Investigation of yield and fracture criteria in composite femur bone using finite element methods

By: Malin Ahlgren

Patient-specific finite element models have been proposed as a tool to improve bone strength and the accuracy of fracture risk prediction in individuals. There is no consensus in the literature about the fracture mechanisms occurring in human femora, and only a few studies compared the different criteria and definition of bone fracture. Many different material properties, failure theories and post-yield properties have been used in studies of the human femur bone. Therefore, the aim of the present study was to evaluate the different failure and post-yield theories for composite femur bone loaded in a single leg stance configuration.

The tested criteria were von Mises, maximum principal stress, Hoffman, Mohr-Coulomb and maximum principal strain. These criteria were evaluated using three different methods when simulating post-yield properties; not applying any post-yield modification of material properties, reducing Young's modulus by 95% and finally reducing Young's modulus in two steps (reducing with 25% and 95% in reference to the original value).

The results from the finite element models were evaluated against experimental data in terms of fracture load, fracture location, force-displacement curves and superficial strains. The maximum principal strain criterion preformed the most accurate results, suggesting that bone fracture mechanism is strain driven. The von Mises criterion, that was the only criterion assuming equal strength limits in tension and compression, had the lowest correlation with the experimental results. Simulating the post-yield properties has a positive effect on the fracture prediction accuracy, both in terms of strain levels, and fracture load and location.

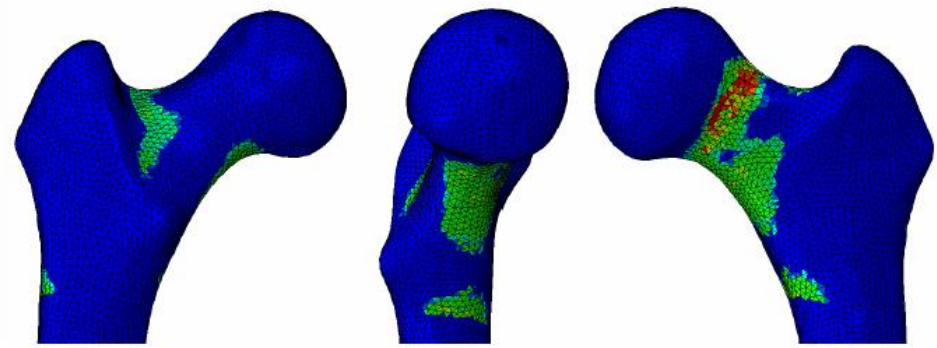

Figure: The estimated fracture load by using the von Mises criterion. Red indicates the failed finite elements, whereas yellow and light blue and green indicate that 1-3 integration points within the element are above the threshold.