Realignment of Collagen Fibers in Mouse Skin

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BACKGROUND. Skin is a planar tissue that resists loads primarily by reorientation of the collagen fibers. In relaxed skin the collagen fibers exhibit a wavy appearance and are nearly randomly oriented in the plane of the skin. Upon loading, the fibers straighten and reorient in the direction of the load [1]. Prior studies of collagen fiber reorientation in skin have focused on uniaxial loading [2]. Skin in its natural state is biaxially loaded and therefore the results observed in uniaxial tests have considerable limitations.

METHODS. Collagen fiber orientation was investigated in 10 mice (CD-1, Charles River Breeders) under 5 loading conditions; the *in vivo* state and 4 states of biaxial tension and shear. Each specimen was mounted in an apparatus where loads could be independently applied to 12 tabs attached to the specimen [3]. Tissue strains were determined from the displacement of markers attached to the skin surface. Specimens were fixed in formaldehyde and scanning electron microscopy was used to obtain images of the collagen fibers. Edge detection software was used to determine the fiber orientation function.

RESULTS. Collagen fibers were generally randomly oriented in the *in vivo* state. There was a strong reorientation of the fibers in the direction of load when the biaxial load was biased in the head/tail direction. The skin was stiffer in the circumferential direction and there was less fiber reorientation when the load was biased in that direction. Despite the isotropic state of stress in equal biaxial tension, fibers reoriented in the head/tail direction with increasing stress. In shear, the fibers reoriented toward the direction of maximum principal stress, however the level of recruitment was modest.

CONCLUSIONS. Skin is a biological example of a composite material that naturally adapts its microstructure to resist applied loads. As with many composite materials, the directions of principal stress and strain were not coincident. In our experiments, collagen fibers tended to align with the direction of principal strain. In uniaxial tests reported in the literature, fiber reorientation occurred readily in the direction of loading and this fact has been used to explain the increase stiffness that occurs with increases in load. However, our work shows that the role of fiber reorientation under biaxial loading conditions is considerably more complex and not as closely associated with mechanical behavior as indicated by the reported uniaxial tests.

REFERENCES.

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