Biomechanical subject—specific simulations of a fractured tibia treated with an intramedullary nail

Michael Roland[1*], Thorsten Tjardes[2], Bertil Bouillon[2], Stefan Diebels[1]

[1]Saarland University
Chair of Applied Mechanics
Campus A4 2, D-66123 Saarbrücken
m.roland@mx.uni-saarland.de

[2]Cologne Merheim Medical Center
Department of Trauma Surgery, Orthopedic Surgery and Sportstraumatology
Ostmerheimerstraße 200, D-51109 Köln
m.roland@mx.uni-saarland.de

ABSTRACT

A patient-specific model of a fractured tibia treated with an intramedullary nail is generated from a tomogram using an fully automated workflow presented in [2]. Therefore, the routinely acquired tomographic data is segmented semi-automatically and the material parameters are assigned with respect to image information given in Hounsfield units. Because of the high computational costs of the finite element simulations, adaptive meshes based on the concept of hanging nodes are generated and analysed.

In the first simulations, an elastic-plastic material model is used to compute the critical stresses and strains which are leading to a failure of the intramedullary nail. These results will be compared with the stresses and strains which are arise during a normal step forward of the considered patient. To achieve realistic boundary conditions for the finite element simulations of the step forward, a new fully integrated sensor insole is used to get the patient-specific ground reaction forces during gait. Then in a second step, the ground reaction forces are integrated in the OpenSim environment to receive the knee forces and the knee moments of the patient during gait. The results of the OpenSim simulations combined with the ground reaction forces achieved from the insole allow the computation of the stresses and strains in the cortical and the trabecular bone as well as in the intramedullary nail during a step forward of the patient.

In a third step, the results of these simulations can be compared with the critical stresses and strains from the computations of the implant failure. These considerations provide the orthopaedic trauma surgeons with more information about the biomechanical behaviour of patient-specific bone-implant-systems and can be used to support the surgeons in the selection and the planning of implants. The results of these simulations can also be used as starting point for several optimization processes, e.g. the fusion in the case of a non-union tibia fracture [1,3].

References

[1] T. Tjardes, M. Roland, R. Otchwemah, T. Dahmen, S. Diebels, and B. Bouillon, "Less than full circumferential fusion of a tibial nonunion is sufficient to achieve mechanically valid fusion - Proof of concept using a finite element modeling approach", BMC Musculoskelet. Disord., vol. 15, no. 1, pp. 1–7, 2014.
[2] T. Dahmen, M. Roland, T. Tjardes, B. Bouillon, P. Slusallek, and S. Diebels, "An automated workflow for the biomechanical simulation of a tibia with implant using computed tomography and the finite element method", Computers & Mathematics with Applications 06/2015; 70(5).
[3] M. Roland, T. Tjardes, R. Otchwemah, B. Boullion and S. Diebels, "An optimization algorithm for individualized biomechanical analysis and simulation of tibia fractures", Journal of Biomechanics, 01/2015; 48(6)