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Strain rate effects on the failure characteristics of excised human skin

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Introduction
Skin is a complex, multi-layered material which exhibits non-linear, anisotropic and viscoelastic behaviour. Its structure is complex and can be broadly divided into three main layers: the epidermis, the dermis and hypodermis. The thickest of these layers, the dermis, consists of strong stiff collagen fibres which govern many of the mechanical properties of human skin [1]. The mechanical properties of skin are important for a number of applications including surgery, dermatology, impact biomechanics and forensic science. Many studies in the literature use human skin substitutes such as pigskin or silicone [2,3], and in vitro tests on human skin are particularly rare.

Objectives
The objective of this study is to determine the strain rate effects on the failure characteristics of excised human skin considering both the rate dependency and anisotropic nature of skin.

Methodology
In a previous publication [1], tensile tests were carried out on excised human skin at quasi-static speeds and the orientation of collagen fibres in the dermis was linked to the anisotropic behaviour of human skin. In this study, tensile tests were performed on excised human skin samples at strain rates varying from 0.012^{-s} to 29^{-s} (0.001 m/s to 2 m/s). The test samples were selected parallel, perpendicular and at 45^{o} to the Langer Lines (natural lines of increased skin tension). The effect of strain rate on the failure characteristics of excised human skin and the anisotropic behaviour of skin was examined.

Results and Analysis
In general, the samples exhibited stiffer behaviour at higher strain rates. As shown in Fig.1, the elastic modulus increased and the failure stretch decreased with increasing strain rates. The failure stress (UTS), and the Strain Energy (area under stress-stretch curve) also increased with strain rate. These experiments also revealed that human skin exhibits similar anisotropic behaviour at quasi-static and at strain rates up to 29^{-s}. Fig.2 below compares tensile test results for skin samples at different orientations at quasi-static strain rates (0.83^{-s}) and at dynamic strain rates (14.5^{-s} to 29.0^{-s}).

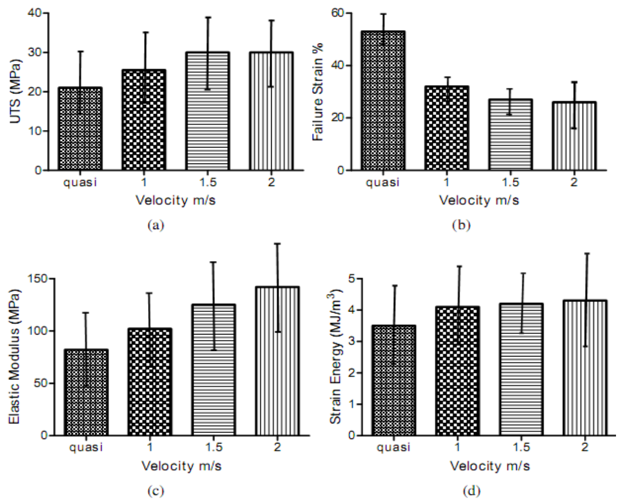

Fig. 1: Means and standard deviations at different test speeds; quasi-static (N=55), 1m/s (N=18), 1.5 m/s (N=11), 2m/s (N=4).

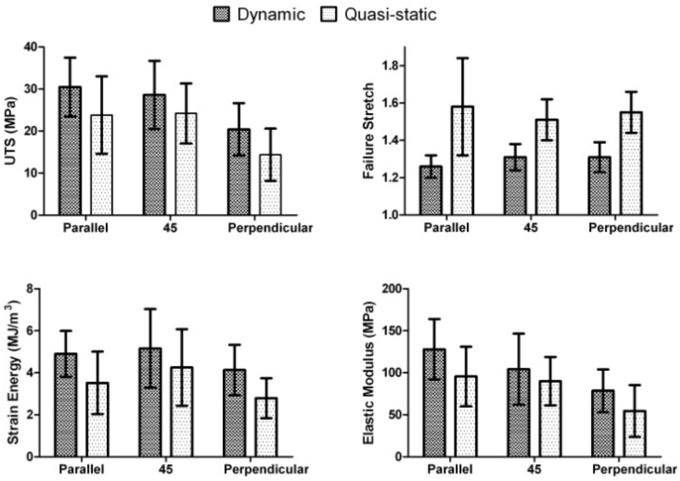

Fig. 2: Effect of sample orientation at dynamic strain rates (N=33, 14.5-29 s^{-1}) and at quasi static strain rates (N=55, 0.83 s^{-1}).

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