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AN X-FEM STATISTICAL APPROACH TO ASSESS FRACTURE STRENGTH OF HUMAN CORTICAL BONE MICROSTRUCTURES

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ABSTRACT

We present a multiple scale approach for modeling multiple crack growth in human cortical bone under tension [2]. The Haversian microstructure, a four phase composite, is discretized by a classical finite element method fed with the morphological and mechanical characteristics, experimentally measured [3], to mimic human bone heterogeneity at the micro scale in Figure 1. The fracture strength of human bone, exhibiting aging signs, is investigated through tensional percolation simulations in statistical microstructures in Figure 2(a), (b) and (c). The cracks are initiated at the micro scale at locations where a critical elastic-damage strain-driven criterion is met. The cracks, modeled by the eXtended Finite Element Method [4], are then grown until complete failure when a critical stress intensity factor criterion is attained [5]. The model provides the fracture strength and the global response at the material scale and the stress-strain fields at the microscopic level. The model creates a constitutive law at the material scale in Figure 2(d), (e) and (f) and emphasizes the influence of the microstructure on bone failure and fracture risk assessment. These results are validated against experiments.

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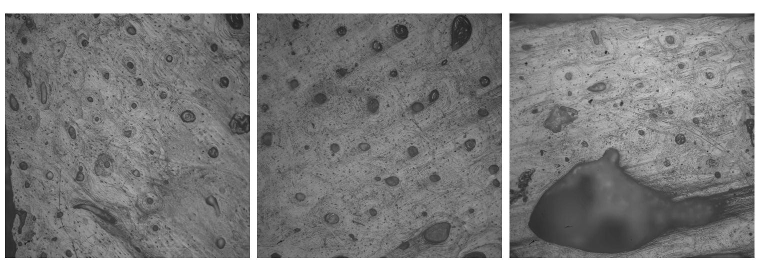

(a) (b) (c)

Figure 1: (a) Light microscope human bone observation $w02_07$. (b) Light microscope human bone observation $w03_07$ (c) Light microscope human bone observation $w10_07$

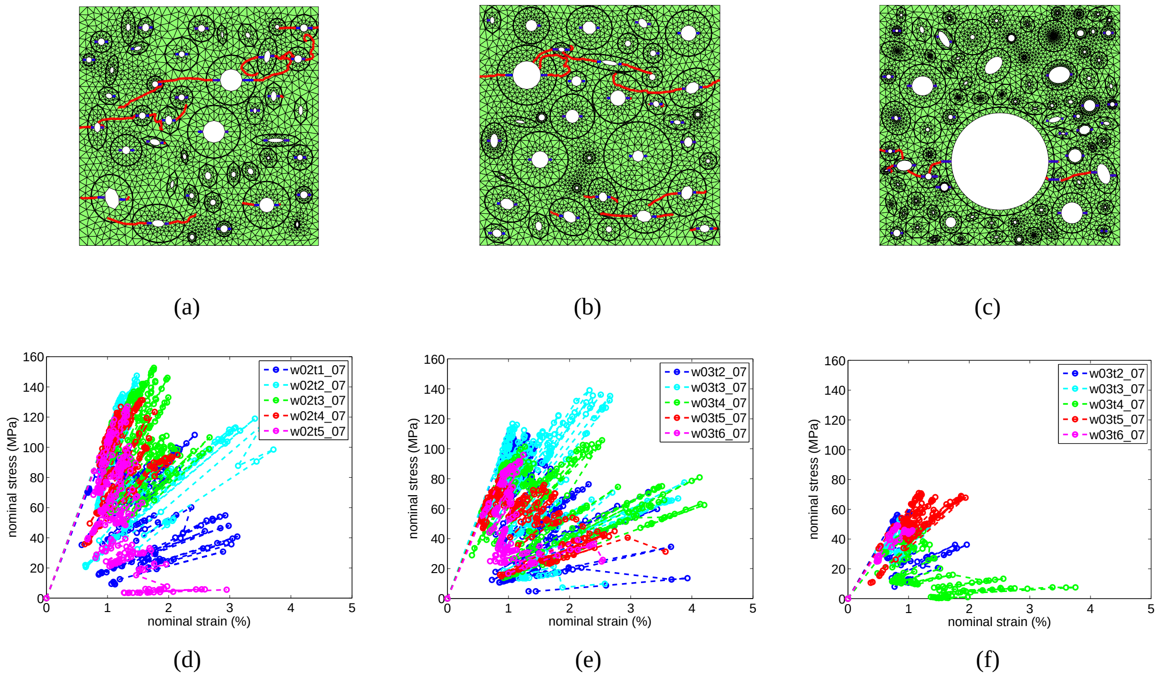

Figure 2: Cracks are initiated by an elastic-damage criterion (0.4 % ϵ_{22} strain [1]). Initiated cracks in blue; crack growths in red using the X-FEM in $w02\_07$ (a), $w03\_07$ (b)) and $w10\_07$ (c). Global stress-strain response in $w02\_07$ (d), $w03\_07$ (e) and $w10\_07$ (f).

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