EXPERIMENTAL ANALYSIS OF PLANTAR SKIN

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Introduction

The plantar skin is a complex multi-layered structure of the foot. Its morphology and composition are related to its main functions, which are to protect the body against mechanical injuries and to adapt to external stresses during daily activities [1]. Its extra cellular matrix is mainly composed of elastic and collagen fibres, which are responsible for a non-linear, time-dependent and anisotropic behaviour [2]. Since skin plays a relevant role, it is important to maintain its integrity. Unfortunately, some diseases, *e.g.* diabetes, can cause skin damage [3]. Even if this topic is very crucial, there are very few studies reporting on skin mechanical properties [4] and none of them has analyzed or tested the plantar skin yet. In this context, this work aims to fully describe the mechanical behaviour of foot skin, in relation to tensile and compressive loads.

Materials and Methods

Experimental tests were performed on plantar skin collected from four male human donors, (56±18 years) undergoing amputation due to cancer, at the Orthopedics and Orthopedic Oncology Unit, University Hospital of Padova (CESC Code: AOP2649).
Samples were collected from the heel pad (HP), central (C) and metatarsal (Met) regions (Fig. 1a). Mechanical tests were performed with the Biomomentum testing machine (Model Mach-1 v500c, ©Biomomentum Inc.): uniaxial tensile tests were performed on 50 specimens cut according to posterior-anterior (PA), lateral-medial (LM) and diagonal (45° inclination D) directions; while compression tests were performed on 30 cylindrical samples (diameter 5 mm). For tensile samples (Fig. 1b), preconditioning was performed before two different protocols of failure (1%/s strain rate) and stress relaxation tests (5 ramps of 7% strain; 10%/s strain rate; 400s of resting). For compression samples (Fig. 1c), preconditioning was performed before two different protocols of loading-unloading (50% strain; 1%/s and 100%/s strain rates) and stress relaxation tests (5 ramps of 1% strain; 10%/s strain rate; 400s of resting).

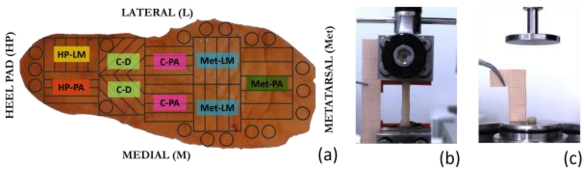

Figure 1: (a) skin samples; (b) uniaxial tensile and (c) compression tests.

Results

The ultimate tensile stress (6.10±2.9 MPa) and the failure strain (49.2±11.9 %), as well as the initial and final Young's moduli, were obtained from failure tensile tests (Fig. 2a). These results demonstrate the plantar skin non-linear anisotropic behaviour, which was also confirmed by stress-strain curves obtained from compression tests. Stress-relaxation results, from both tensile and compression tests, highlighted the tissue's time-dependent behaviour (Fig. 2b) (relaxation decay around 43%) and allow us to compute tissue viscoelastic parameters.

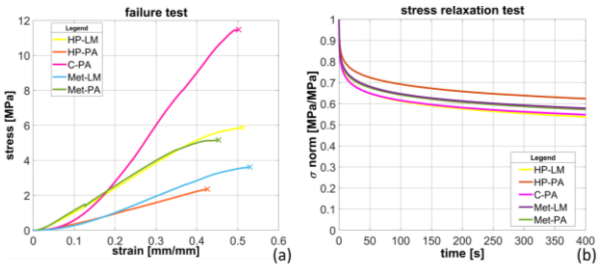

Figure 2: an example of results from (a) failure and (b) stress relaxation tensile tests.

Discussion

Experimental results showed differences in the mechanical behaviour among different skin regions. Anisotropy has been observed in the heel pad and central regions and a higher stiffness was observed in the central one. These differences can be explained by observing the arrangement of skin Langer's lines, which are concentric in the heel pad and metatarsal regions (giving high resistance to compression stress), while they are longitudinal in the central ones (conferring to the skin a high resistance to tensile stress). All the information obtained will be useful to develop in silico tools of the foot, for the evaluation of the influence of different pathologies, *e.g.*, in diabetic patients, or to investigate the interactions between foot and footwear.

References

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