# Directional Biomechanical Properties of Skin Tissue

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Skin tissue is a multilayered composite material and composed principally of the proteins collagen, elastic fibers, and fibroblasts. The direction-dependent material properties of skin tissue is important for physiological functions like skin expansion. This study provides a comparison and analysis of the anisotropic behavior of porcine skin tissue that have undergone expansion and those that haven't. It is observed that parameters of material stiffness of skin tissue before 48-hour cyclic expansion are 8.833±2.490 MPa in the preferred-fiber direction and 3.082±0.787 MPa in the cross-fiber direction. After 48 hours skin expansion, the parameters of material stiffness are 11.480±3.128 MPa in the preferred-fiber direction and 9.41±1.927 MPa in the cross-fiber direction. It is concluded that less anisotropy of material property is observed for the post-expansion skin tissue.

**Introduction:** In regenerative medicine, a significant effort is focused on increasing the area and volume of skin tissue using mechanical strain methods. The main intent is to plastically deform this biological material so that its surface area increases and over time regain its full thickness due to cell proliferation in a bioreactor. The driving force is the high fatality of severely burned patients with a large area of thermally or chemically burned skin tissue. To treat patients with severe burns, small skin grafts can be harvested from healthy places on the body, quickly expanded to much larger areas *in vitro*, compared to the original area, and then be transplanted back to a burnt area of the body. Thus, skin expansion has become a valuable method in plastic and reconstructive surgery. However, current prototype skin expansion bioreactors have been reported to cause tissue tearing due to uneven loading, gripping methods, stress concentration, and other factors intrinsic to the tissue properties. Therefore, the current study aims to provide a method to better obtain fundamental quantitative data delineating direction-dependent mechanical properties of porcine skin tissue. It is expected that the identification of directional mechanical properties will optimize functional surface area enlargement of skin tissue, and hence better serve burned patients in health-care communities.

**Materials and Methods:** Though biaxial testing of skin has been studied by Lanir and Fung, the current work focuses on establishing a method to characterize direction-dependent mechanical properties. A biaxial tissue tester (BioTester 5000, CellScale, Waterloo, Canada), equipped with two load cells and actuators for each axis of loading, was used for measuring the force and displacement of the skin tissues. The measured values were used to further obtain stress-strain curves and to calculate the parameters of material's stiffness. When tissue samples are prepared, it is difficult to visualize preferred and cross-preferred collagen fiber directions. The minimized coupling effects between preferred and cross-fiber directions are generally observed when their mechanical properties exhibit the most differences between them, i.e., anisotropy. Therefore, to identify preferred and cross-fiber directions, the samples are rotated counterclockwise at approximately 25-30 degrees after each set of tests. Due to the symmetry, three testing angles are used: 0-degree, 30-degree and 60-degree.

**Results and Discussion:** The directional-mechanical properties of skin tissue is measured biaxially and identified via the anisotropic behavior of tissue samples. It is observed that skin tissue has an anisotropy biomechanical behavior (**Table 1**). The anisotropic mechanical properties of the post-stretched samples are no longer as apparent as in the pre-stretched ones. The result from the current study provides a strong foundation for the skin stretching optimization, where the increased surface-area is required in modern skin grafts and reconstructions.

**Table 1:** Piecewise parameters of materials stiffness of pre- and post-stretched samples.

| Modulus (kPa) | 0-25% of strain | | 25-30% of strain | | 30-35% of strain | |
|---|---|---|---|---|---|---|
| | Pre-stretch | Post-stretch | Pre-stretch | Post-stretch | Pre-stretch | Post-stretch |
| **Preferred-fiber-direction (p)** | 161±270 | 167±314 | 2905±1134 | 3907±1664 | 8833±2490 | 11480±3128 |
| **Cross-fiber-direction (c)** | 69±114 | 146±307 | 1113±400 | 37151±1530 | 3082±787 | 9441±1927 |

**Conclusions:** Biological tissues have a complex microstructure and their biomechanical behaviors are highly related to inhomogeneous collagen fiber architecture. The current study provides a method to quantify directional mechanical properties of skin tissues. Therefore, the current study provides information to facilitate a better understanding of biomechanical properties of skin tissue allowing higher rates of success in skin graft procedures, and thus better serve patients who have suffered from burns or other injuries.