at least partly, in the defected area. Similar methods have been proposed in previous works[2], but our approach enhances the template with Laplacian smoothing[3], followed by Delaunay triangulation[4], to give the implant a significantly better fitting shaped.

Methods

For the cranial implant planning, a custom data-flow network was set up in MeVisLab[5], a popular medical imaging platform. In an first step, the patient's dataset is loaded twice, whereby one object is mirrored to serve as a template (figure 1 left, green). Furthermore, for the planning process, it is necessary to have a view from the outside as well as from the inside onto the defected area. Therefore, we established a module network generating a cutting plane for both the original and the mirrored skull (figure 1 right). Then, markers are set, beginning with so-called edge markers for the borders of the implant. Next, we set the surface markers, which fit the mirrored object into the defect area. This is done for both sides, the inside and the outside edges and surfaces, to define the shape of the implant (figure 1 middle). The markers serve as input for the Delaunay triangulation module, available in MeVisLab. The triangulated mesh can be further enhanced by the user with a Laplacian smoothing module.

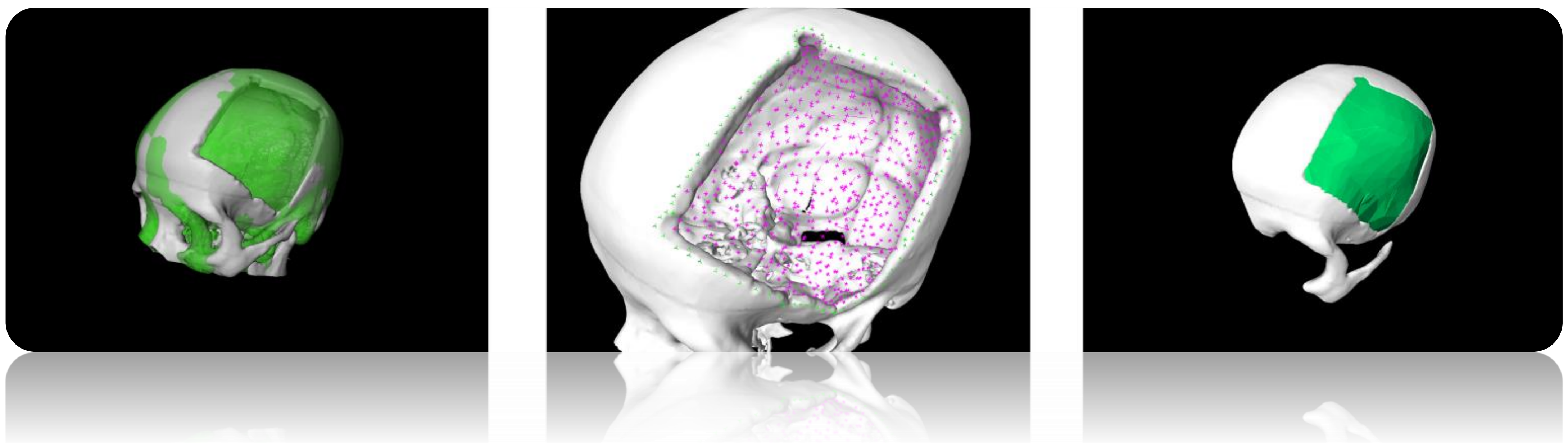

Figure 1 – Overall planning workflow, left: original skull (white) and mirrored skull (green), middle: marker cloud with edge (green) and surface (magenta) markers, right: final implant.

Results

On average, the overall planning time for a sufficient cranial 3D implant could be reduced to under thirty minutes, in comparison to three hours reported by our clinical partners. The mirroring of the skull, the setting of the markers and the smoothing is integrated in a user-friendly planning prototype. Our prototype was found easy to use and much faster. The prototype enabled planning a 3D implant in under thirty minutes by a surgeon, while the first author was able to obtain a similar result in twelve minutes. Figure 2 presents the result of a clinical case with a large cranial defect on the left side. The resulting output shows a well-fitting 3D implant on the inner as well as on the outer surface. The outcome of an additional Laplacian smoothing is shown on the right side of Figure 2 (red circle). Tweaking on the vertex level is not necessary in our prototype, because markers can directly be placed on existing surfaces. However, individual markers may also be manipulated individually as fallback option, providing a higher degree of freedom.

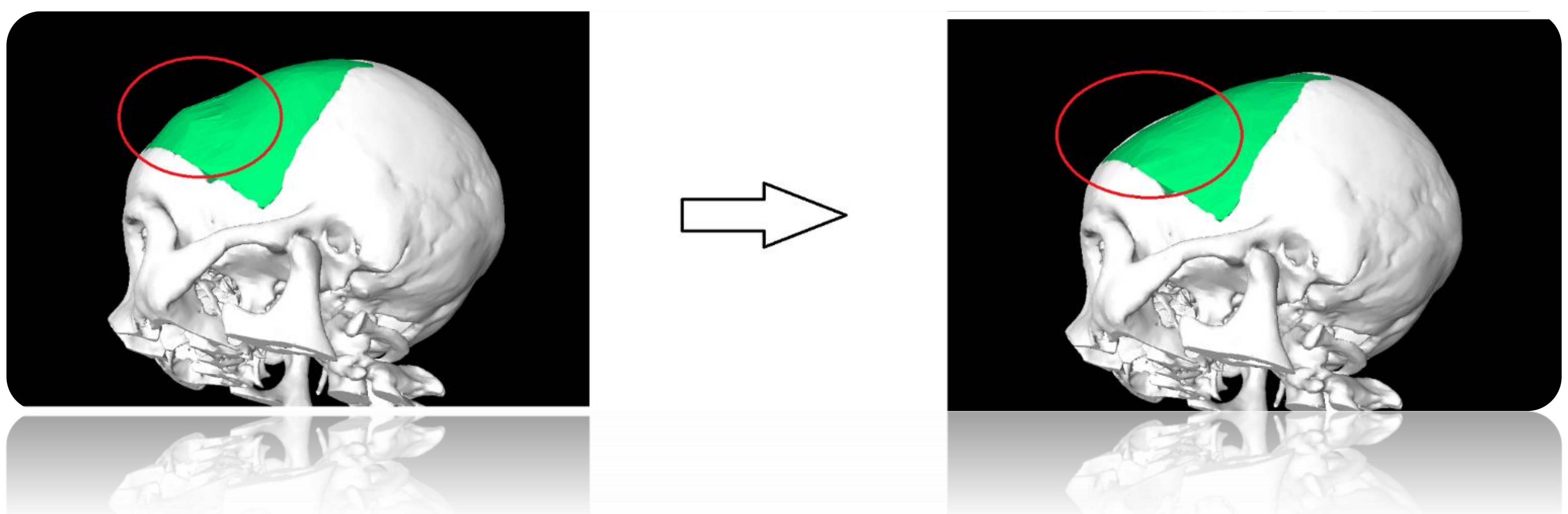

Figure 2 – Outcome of an additional Laplacian smoothing (red circle).

Conclusion

In this contribution, the semi-automatic planning of cranial 3D Implants under MeVisLab has been presented. We describe a MeVisLab prototype consisting of a customized data-flow network. Results shows that MeVisLab can be an alternative to complex commercial planning software which may also not be available in a clinic. There are several areas of future work, for example a comprehensive comparison and evaluation with commercial software products and an open-source version of our prototype[6].

Video Tutorial

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

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