COMPUTATIONAL OPTIMIZATION OF THE PRIMARY FIXATION STABILITY OF PROXIMAL TIBIA FRACTURES

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Introduction

Bone fractures cause about two million hospitalizations per year just in the US. Some of them are highly complex with complication rates of up to 28% [1]. It is often unclear how the screws and plates shall be positioned for a specific fracture case and outcomes heavily depend on the surgeon's experience.

An objective measure for the performance of clinically accomplished fracture reconstructions by means of finite element models (FEMs) under biomechanical loading was previously described [2].

The goal of this study was to use the same computational method for optimizing screw and implant placement of a clinically failed, multifragmentary tibia plateau fracture reconstruction (Schatzker VI).

Methods

Using the previously introduced method the clinical reconstruction was reverse engineered by means of a preop and postop CT scan for the segmentation of bone fragments and hardware materials (i.e. osteosynthesis screws and plates), respectively [2]. Hounsfield-Unit-derived bone material properties as well as joint and muscle forces from subject-specific musculoskeletal gait models were integrated in the FEM (**Figure 1**).

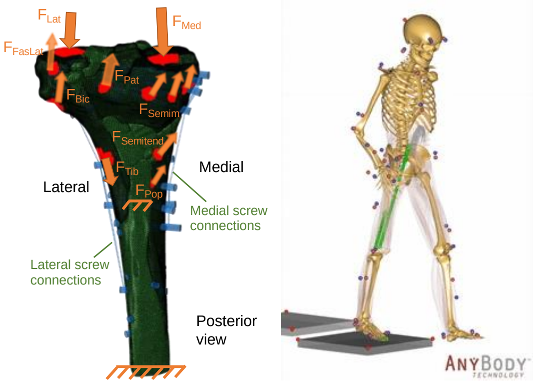

Figure 1: Setup of FEM (left) with bone fragments (green), screws (blue), knee joint reaction and muscle forces (orange); musculoskeletal gait model (right).

The case presented herein was clinically reconstructed with a posteromedial, lateral, and distal medial plate but required revision surgery one year postoperatively due to a non-union including failure of two medial screws. Thus, the reconstruction was optimized in two ways and compared to the clinical configuration:

- The medial plate was shifted more posteriorly to counteract the posterodistal fragment motion.
- A fully new configuration of screw placement with design freedom for patient-specfic implants.

Results

By shifting the posteromedial plate more posteriorly, the maximum fragment motion in a gait cycle was reduced by 28% and the load on the screws was distributed more evenly. By using the full design freedom for the fracture fixation construct, the fragment motion could be reduced approx. tenfold, whereby the von Mises stresses on the screws also highly decreased (**Figure 2**).

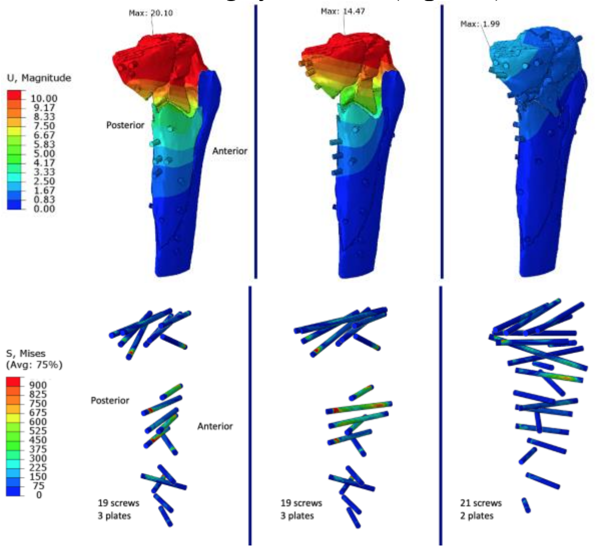

Figure 2: Fragment motion (top) and screw loading (bottom) of the clinical reconstruction (left, posterior plate shift (middle) and new screw configuration (right).

Discussion

The case study presented herein illustrates the potential for biomechanical optimization of complex fracture fixation constructs, although absolute values need to be interpreted with caution as this method has not yet been validated experimentally. However, the clinically broken screws also showed the highest von Mises stresses in the FEM, providing a qualitative clinical proof-of-concept. After validation of the model, clinical outcomes of the fracture fixation could be predicted by means of fragment motion and screw loading.

References

1. Ruffolo et al, J Orthop Trauma, 29(2):85-90, 2015
2. Comtesse et al, ESB Congress, Porto, June, 2022.

Acknowledgements

Our gratitude to Alex Baker and Marco Drago from the Institute for Biomechanics for their support.