Simulation of soft tissue injuries under blunt impact

Name: Felicitas Lanzl
E-Mail: Felicitas.Lanzl@med.lmu.de
Supervisor: Prof. Dr.-Ing. habil. Fabian Duddeck
Associate Professorship of Computational Mechanics
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Motivation and objectives
Cutaneous soft tissue injuries under blunt impact such as lacerations are frequent injuries, but little is known about the injury mechanism itself. There is a need for a better understanding of this phenomenon as traumata caused by blunt impact play an important role in the evaluation of assaults or accidents and the following legal proceedings. But visual examination of these injuries proves complex as the visual appearance is influenced by impact force as well as the geometric properties of the impacting object and can therefore not be easily related to the origin of the inspected wounds [1]. A promising alternative for the assessment of soft tissue injuries is represented by the finite element (FE) method. A great advantage of FE models compared to other possible evaluation methods is that they allow insight into the stress and strain distribution during impact at the tissue level as well as into the influence on the involved tissue types on the injury mechanism [2]. However, modeling of material behavior and failure of soft tissues remains challenging as they exhibit complex material properties that involve non-linearity, anisotropy and strain rate dependency [3–4]. Thus, the objective of this project is the development of computational models for the soft tissues involved in superficial injuries under blunt impact, i.e. mainly skin and subcutaneous adipose tissue. The models shall be validated against experimental data on two different levels – on tissue level (isolated tissue type) and on regional level (combination of skin and adipose tissue). Afterwards the models shall be extended to include failure models capable to simulate the formation of soft tissue laceration. The failure models shall also be validated against experimental data on tissue and regional level.

Status and outlook
Experimental data has been acquired to enable the validation of computational models for skin and subcutaneous adipose tissue on tissue and regional levels. The experiments were designed with regard to the subsequent simulations i.e. they were kept relatively simple to establish boundary conditions as precise as possible for the simulations.
A drop-test setup was chosen, in which the specimen (skin, adipose tissue or a combination of both) is impinged by an impactor and impactor acceleration is recorded. For some tests geometry of the specimen before impact and the injured specimen after impact were recorded by photogrammetry and 3D computational models were established for a more comprehensive validation of the soft tissue failure models (compare Figure 1).

Hyperelastic, phenomenological material models for skin and adipose tissue have been developed for both, tissue and regional level. Simulations involving adipose tissue revealed that due to its ability to deform to a great extent a different modeling approach than standard FE methods might be required. Therefore, advanced numerical methods are investigated to model the deformation behavior of adipose tissue. In addition, the attempts to include failure in the developed model for skin indicate that a micro-mechanical model accounting for the specific structure of the skin is necessary to adequately represent the failure mechanism of skin. Therefore, the Gasser-Holzapfel-Ogden model, which is a micro-mechanical material model for various collagenous soft tissues [5], is implemented as user defined material model in LS-DYNA. The model is examined for its ability to represent the material behavior as well as the failure mechanism of skin and will be adapted where necessary.

References