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Synthetic test-beds for assessing human-object tribological interactions

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The complex tribological behaviour of biological tissue when in contact with products, devices and surfaces brings about many challenges when developing test-beds capable of replicating human-object interactions. Recent studies have used a combined approach including in vivo imaging of biomechanical response to loading, candidate material assessment and validation protocols to develop successful synthetic test platforms capable of assessing products, and the effect of contaminants, in relation to frictional interactions with human systems.

Keywords (from 3 to 5 max): biotribology, biofidelic, surrogate, synthetic test-bed

1. Introduction

Assessing skin/tissue-surface friction using human participant testing brings with it many challenges including, repeatability, cost and ethical considerations. Ex-vivo animal tissue testing can be used, but has its own limitations. Human skin and underlying tissues make up a highly complex system that responds differently to environmental conditions, the local anatomy [1] and the presence of contaminants such as topical treatments, sweat etc. Previous studies have generated good understanding of the major tribo-mechanisms at play, but it is not easy to predict how these combine together for each situation. Synthetic test-beds (biofidelic surrogates) have a role in the assessment of products and materials, particularly in aggressive loading conditions that could cause discomfort or injury to human participants, or where large scale studies are required.

2. Methods and Discussion

2.1. Understanding human-tissue system and behaviour

In order to develop a test-bed, the geometry of the local anatomy and its biomechanical behaviour when subjected to shear loading must first be understood. Imaging techniques such as Digital Image Correlation [2] can assess surface response to loading whilst Optical Coherence Tomography (OCT) [1,2] and Ultrasound (US) [3] can be used to measure geometry and deformation in the dermal and sub-cutaneous regions respectively (see Figure 1).

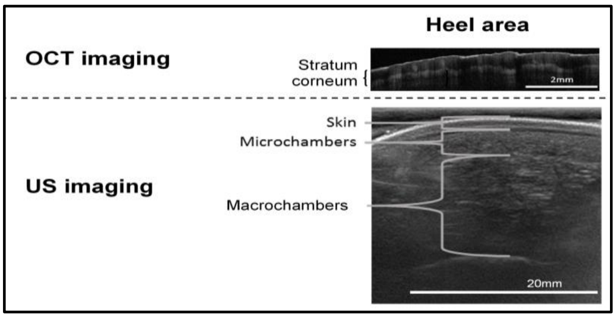

Figure 1: Example OCT [1] and US [3] images taken from a human heel.

2.2. Design, development and manufacture

A huge variety of synthetic materials are used as skin and tissue surrogates, with elastomers and gels being common for replicating mechanical properties [4]. Commercial products are also available on the market, including layered systems. Candidate materials should first be assessed for their ability to replicate loading [5] and frictional behaviour [6]. Other considerations include cost, manufacturability, robustness to testing and shelf life. Numerical models can assist in the process of ascertaining the required level of complexity to suitably replicate behaviour. A multi-layered system of the required complexity can then be designed and built according to the measured anatomical properties of the human system being simulated. This has been achieved at the University of Sheffield for regions of the feet, hands, volar forearm, shoulder and ear [5, 7].

2.3. Validation and adoption

Finally, the loading and frictional behaviour of the test-bed should be compared with that of the biological system. This could be done at low levels of loading with a human system in vivo and/or using ex vivo animal tissues for more aggressive loading situations [5-7]. Where appropriate cell cultures can also be used. Once validated, the system and associated test protocols can be adapted for impactful use, whether in a research, industrial or test-house environment.

3. References

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