D8 Low-Energy Bone Fractures: Part III

David Pienkowski, PhD, University of Kentucky, AB Chandler Hospital, Rm MN 564, Lexington, KY 40536-0298; and Hartmut Malluche, MD, University of Kentucky, Chandler Medical Center, 800 Rose Street, Lexington, KY 40536*

The goals of this presentation are to raise attendees' awareness of bone microdamage, illustrate how above-normal levels of bone microdamage are linked to altered load-bearing mechanical competence, and thereby help the forensic investigator understand how excess levels of microdamage may partially explain low-energy bone fractures.

This presentation will impact the forensic science community by providing a partial explanation for seeming incongruities among low-energy events, reconstruction-derived traumatic event energy (or force) amplitudes, and bone fractures. Bone fractures accompanying low-energy trauma are perplexing to the forensic investigator. Ostensible disparities between the energy (or force) amplitude of the traumatic event and the level of injury can often lead to uncertainty regarding the facts of the event or the validity of the reconstruction.

Application of service loads to engineering structures creates stresses in the constituent materials. These stresses generate material defects which, if accumulated, result in reduced structural stiffness, diminished load-bearing capacity, and may eventually lead to catastrophic failure.

Bone is unique among engineering structures because of its capacity for self-repair of defects caused by physiologic loading. These defects are known as "microdamage" and consist of observable microcracks and not-so-readily observed diffuse damage. Microcracks are quantified by crack number, crack length, and number/length density distributions. Bone microdamage is self-repaired by bone turnover, a complimentary set of on-going cellular events consisting of bone resorption (targeted local destruction of bone with microdamage) followed by bone matrix formation (production of new organic material for subsequent mineralization and maturation into mechanically competent bone). Normal bone turnover prevents damage accumulation from reaching critical levels and confers bone with the biomechanical properties needed to resist excess deformation and avoid fracture.

Rates of bone formation and resorption must be maintained, from both relative and absolute perspectives, to sustain these biomechanical properties. Relative rates of resorption and formation must be equal to avoid losing or gaining bone mass. Absolute rates of turnover must also be controlled to avoid premature bone resorption or prevent microdamage accumulation. Specifically, if the rate of bone turnover is inadequate, then the rate of microdamage repair is less than the rate of microdamage creation and the net amount of microdamage increases. Unrepaired microcracks will increase in length while bone is physiologically stressed and these cracks will eventually coalesce to form larger cracks that could become macroscopic. Thus, bone with above-normal levels of microdamage will have a reduced load-bearing mechanical competence, a diminished injury threshold, and may catastrophically fail (fracture) when subjected to low-energy trauma.

The forensic investigator should appreciate the variety of bone-quality factors, including microdamage, which collectively govern the mechanical competence of this organ. To reconcile the seeming disparities between fracture and low-energy trauma, the forensic investigator should search for mechanisms linked to abnormal bone turnover. This search should begin with a review of the subject's medical history because low bone turnover is a "silent" phenomenon that accompanies particular diseases or therapies. Excess consumption of certain anti-osteoporosis medications, for example, is known to cause low bone turnover. Advanced age also is associated with low bone turnover. A more thorough investigation requires a surgically procured bone sample upon which histological processing and quantitative microscopic analytical measurement methods are employed to quantify the distributions of mean crack number, length, and density.

The material quality analytical approach described in this and related prior "low-energy bone fracture" presentations offer the forensic investigator a general tool for reconciling low-energy traumatic events with seemingly incongruous injuries in other non-osseous tissues or organs.

Low-Energy Bone Fracture, Human Injury Analyses, Accident Reconstruction