Multi-Modal Framework for Subject-Specific Finite Element Modeling of the Buttocks

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Introduction

Biomechanical finite element (FE) modeling of the buttocks soft tissues is essential for an efficient prevention of pressure ulcers. Indeed, internal deformations not only depend on external skin pressures, but also on each individual's morphology. This abstract presents a fast, automatic and robust technique for the generation of patient-specific models to be used within a personalized pressure ulcer prevention strategy. The technique resorts to multiple complimentary modalities to gain insight at the patient's morphology while maintaining an acceptable prevention benefits vs imaging risks (or costs) ratio.

Methods

In order to produce high quality personalized FE models, it is necessary to resort to medical imaging and acquire the most relevant possible description of the modeled morphology. Yet building a FE model from a medical data set can be a challenging and time consuming task. To overcome the commonly encountered problems, a "mesh warping" approach has been chosen for its versatility [1]. In this framework, a generic or "atlas" model representing a typical organ is first assembled. Then, for each patient the atlas model is warped, or registered, so that its shape accurately represents the target morphology. An economically acceptable and practical image acquisition workflow must be designed in order to make personalized biomechanical modeling suitable for the largest number of wheelchair-ridden persons. We propose to use three different modalities providing an increasing insight at the patient's morphology: (1) Kinect surface scanner (giving access to the external shape of the organ only, the internal structures are inferred by the registration process); (2) EOS bi-planar X-Ray imaging (skin surface and bony structures can be reconstructed, other soft tissues are inferred); and (3) CT for validation purpose only as the modality costs and irradiation may not even out its benefits.

Results

The atlas FE mesh was produced using a hexahedral dominant meshing technique [2] and comprises 14,868 elements (8,052 hexahedrons, 2,554 pyramids, 2,534 tetrahedrons and 1,728 prisms). The pelvis and femurs are considered as fixed rigid bodies. The EF mesh registration procedure was tested on 3 young healthy subjects (2: Kinect only, 1: CT). In all cases skin surface representation mean error was less than 1mm. Pelvis and femurs were modeled within segmentation accuracy in the CT case. Fig. 1 illustrates the FE mesh personalization workflow in the case where only the external Kinect scan is available.

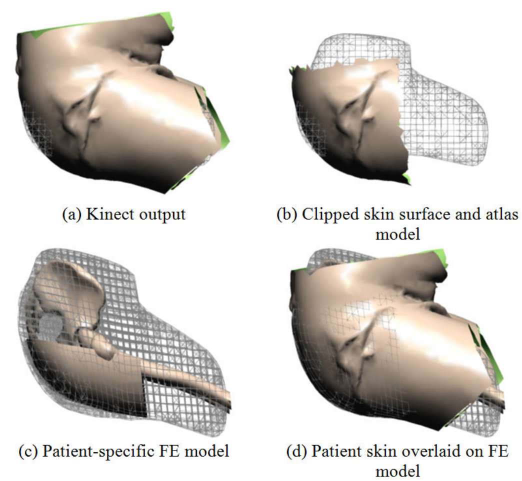

Fig. 1: *Kinect-based FE model generation (sagittal view).*

Discussion

The presented modeling framework takes into account restrictions on the availability of medical images in situations where the benefits of the ulcer prevention strategy are deemed insufficient in regard of the imaging costs or incurred radiations. A low-cost and radiation-free scenario based on the publicly available Microsoft Kinect is proposed. The approximations in the biomechanical model when imaging of internal structures is not available are currently under study and will be published once a corpus of "ground truth" CT exams has been collected and processed.

Clinical relevance

The modeling technique enables the implementation of personalized biomechanical modeling of soft tissues.

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Conflict of Interest

Some authors are involved with the TexiSense Company (http://www.texisense.com/home_en).

References

[1] Bucki M. *et al.*, MedIA. 14:303-17, 2010
[2] Lobos C. *et al.*, C. Mec. Comp, 10(1): 167-76, 2012