A novel method for observing hip fracture during impact simulating a sideways fall

Emily Bliven, Pierre Guy, Peter A Cripton

Background

Hip fracture is a traumatic and increasingly prevalent injury with high rates of morbidity and mortality. Understanding the biomechanics of how these fractures occur is essential for the advancement of successful treatment and prevention strategies. However, bone surfaces are usually not visible during impact tests of biofidelic specimens (with soft tissue surrogate), prohibiting proper visualization of fracture occurrence. Researchers often resort to limited methods such as observing fracture mechanics in bone-only impacts, or extrapolating results from soft tissue marker data recorded using high-speed cameras. The use of high-speed video alone to analyze impact tests of such configurations does not allow for a comprehensive understanding of the fracture mechanics taking place at high speeds during impact, especially since some fractures may initiate in the cancellous bone. Our research aims to develop and evaluate the suitability of a high-speed x-ray system as a tool for visualizing hip fracture, throughout the volume of the hip, during a realistic sideways fall impact.

Methodology

Previous work in our lab focused on development of a pendulum impactor shown to successfully produce clinically relevant hip fracture patterns when full cadaveric femur-pelvis constructs were subjected to inertia-driven impacts simulating a sideways fall.[1] Our goal in the present study was to supplement the previously-validated experimental set-up with a custom high-speed x-ray system consisting of an x-ray source, image intensifier, and high-speed video camera.[2] Preliminary methods included the optimization of the novel system by identifying parameters such as configuration, resolution, capture rate, and x-ray exposure factors. The feasibility of implementing the proposed imaging method was then tested iteratively with pilot tests, in which a surrogate femur-pelvis construct (Sawbones) was subjected to a sideways fall impact on the greater trochanter at 3.1 m/s. The impacting femur was later notched at the inferior femoral neck to increase propensity for fracture occurrence.

Results and Discussion

Notching of the inferior femoral neck of the ipsilateral femur resulted in the occurrence of a multifragmentary pertrochanteric fracture upon impact, which was captured using the described x-ray system. As expected, fracture was observed to initiate at the notch location, and traversed laterally across the femur within a span of 1.3 ms. Optimized exposure factors used in this test were determined to be 160 kV, 4mA, and an exposure of 20 µs.

The results of this pilot work demonstrate the ability to observe hip fracture using the high-speed x-ray system with the developed pendulum impactor. The presented tool is theorized to offer more robust capabilities than current imaging techniques to observe bone mechanics during impact tests. Obtaining such data could be key to understanding and ultimately preventing hip fractures. Our work presents the proof-of-concept feasibility of a novel tool for observing the complex bone mechanics intrinsic to hip fracture in a realistic and biofidelic impact scenario.