
# Mechanisms of Injury

## Rate-Dependent Fracture Modes in Human Femoral Cortical Bone

An accurate understanding of human bone fracture under complex loading scenarios is critical to predicting fracture risk. Cortical bone is subject to complex loading because of inherent multiaxial loading conditions which are influenced by the anisotropy of the microstructure. However, when determining critical fracture parameters, bone is traditionally idealized as isotropic. In FY14, researchers at USARL, sponsored by the Army Materiel Command (AMC) and the Research, Development, and Engineering Command (RDECOM) investigated a method to examine rate-dependent mode mixity associated with cortical bone crack initiation. Four-point bend experiments were conducted on cortical femoral bone samples from three human donors, and digital image correlation (DIC) was used to obtain full-field displacement maps at the crack tip during the experiments. An over-deterministic least squares method was used to evaluate Mode I (opening) and Mode II (shear) stress intensity factors (SIFs) for fracture initiation at low, intermediate, and high loading rates. Assuming material anisotropy under dynamic loading, the critical Mode I SIF was approximately 50% lower than fracture toughness. Additionally, critical Mode I and II SIFs had the lowest values at the highest loading rate examined, decreasing to one-third of their values under the low loading rate. Crack growth at the low and intermediate loading rates appeared to be Mode II dominant, and transitioned to mixed-mode at the high loading rate. This study suggests that the conventional assumption of isotropy is a conservative estimate at low and intermediate rates, but overestimates fracture strength at dynamic rates. This analysis will enable the design and evaluation of protection devices that mitigate bone fracture during blast and impact loading. A paper describing this study has been submitted to the *Journal of Fracture Mechanics*.