

# The post-yield behavior of bone: From nano to macroscopic length scales

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Age-related and osteoporotic bone fractures are a major concern for the health care of elderly and postmenopausal women populations. One of the leading reasons for such fractures is the deteriorated toughness of bone (a measure of bone quality) in addition to loss of bone mass and changes in tissue architectures. Recent evidence has evinced that bone may experience two distinct stages in the post-yield deformation: it begins with acute increases in microdamage accumulation and viscous response (Stage I), and then is dominated by the plastic deformation and saturated viscous response (Stage II). Intriguingly, such a bulk behavior of bone appears to be very similar independent of loading modes (e.g., tension and compression), suggesting that the post-yielding of bone follows a similar mechanism. In addition, internal strains in individual mineral and collagen phases have been found to be different and such a discrepancy increases considerably as bones yield. Moreover, it is shown that hydration plays a significant role in sustaining the toughness of bone, but such effects diminish with

aging. In general, elderly bones tend to fail prematurely with very limited permanent (or plastic) deformation compared with the younger bones. Thus, elucidating the underlying mechanics of the post-yield behavior of bone is crucial for understanding the influencing factors to age- and disease-related bone fractures. In this presentation, it is intended to explore the relationship between the bulk and ultrastructural behavior of bone based on the current understanding on this issue reported in the literature and from our own studies. Several aspects will be discussed: 1) Bulk post-yield behavior of bone and its relationship with the ultrastructural response of the tissue using a novel progressive loading protocol; 2) A nanomechanics and probabilistic fracture mechanics based simulation of microdamage accumulation in bone; 3) Evaluation of *in situ* mechanical behavior of bone using nano techniques; 4) Interfacial behavior between the mineral and collagen phases in bone and its contribution to the post-yield behavior of bone; 5) Several potential pathways affecting the post-yield behavior bone.

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