DXA-DRIVEN PIPELINE FOR BUILDING BIOFIDELIC FEMS FOR HIP FRACTURE RISK ASSESSMENT IN CLINICAL COHORTS

D. Jha (1,2), A. Baker (2), A. Fung (2), V. S. Cheong (1,2), N. Hong (3), I. Fleps (2), Y. Rhee (3), P. Gupta (4), E. L. Lamoureux (4,5), S. J. Ferguson (1,2), B. Helgason (1,2)

1. Singapore-ETH Centre, Singapore; 2. ETH-Zürich, Switzerland; 3. Yonsei University College of Medicine, South Korea; 4. Singapore Eye Research Institute, Singapore; 5. Duke-NUS Medical School, Singapore

Introduction

Osteoporosis is a chronic disease characterized by low bone mass and reduced structural integrity of bone [1]. Stratifying fracture risk based on aBMD alone lacks sensitivity for clearly identifying individuals at risk [2]. Femoral strength predicted using CT-based subject-specific biofidelic Finite Element Models (FEMs) is a promising alternative [3]. However, CT scans are associated with higher costs and radiation compared to DXA scans, which are currently used for diagnosing osteoporosis. In this project, we developed an automatic pipeline, for building biofidelic FEMs based on input from 3D optical- and DXA scanners, for quantifying fracture risk with and without preventive intervention in large clinical cohorts.

Methods

The automatic modeling pipeline was scripted in Python (vers. 3.9), utilizing different open-source and commercial software for solving various tasks. Inputs available for building the models are hip and whole body DXA scans (Hologic Horizon W), a database of 3D Shape scans using TC^2® (vers. 19M) from subjects in a cohort of community-dwelling elderly Singaporean, and a database of pelvic FEMs.

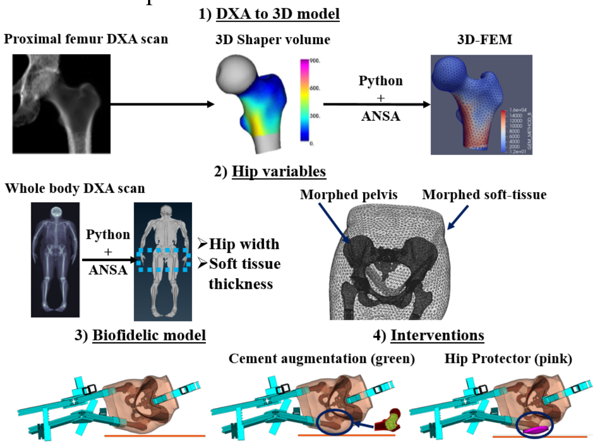

Figure 1: (1) DXA to a 3D-FEM, (2) Hip variables from whole body DXA scans, BMI matching pelvis and 3D shape scans, (3) Biofidelic model without intervention (4) Biofidelic model with cement augmentation and hip protector intervention.

The steps for building the biofidelic FEMs (Figure 1), demonstrated on a sample subject are: 1) 3D-FEM derived from the DXA scan of the proximal femur using 3D-Shaper® (vers. 2.11.1) and ANSA (vers. 22.0.1). Material properties are mapped to the FEMs as in [4]. 2) Descriptive variables for the hip are measured based on the whole body DXA scan, and a soft tissue and pelvis morphed to shape matching BMI matching of the subject. 3) The assembled model is subjected to a simulated sideways fall (LS Dyna 12.0) at an impact speed of 3 m/s [3]. 4) Preventive intervention module is called for modelling a selected risk mitigation strategy [5,6]. The femur is considered fractured if the 1st principal strain >2.8% as described in [7].

Results

The simulation results for a sideways fall of a female (age-62, height-146 cm weight-40kg, aBMD-0.689) with and without the use of interventions are shown in Figure 2. Augmenting the femur with cement injection increased the femur strength by 5%. Hip protector attenuated the femur force by 11%. Both interventions prevented fracture in the femur.

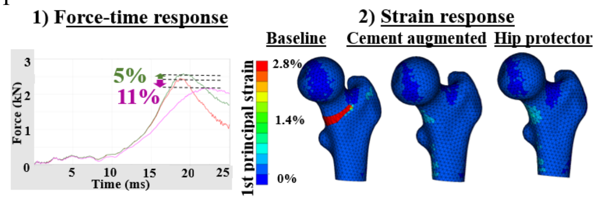

Figure 2: (1) Force-time response for baseline (red), cement-augmentation (green), and hip protector (pink); (2) First principal strain response for baseline, cement-augmentation and hip protector model.

Discussion

A novel automatic pipeline has been developed for building biofidelic FEMs from DXA scans. The high level of automation will allow us to model large cohorts of elderly subjects for studying the efficacy of existing and emerging preventive treatments. The outcomes will be used to inform health-care economic models on expected risk reduction in the treatment arm vs. the placebo arm.

References

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