Impact Testing of a Proximal Femur in a Fall Configuration

Gilchrist S[1,2,3,‡], Guy P[3,4], Cripton P[1,2,3,4]

1: University of British Columbia (UBC), Department of Mechanical Engineering; 2: UBC Bridge Program; 3: Centre for Hip Health and Mobility, Vancouver General Hospital; 4: UBC Department of Orthopaedics

Introduction

- Hip fracture is a prevalent problem
- 74% of those with fracture are undiagnosed with osteoporosis by bone mineral density (DXA) scanning [1]
- Possible bone architecture explanation
- Previous studies looking at architectural explanation had significant limitations
  - Low loading rate ≠ Fall from standing
  - Imposed fracture ≠ Physiologic fracture

Objectives

1) To impact a femur with energies, forces and velocities similar to those experienced in a fall to the side.
2) To determine the influence of architectural features in the cortical bone on the fracture load, location and course.

Methods

- One fresh frozen proximal femur
- Bone surface prepared with speckle pattern for digital image correlation
- Placed in the Orthopaedic and Injury Biomechanics Group's drop tower in the standard fall configuration (Fig 1) [2]
- Dropped mass = 16.5 kg
- Impact velocity = 3.5 m/s [3]

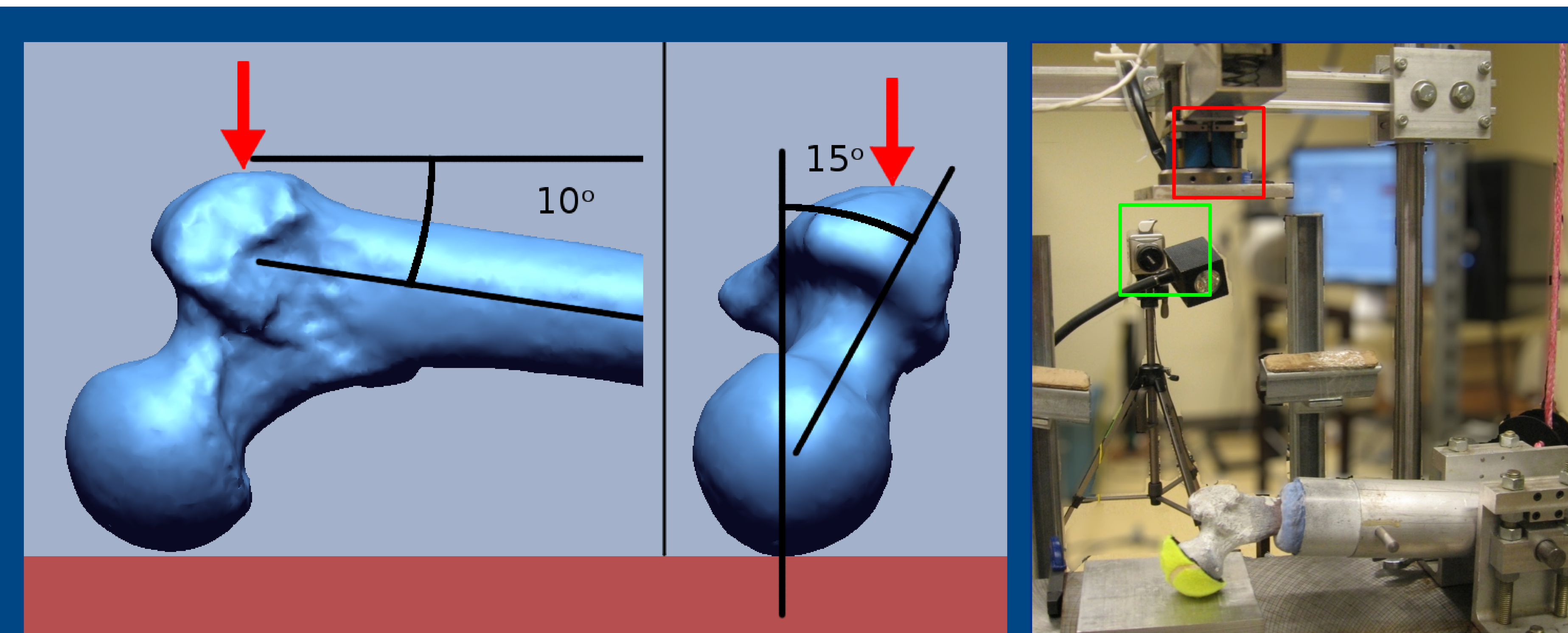

Figure 1: Femur orientation and setup of the experiment
The loading configuration, shown on the left, simulates a fall in the posterio-lateral direction, or a fall to the side and slightly backwards. The apparatus used to impact the femur, shown on the right, consisted of an instrumented impactor on the drop tower gantry (red box) and two high speed video cameras (green box). The cameras collected at 9009 frames/second at a resolution of 384x384 pixels. Data from the impactor was collected at 90 kHz, synchronized with the video frames.

Results

- Femur was impacted at the desired energy and velocity
- Fracture began at 4.88 ms after impact and continued for 3.33 ms (Fig 2)

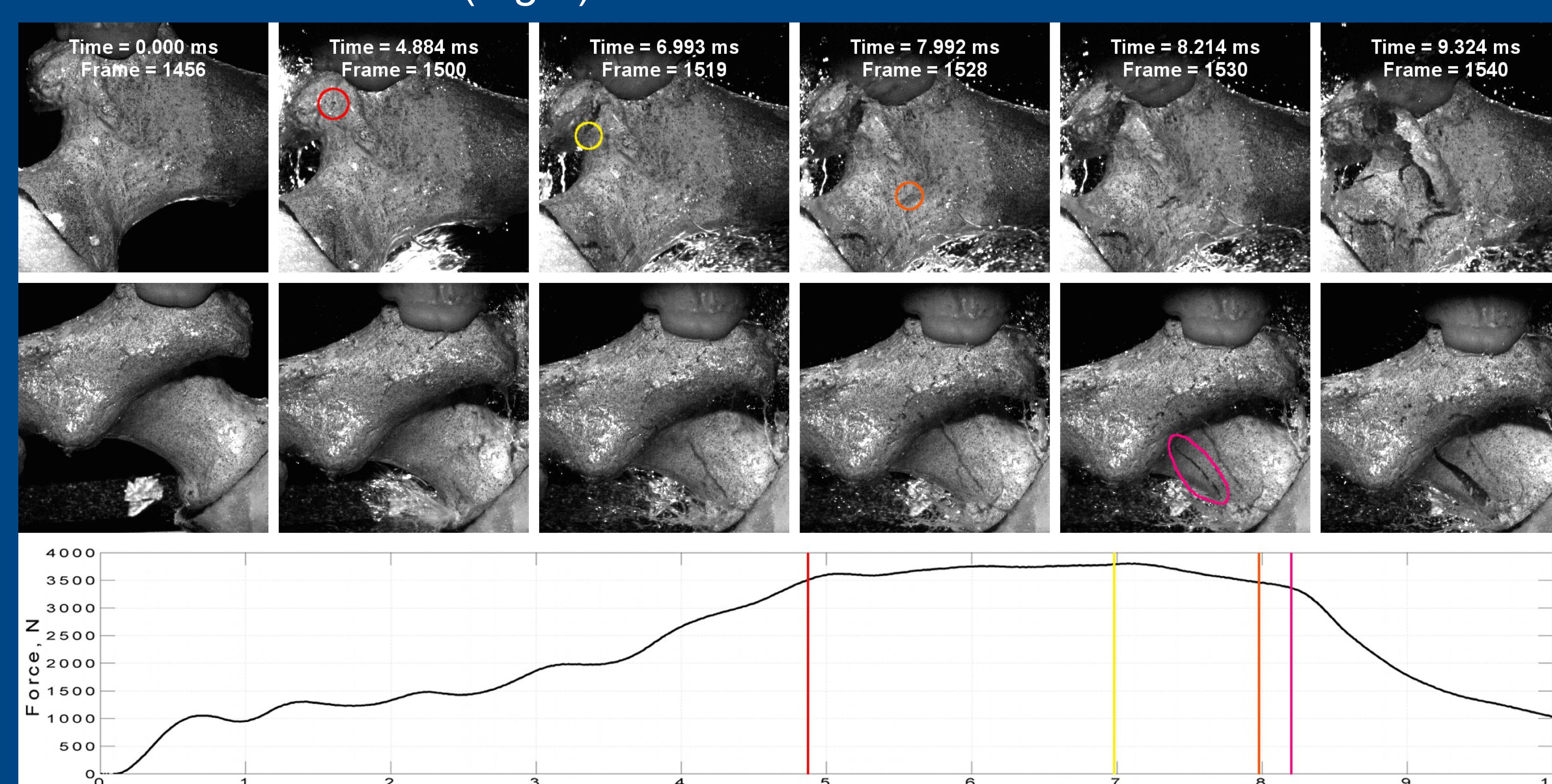

Figure 2: High speed fracture sequence. Top row of images shows the anterior camera and the bottom row is the posterior camera. Circles on the top row images correspond to fracture events and are indicated on the force vs time trace on the bottom.
The fracture began at 3520 N at 4.88 ms in the greater trochanter. The load plateaued, but continued to increase until 3800 N at 6.99 ms when another fracture progressed along the superior femoral neck. At this point, the load began to decrease and general yielding was observed lateral to the trochanteric line. At 7.99 ms a crack opened on the anterior surface of the neck, passing through a vascular perforation. This was shortly accompanied by a fast-moving crack on the posterior neck and a precipitous drop in load carrying capacity.
Finally, a highly comminuted fracture resulted.

Discussion

- Fracture began in region shown to be vulnerable in previous tests [4]
- Fracture highly comminuted and pulse duration short [3]
- Modelling of surrounding anatomical structures will be used to modify pulse duration

Conclusion

We impacted the femur with correct energy and velocity and created a clinically relevant fracture, noting influence of structural features.

In next phases of the research, surrogate soft tissues will be added over the GT and the pelvic compliance will be included in order to render the pulse duration more representative of that observed in human volunteers [3].

‡: **Corresponding Author**: seth@mech.ubc.ca

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References [1] E. S. Siris et al., Arch Intern Med, 164(10): 1108-1112, [2] A. C. Courtney et al., Calcified Tissue International, 55(1):53-58 [3] A. C. Laing et al., Journal of Biomechanics 43(10):1898-1904 [4] P. M. de Bakker et al., Journal of Biomechanics, 42(12):1917-1925