AI-Supported Osteosynthesis Planning: A Web-Based Approach

J. N. Zierke[1], M. Heyland[1], A. Bejaoui[2], T. Meyer[2], R. Bandelin[2], H. Tzschätzsch[2], F. Balzer[2], N. Tuttle[3], S. Hölzl[3], H. Zhou[4], P. Damm[1], T. A. Auer[5], G. N. Duda[1], D. A. Back[3]

[1] Julius Wolff Institute, BIH at Charité – Universitätsmedizin Berlin, Germany; [2] Institute of Medical Informatics, Charité Berlin, Germany; [3] Center for Musculoskeletal Surgery, Charité Berlin, Germany; [4] Learning and Intelligent Systems, Technische Universität Berlin, Germany; [5] Department of Radiology, Charité Berlin, Germany

INTRODUCTION

Musculoskeletal trauma represents a serious economic burden, with proximal tibial fractures occurring at an incidence of 10.3-32/100,000 per year [1,2]. These fractures are often caused by falls or road traffic accidents [3]. Surgical outcomes are influenced by the surgeon's experience [4]. Providing pre- and intraoperative planning support could help manage complex fracture reduction and stabilisation procedures more effectively. As a potential solution, an AI-based algorithm developed within the *REPAIR* Project (repair.charite.de) has been applied to provide evidence-based recommendations for anatomical reduction and fixation to improve fracture treatment. This approach is demonstrated here using proximal tibial fractures, which can vary widely in severity and pose significant treatment challenges.

An additional aim of the project is to implement the *REPAIR* osteosynthesis planning algorithm within an internal server environment to provide clinic-wide access via a web-based platform.

MATERIAL AND METHODS

Osteosynthesis algorithm

The automated workflow is currently under development and will include several sub-algorithms (figure 1), starting from preoperative CT and patient metadata:

1. **CT based fracture segmentation** using U-net neural networks
2. **Fracture classification** according to different classification systems, e.g., AO or Schatzker
3. **Virtual fracture reduction** using Spatial Transformer Network (STN), Auto-encoder (AE) architectures and Blackbox Optimisation for registration and prediction of correct bone fragment reduction
4. **Landmark detection** using Spatial Transformer Networks
5. **Osteosynthesis** choice and placement **recommendations** using a decision algorithm based on surgical evidence derived from scoping reviews, retrospectively analysed fracture cases, and expert knowledge

The algorithm code is compiled as a *Singularity Image File* and stored on the Charité High Performance Computing (HPC) Cluster.

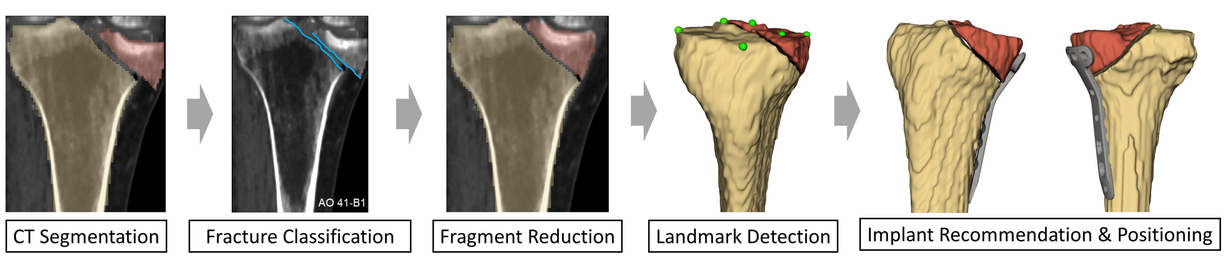

Figure 1. Subalgorithms of the REPAIR osteosynthesis planning algorithm.

Web-based implementation

In collaboration with the *BIOQIC* research training group, an existing internal server infrastructure [5] was extended to integrate the *REPAIR* algorithm as a web-based application. The system architecture is illustrated in figure 2.

The web interface guides users through three main steps:

1. **Data upload** – uploading CT image data along with associated patient metadata
2. **Pipeline selection** – selecting the desired processing workflow, such as individual CT segmentation tasks or comprehensive osteosynthesis planning
3. **Result visualisation and download** – viewing and downloading the processed output (see figure 3)

Once data is uploaded, it is securely transferred to the Charité High Performance Computing (HPC) cluster for processing. To initiate the selected analysis pipeline, a message broker (*RabbitMQ*) sends a control message to the HPC system. There, the job is scheduled and executed using the *Slurm* workload manager. The required computational resources are automatically allocated, and the selected algorithm is run on the HPC cluster. After completion, the output data is transferred back to the *BIOQIC* server. It is then made available to the user through the third interface for interactive visualisation and download (figure 3).

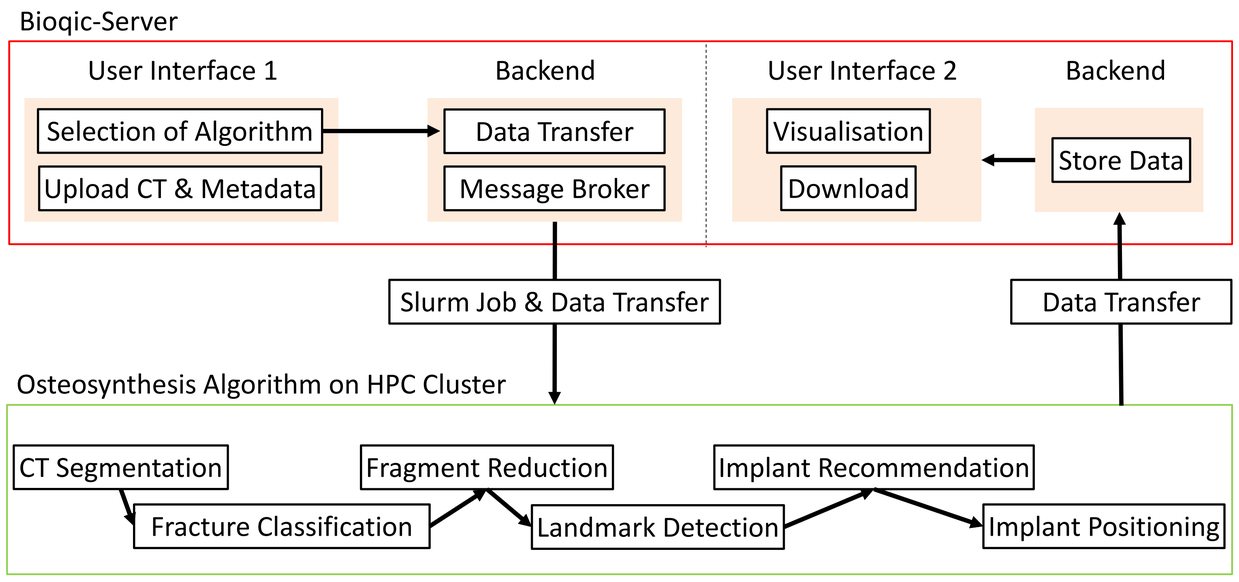

Figure 2. Schematic structure of the REPAIR web app prototype.

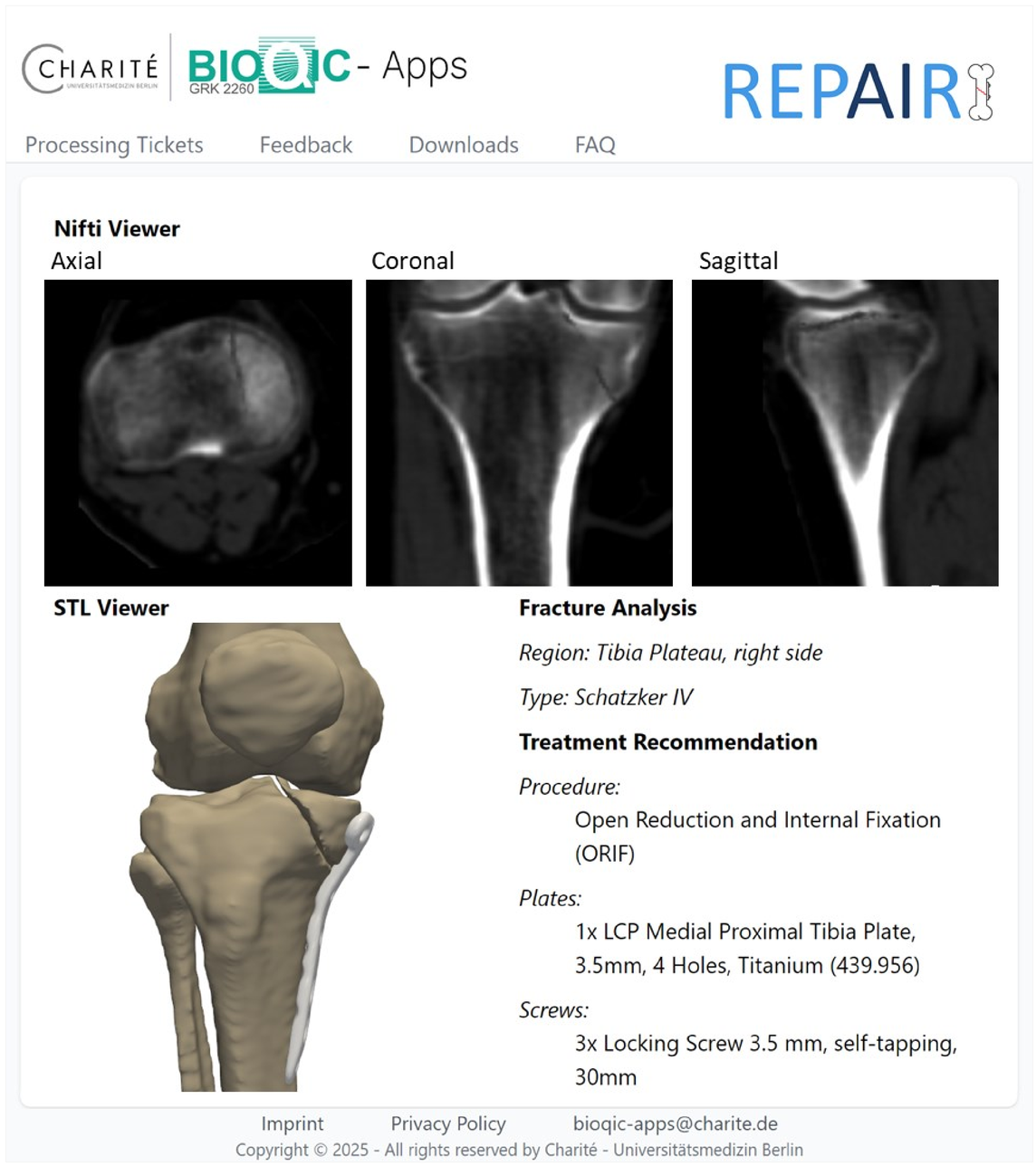

Figure 3. REPAIR web app prototype showing the results of an osteosynthesis planning: CT slice viewer, 3D STL model viewer and text-based recommendation.

RESULTS AND DISCUSSION

The initial prototype is a web-based application offering a selection of algorithms, including an early version of an osteosynthesis planning tool. After uploading fracture CT scans and patient metadata, the decision algorithm runs on an HPC cluster to recommend the implant type and positioning. The results are displayed in dedicated interface panels (figure 2), featuring a CT viewer with axial, coronal, and sagittal views, a text summary of the analysis and recommendations, and a 3D viewer showing bone structures and suggested implants. In future iterations, the application's functionality will be expanded and prospectively evaluated by surgeons of a level 1 trauma centre during routine clinical use.

Additional details about the project can be found at repair.charite.de.

ACKNOWLEDGEMENTS

This work was supported by the Innovation Fund of the Federal Joint Committee Germany (Gemeinsamer Bundesausschuss, G-BA; project no. 01VSF22039), German Research Foundation (SFB1340 Matrix in Vision, GRK2260 BIOQIC, FOR5628) and OrthoLoad Club

REFERENCES

[1] Elsoe et al., Orthopedics, 38:e780-e786, 2015; [2] Vestergaard et al., Acta Orthopaedica, 91:109-114, 2020; [3] Wennergren et al., Injury, 49:2068-2074, 2018; [4] Maruthappu et al., Annals of Surgery 26:642-647, 2015; [5] Meyer et al., Magn Reson Med. 88:1840-1850, 2022