THE EFFECTS OF PARTIAL WEIGHT BEARING ON THE HEALING PROCESS VIA BIOMECHANICAL SIMULATION

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Introduction

Interfragmentary movement (IFM) is a key quantity for fracture healing and determined by the gait cycle and the weight bearing of the patient. Partial weight bearing is part of postoperative treatment schemes and the orthopedic surgeon usually gives instructions, such as 10kg, 20kg or half body weight bearing. Only personalized simulations can identify the effect of different partial weight bearing regimes on the IFM of individual patients. To realize a high degree of individualization in the virtualization process, we aimed to define patient-specific boundary conditions via musculoskeletal simulations based on motion capturing data of patients with fractures of the lower extremity. We hypothesized that different levels of partial weight bearing can be tested virtually, and that the impact on the IFM can be individually quantified.

Methods

To cover a wide range of partial weight bearing scenarios, data were collected from healthy subjects (n=22) in various partial weight bearing tests. Both, healthy subjects and patients were monitored with the motion capturing system Xsens^{TM}. To guarantee compliance with the different partial weight bearing regimes during each exercise, sensor insoles (Moticon^{TM}) were used as a live feedback system. In addition, the sensor insoles allowed for a subsequent analysis of the ground reaction forces and the gait line of both healthy subjects and patients. The subjects completed the timed up and go tests with and without crutches under different partial weight bearing loads with respect to their body weight. The collected data were then biomechanically analyzed and the individual movements were passed to the musculoskeletal simulation system AnyBody^{TM} (Figure 1 a)) to compute the corresponding joint and muscle forces and moments. These data now allowed to fit the patient data (n=5), collected in a similar way, to a wide variety of weight bearing regimes in order to investigate their influence on the IFM. Digital twins of the respective bone-implant-systems were generated based on post-operative clinical imaging and the corresponding joint forces were applied as boundary conditions in the simulations.

Results

The results revealed that a virtual analysis via a biomechanical simulation workflow of different partial weight bearing scenarios and their influence on the local mechanics in the fracture gap of the patients is possible (Figure 1, b)). Linking local stresses and strains in the fracture gap to the healing window (Figure 1, c)), cf. [1] and [2], offers the possibility to use the results in rehabilitation planning [3]. Furthermore, pathological processes resulting in non-union, or fractures displacement, especially in periarticular fractures, can be anticipated in the simulations and, therefore, can be avoid by personalized weight bearing recommendations.

Discussion

Since it is not possible to monitor a wide range of partial weight bearing regimes in one individual patient, a simulation-based workflow was chosen. This shows a clear correlation between fracture morphology, its treatment and the individual partial weight bearing. The effects on fracture healing are significant and have great potential for individualizing rehabilitation programs.

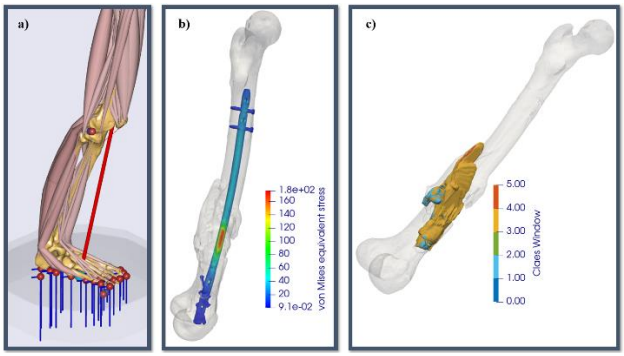

Figure 1:

a) Musculoskeletal Simulation
b) Mechanical Situation of the Treatment
c) Fracture Gap with Claes Window

References

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