A patient-specific 3D musculo-skeletal finite element model of ankle arthrodesis

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In the context of advanced ankle arthrosis, arthrodesis is a popular surgery option. After arthrodesis the motion of other ankle joints can be modified under muscle activation and this modification was investigated in this study. Apart from that, the muscle functions may vary as a result of the constrained ankle. In this study a combination of Finite Element (FE) and rigid body was used to model the foot taking into account contact and muscle activation. To simulate such complex model, the ArtiSynth platform (artisynth.org) was used thus providing powerful tools to efficiently combine rigid body and soft tissue. A high-resolution CT volume acquired on the unloaded right foot of a volunteer was used to segment the 30 bones and reconstruct their 3D shapes. Rigid body contact constraints were implemented in the Artisynth framework to model joint interactions. All 33 joint motions were further constrained by 210 ligaments modeled by cables and inserted on the bones using CT images of the subject. Such contacts between bones and ligaments attached to the bones were thus used guiding the foot kinematics. The Aponeurosis was modeled using five ligaments linked by transverse structures. Finally, 15 Hill's model muscles were positioned according to their anatomical course and can be independently activated. Soft tissues were modeled by a FE mesh comprising three sub-domains representing skin, fat and muscles tissues. Neo-Hookean material model was used to account for large deformations and all the modeled elements are subject to gravity. This generic model of the whole foot allows simulating a virtual arthrodesis and predicting the post-operative foot kinematics. Since the computation time for running such complex model is still very high, we are currently implementing model order reduction techniques to decrease such computation time to make the simulations compatible with clinical routine.

Keywords : Ankle Arthrodesis, Musculo-skeletal model, Patient-specific, Finite Element