An Online Platform for Automatic Skull Defect Restoration and Cranial Implant Design

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INTRODUCTION

We introduce a fully automatic system for cranial implant design, a common task in cranioplasty operations. The system is currently integrated in Studierfenster (http://studierfenster.tugraz.at/), an online, cloud-based medical image processing platform for medical imaging applications (see Fig.1). Enhanced by deep learning algorithms, the system automatically restores the missing part of a skull (i.e., skull shape completion) and generates the desired implant by subtracting the defective skull from the completed skull. The generated implant can be downloaded in STereoLithography (.stl) format directly via the browser interface of the system. The implant model can then be sent to a 3D printer for in loco implant manufacturing (See Fig.2). Furthermore, thanks to the standard format, the user can thereafter load the model into another application for post-processing whenever necessary. Such an automatic cranial implant design system can be integrated into the clinical practice to improve the current routine for surgeries related to skull defect repair (e.g., cranioplasty). Our system, although currently intended for educational and research use only, can be seen as an application of additive manufacturing for fast, patient-specific implant.

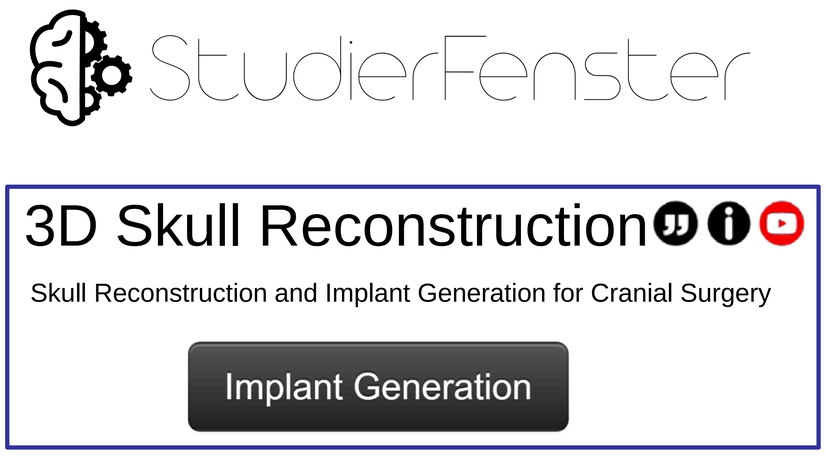

Fig. 1. Logo of the online medical image processing system Studierfenster (http://studierfenster.tugraz.at/) and the automatic cranial implant generation module in Studierfenster. Note: the YouTube icon shows a video demonstrating the usage of the module.

METHODS

The automatic cranial implant design module is built upon Studierfenster, which is a client-server based platform. As shown in Fig. 3, the server side is responsible for computation-heavy tasks, e.g., skull shape completion using a deep neural network and mesh conversion. The client side is a browser, where users can download the generated 3D implant model and interact with the results. Fig. 4 shows the boundary and thickness requirement for a clinically usable implant.

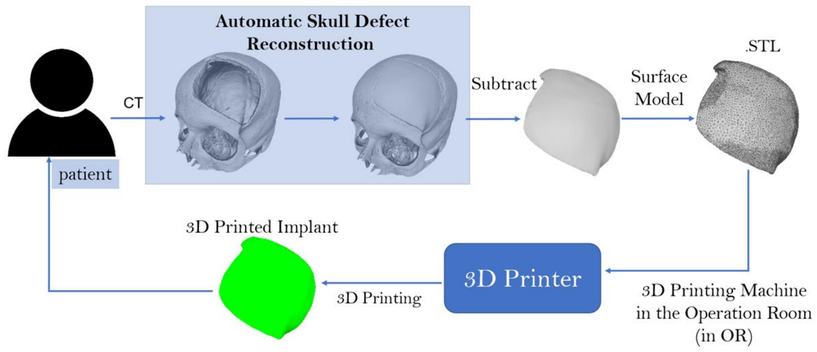

Fig. 2. An optimized cranioplasty workflow where the cranial implant is modelled and then manufactured directly in the operation room.

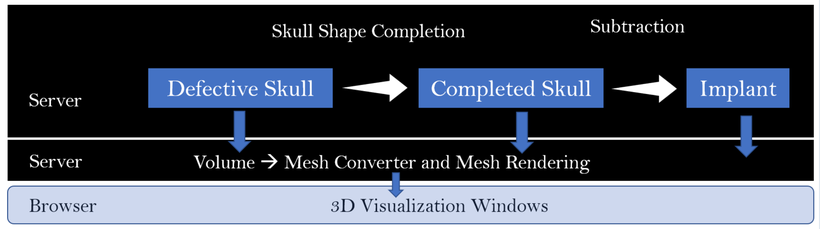

Fig. 3. The overall architecture of the cranial implant design module in Studierfenster. On the server side runs the skull shape completion network and the volume to mesh conversion unit. The browser side renders the mesh for user interaction.

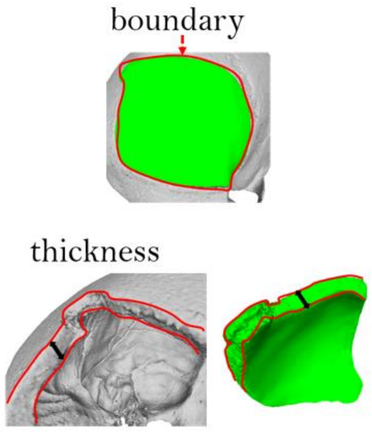

Fig. 4 How the cranial implant (illustrated in green) should fit with the skull defect (gray) regarding the defect boundary and bone thickness.

RESULTS

Qualitative (Fig. 5) and quantitative (Fig. 6 & Tab. 1) evaluation of the online system.

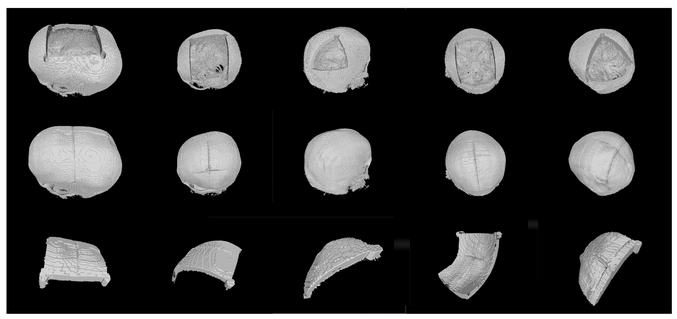

Fig. 5 First to third row: mesh rendering of the defected skull, the completed skull and the implant for case 01 –case 05, corresponding to the first to third window in the implant generation module.

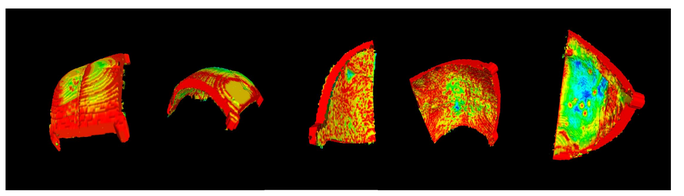

Fig. 6 3D Red-Green-Blue colormap of the Hausdorff Distance (HD) for case 01 – case 05.

Tab.1 Hausdorff Distance (HD) for case 01 – case 05.

case	minHD	maxHD	meanHD	RMS
case 01	0.0000	6.7454	0.9959	1.3646
case 02	0.0000	4.6368	0.7094	1.0114
case 03	0.0000	3.5178	0.5328	0.7998
case 04	0.0000	4.8477	0.7525	1.0836
case 05	0.0000	5.8737	1.4917	2.0154

REFERENCES

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[2] Li, J. and Egger, J. Towards the Automatization of Cranial Implant Design in Cranioplasty: First Challenge, AutoImplant 2020, Held in Conjunction with MICCAI 2020, Lima, Peru, October 8, 2020, Proceedings, Lecture Notes in Computer Science, Springer International Publishing.

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