Modeling the human heel pad

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INTRODUCTION

The human heel pad acts as an efficient shock absorber reducing the impact forces during gait. It presents anisotropic, non-linear, visco-elastic characteristics as with the majority of the human soft tissues. It constitutes a complex structure with neuronal, vascular, fibrous and elastic components intertwined with fat cells [1]. Trauma to the heel pad and/or diseases of the heel may cause the "destruction" of its intricate septation which results in permanent damage of its shock absorbency capability. Palpation is still widely used as an important diagnostic tool. The standard medical practice of soft tissue palpation is based on qualitative assessment of the low-frequency stiffness of the tissue. Unfortunately, this qualitative technique is not powerful enough for a medico-legal assessment. In order to obtain a quantitative evaluation, and to gather information on the complete deformation of the tissues it is necessary to develop and use a device based on an indentation experiment. However, this alone does not provide sufficient information allowing a description of the tissue damage at a microscopic level. A computational simulation of the heel pad seems necessary, in order to obtain such description. The aim of the present work is to develop the model of a healthy heel pad in order to simulate the biomechanical behavior when subjected to a known external compression. Once validated by experimental tests, such simulation may pave the way for quantitative classification of healthy and diseased heel pad tissue.

MATERIALS AND METHODS

In the present work the 3D model of a 30 year-old Caucasian female's heel pad was built on the basis of MRI scan data [Siemens Magnetom Trio (3T), Fat-suppressed 3D dual echo steady state (DESS) sequence with (0.7 mm)^3 isotropic resolution, matrix 320x576x104. TE/TR=5.5/13ms, flip angle 25 degrees, 5 min. acq. time)]. All MR images (DICOM format) were imported in SIMPLEWARE®-ScanIP 3.2. The segmentation of the images was done in order to characterize the different tissues forming the heel pad. By applying proper thresholds, region growing and the function pain has been possible to distinguish the calcaneum bone, muscles, fat tissue, septa and skin. Two filters - morphological close filter and recursive Gaussian smoothing filter - were then applied to merge each identical structure and to improve the consistency of the final model. The 3D heel pad model was then exported in SIMPLEWARE®-+ScanFE 3.1.4. Mesh parameters were assigned, nodes and contact surface were defined in order to export the mesh in Ansys.

RESULTS

Fig.1 shows the segmentation of the heel pad images and creation of the model in ScanIP. Specifically, the bone is shown in red, the muscle in green, the skin in violet, the septa in pink and the fat tissue in light blue. Fig. 2 shows the mesh of the heel pad created in +ScanFE, ready to be exported in Ansys.

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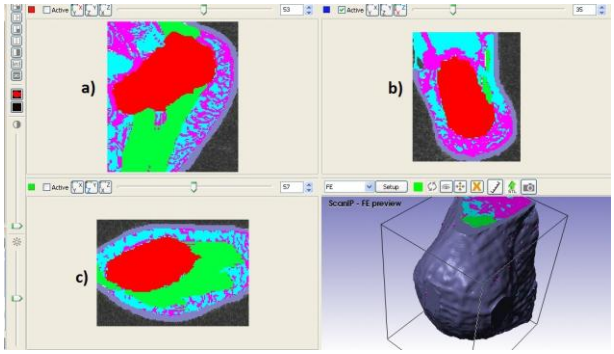

Fig. 1: Segmentation in ScanIP. a) sagittal view, b) axial view, c) coronal view.

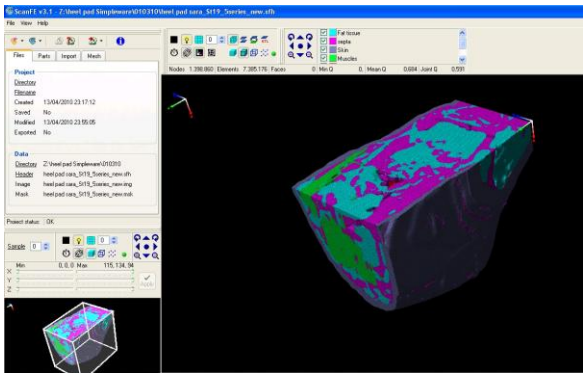

Fig. 2: Mesh creation in ScanFE

DISCUSSION

So far, the challenging part of the heel pad modeling is the identification of the intricate internal structure of the heel fat pad, made of fat tissue and septa. The reconstruction of this honeycomb microstructure [1] may help in differentiating diseased tissues from healthy ones. Indeed, the mechanical integrity and functioning of the heel pad as a whole is dependent on the integrity of the septa that enclose each independent chamber [1].

REFERENCES

[1] Jahss, M.H., et al., Investigations into the fat pads of the sole of the foot: anatomy and histology. Foot&Ankle, 1992, 5: 233-242.