Computer-aided Reconstruction of Facial Defects

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Purpose

Facial reconstruction after bone fractures is an important application of computer-aided surgery[1]. A common method of osteosynthesis are adaptive miniplates[2], titanium made metal plates placed with at least two ring sections per fracture fragment. For plate fixation on the bone special fixation screws are drilled. The implants are available in different sizes and dimensions and are usually bent intraoperativly to adapt them on the underlying bone. In this contribution, we propose a novel method for computer-aided planning and the creation of individually designed patient implants in facial reconstruction using miniplate osteosynthesis.

Methods

CT-datasets from the clinical routine were used in a prospective study for the creation of individual designed osteosynthesis materials. An interactive planning software has been implemented in C++ with the medical prototyping platform MeVisLab[3]. Computation runs in real-time on a standard desktop computer (Intel Core i7–930 CPU, 4 × 2.80 GHz, 6 GB RAM, Windows 8.1), allowing for interactive feedback. On the workstation the user chooses an implant type and selects any location on the surface of the facial model to place the implant's center point. Using the center as a seed point, the baseline curvature is calculated by casting rays along the baseline and checking for surface intersection positions. Using the resulting curved baseline, the implant shape is generated by placing precomputed polygonal meshes at the locations along the curved baseline corresponding to the implant's dimensions. Each ring element of the implant is oriented to be aligned with the surface tangent plane so that the plate fits perfectly to the underlying bone structure. Finally, the straight sections bridging the rings are generated by deforming a template mesh with rectangular footprint. Runtime is optimized by limiting computations to the region of interest around the seed point. Finally plate positions and adaption was independently assessed by two specialists for maxillofacial surgery by completing given tasks by the system. Figure 1 gives an overview of the workflow.

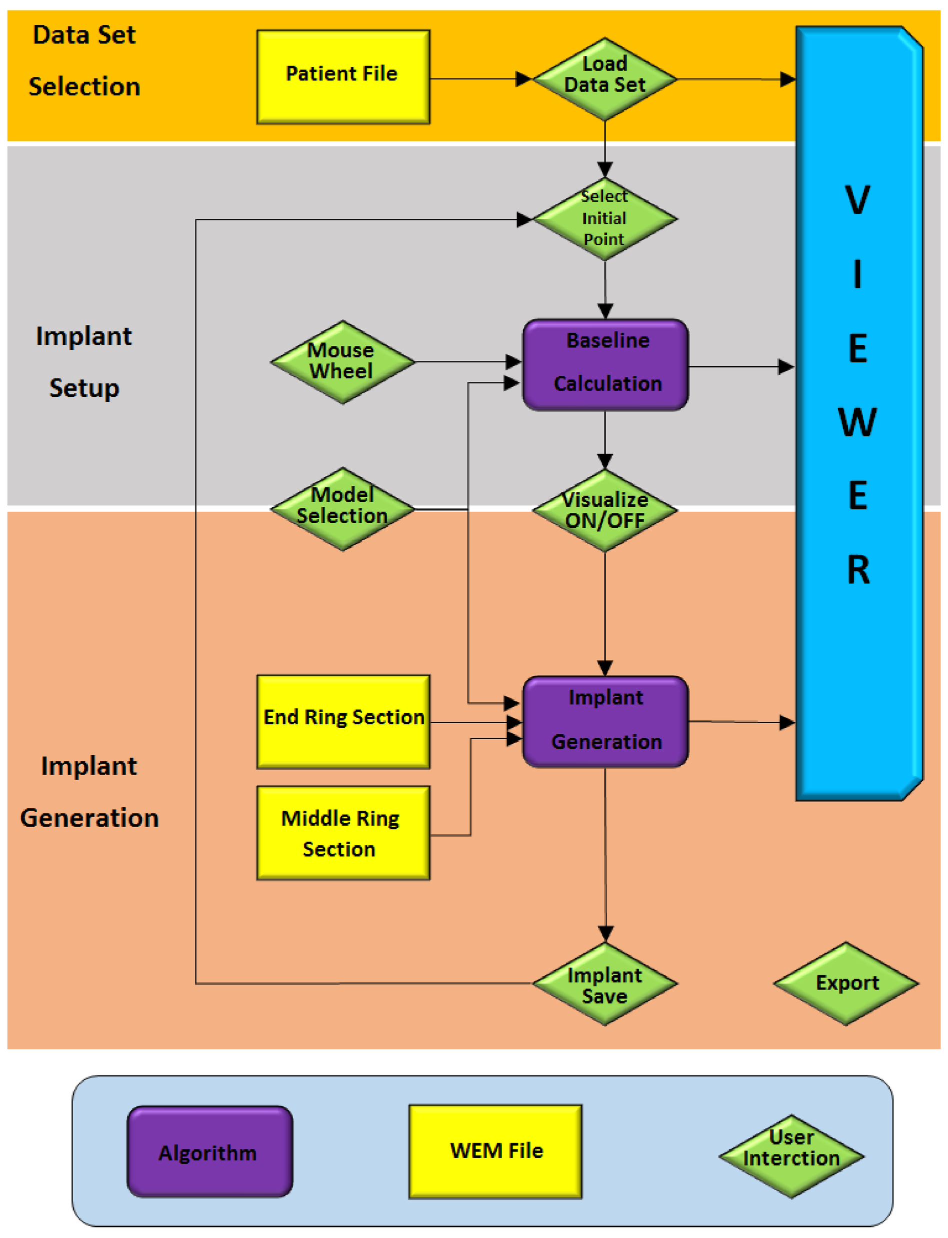


Figure 1 – Overview of the implant generation. In the orange section, the user loads the patient's data set which is then visualized by the *viewer* block. Followed by the implant set up (grey section) where the user sets the initial point (implant center). Next, the baseline is to calculated which shows the user the current position and direction of the implant, depending on the mouse wheel value, the selected implant model and the initial set point is also visualized by the viewer. In the apricot section the implant is calculated *Implant Generation* Block) by activating the *Visualize ON/Off* button. For the implant generation also the implants ring sections, middle and end parts, are required. The final implant is then visualized together with the baseline and the patient's data set. By using the block *Implant Save*, the user saves the current implant(s) for this session and starts setting up new ones. By exporting, the current visualized implants are stored as a STL file on a local path.

Results

Computer-aided bone plate adaption was able for every type of minplate that was used with the software. Virtual plate adaption. provided correct positioning and satisfying results at any position on the facial bones. Medical specialists did neither require any further training time to use the software's functions, nor they fail in completing any given task by the system. Figure 2 shows the result of adaptive miniplate placements at a variety of positions and Figure 3 shows the user interface including a loaded data object, baseline and **individually** generated implant.

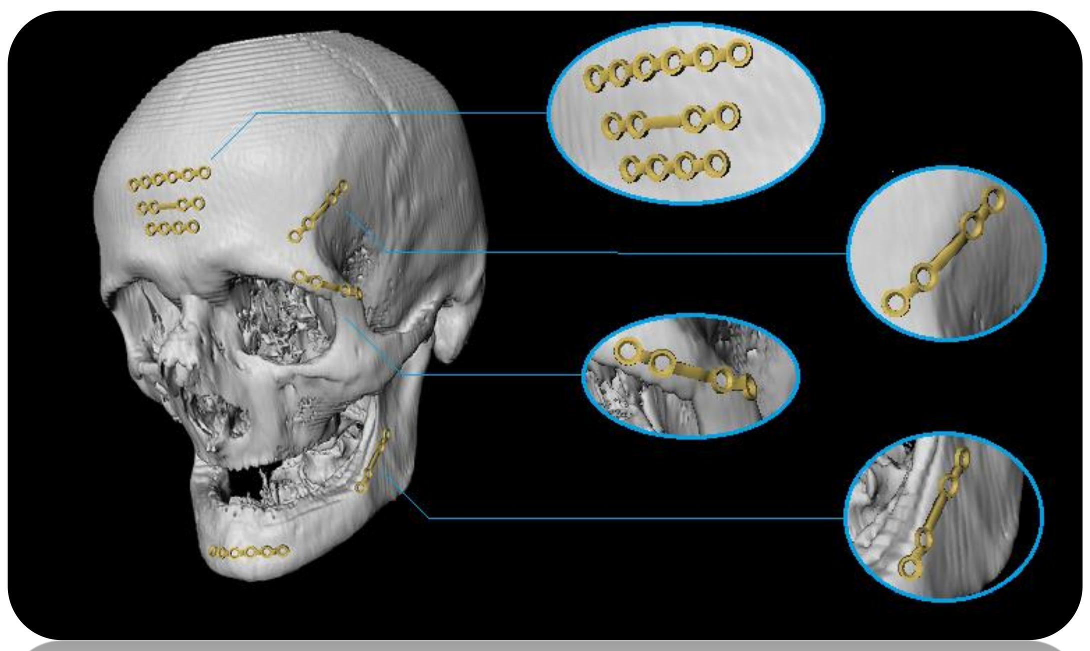
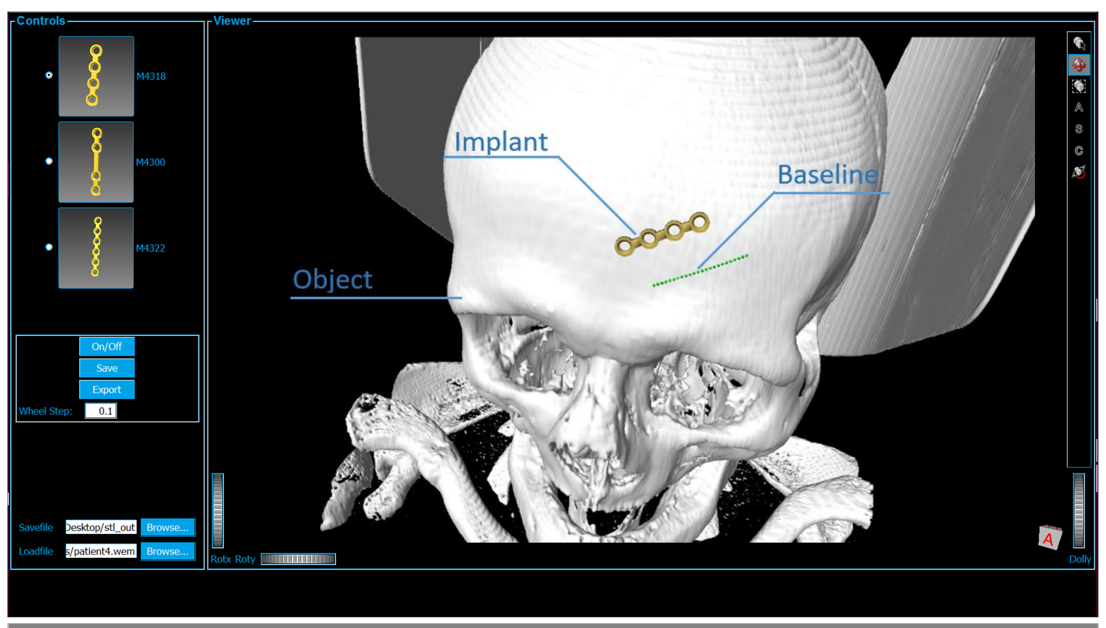


Figure 2 – Result of computer aided adaptive miniplate placements in various directions and locations.

Figure 3 – User interface including object, baseline and generated implant.



Conclusion

The software was used on patient CT data provided from the clinical routine by the Clinical Department of Oral and Maxillofacial Surgery of Medical University Graz. Bone plates were well adapted with respect to the underlying surface and anatomical structures, providing an perfectly fitting osteosynthesis material for an ideal postoperative result in a reduced operation time. Further, the generated implant models can be stored in STL-file format, which is a common format used in 3D-printing. Therefore, surgeons have the opportunity to create the individually designed implant with a 3D printer, instead of time consuming intraoperative bending of osteosynthesis materials. Moreover, the physicians describe the handling as very user-friendly and accurate. By selecting the placement point on the patient's surface, the surgeons are able to place the implant at any desired position with the option of further change in position as well as changes in the implant's pointing direction and implant type. In summary, the developed software provides a tool for surgeons, to design and in a second step produce individually created patient implants for osteosythesis of facial defects, within the clinical center but without using any monetary services provided by the industry. Additionally this tool can easily be tested and further developed by other groups, since the software is based on an open-source platform.

There are several areas for future work, like offering more complex implants to the user and a comparison and evaluation with commercial software products.

Video Tutorial

https://www.youtube.com/watch?v=Od5xxuERJ8E

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