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Human heel internal tissue displacements and strains calculated from Magnetic Resonance Imaging

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Introduction: Pressure ulcers are defined as localized areas of damaged skin and underlying soft tissues caused by sustained mechanical loads on the skin surface. They are common in the posterior heel region in bedridden patients. It is still not completely understood how external loads lead to high local internal strains and how these strains cause tissue damage. Finite Element(FE) analysis is a powerful tool to help understanding how such external loads lead to deep internal strains. However, it has been highlighted how this numerical analysis lacks proper validation(Keenan 2021). This abstract aims to describe an in vivo methodology that will be implemented for evaluating the simulations of an FE model of the human heel. This solution is based on applying various loading configurations on the heel while recording Magnetic Resonance (MR) scans.

Methods: A healthy male volunteer(aged 30 years) gave his informed consent to be scanned using a 3T MRI platform1. A T2 DESS MRI sequence with a 0.6mm isotropic voxel size was used to image the foot in a series of configurations (unloaded, loaded on hard surface, loaded on mattress, loaded with shear, and loaded with an indenter) (Figure1). The unloaded and loaded MR images were then registered using the registration toolbox2 to extract the displacement field and strain maps for the soft tissues(Trebbi 2021).

Results: The high-resolution MR acquisitions allowed a clear distinction of the tissues that compose the human heel and their displacements due to the application of the various loads(Figure2). As expected, the implementation of a mattress on the supporting surface reduced the amount of deformation and strains. Conversely, the loading configuration involving the indenter generated the highest levels of max Green Lagrange shear strain.

Figure1: MR set up with the participant's heel loaded on a soft cushion.

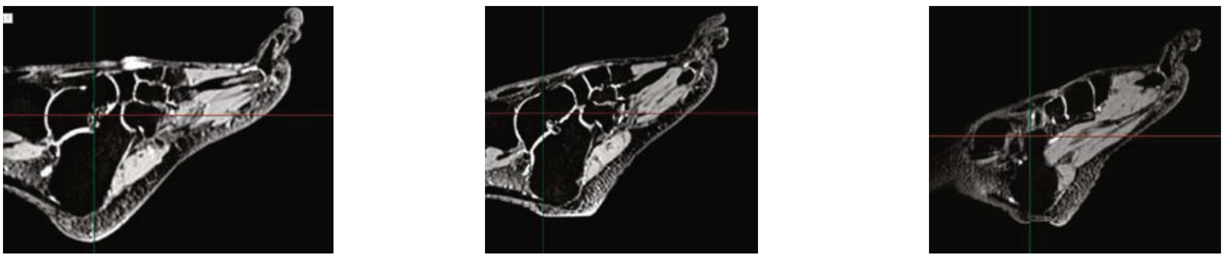

Figure2: MR images related to the configurations for A unloaded, B loaded on hard surface, C loaded with an indenter.

Conclusions: The implemented technique can give insight for several applications. First, it adds a useful tool for better understanding the propagation of deformations in the heel soft tissues that could generate pressure ulcers. Second, this procedure can be used to obtain data on the material properties of the soft tissues to define constitutive laws for FE simulations. Third, image registration offers a promising technique for evaluating FE models. Finally, these outcomes could be implemented to evaluate performances of orthotics and dressings aiming for preventing pressure injuries.

References

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Trebbi,A., Perrier,A., Bailet,M., & Payan,Y. (2021). MR-compatible loading device for assessment of heel pad internal tissue displacements under shearing load. Medical.Engineering.&.Physics.

1 3T Siemens Magnetom Prisma system

2 Registration toolbox Elastix