Personalized musculoskeletal modeling for decision making in planning for derotation osteotomy

Philippe Bähler

Supervisors: Dr. Patric Eichelberger, PD Dr. Heiner Baur, Dr. med. Emanuel Liechti
Institutions: Bern University of Applied Sciences, Bern Movement Laboratory, Physiotherapy
University Hospital Bern (Inselspital), Department of Orthopedic Surgery and Traumatology
Examiners: Dr. Patric Eichelberger, PD Dr. Heiner Baur

Introduction

Torsional deformities of the lower leg are associated with hip impingement, patellar instability, patellar hypercompression, and are known risk factors for osteoarthritis in the hip and knee joint [1, 2].
Derotation osteotomy is the most effective treatment to normalize the torsion angle, reduce pain, improve function and delay the need for joint replacement. Today, surgical decision-making for derotation osteotomy and the amount of correction are mainly based on surgeon's experience. The aim of this project is to develop a simulation workflow using a personalized musculoskeletal model to evaluate the effects of derotation osteotomy as a basis for surgical planning.

Materials and Methods

Information from CT and 3D gait analysis are used to personalize and drive the musculoskeletal model in OpenSim (V4.4 Simbio, Stanford University), an open-source software for musculoskeletal modeling and simulation. Backward simulation including inverse kinematics and dynamics, static optimization, and joint reaction force and muscle analysis, is conducted to assess the gait performance of the patient prior to the surgery. Forward simulation is used to predict the surgical outcome. The simulation workflow is automated in Matlab (R2020a, MathWorks).

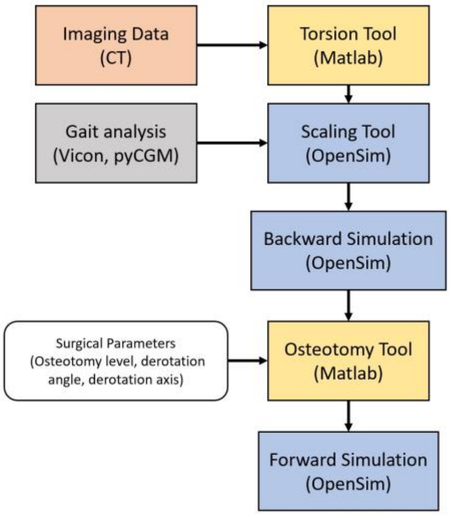

Fig. 1 Flowchart of the simulation workflow including personalization of the musculoskeletal model, backward and forward simulation to assess the gait performance of the patient pre- and post-surgery.

Results

The simulation workflow (Fig 1) was developed and implemented. The backward simulation is established and validated with literature data for healthy participants undergoing gait analysis. Modeling of the torsional deformity as linear rotation in the proximal part of the affected bone along the anatomical axis is possible as well as the modeling of the derotation osteotomy procedure on different levels (femur: subtrochanteric, supracondylar) with user specified angle and around either the anatomical or mechanical axis.

Discussion

The results of the backward simulation with data from healthy subjects correspond to reference data from the literature and provide a valuable overview of patient's pre-operative gait performance. Further improvement in the individual workflow steps and finalization of the forward simulation are needed to improve the stability of the simulation and reliability of the results. Musculoskeletal modeling is a promising approach to predict the outcomes of a surgical intervention. The validation of the established methods with patient data is pending.

Outlook

Introduction of stable configuration for the forward simulation is necessary to complete the first version of the simulation workflow. Compare pre-surgery forward simulation with post-surgery inverse simulation results from patients undergoing surgery. Include MRI images to workflow to create a patient-specific musculoskeletal model. Evaluate patient-specific models vs. personalized standard models for inverse and forward simulation.

References

[1] Tönnis D. and Heinecke A., Acetabular and Femoral Anteversion: Relationship with Osteo-arthritis, J Bone Joint Surg 81(12): 1747-70, 1999.
[2] Siebenrock KA, Steppacher SD, Haefeli PC, Schwab JM, and Tannast M., Valgus hip with high antetorsion causes pain through posterior extraarticular FAI, Clin Orthop Relat Res, 471(12), 3774-80, 2013

Acknowledgements

Many thanks to Dr. Patric Eichelberger, Prof. Dr. Heiner Baur and Dr. med. Emanuel Liechti for the opportunity to work on this interesting challenging project in the interdisciplinary field of movement biomechanics.