## D30 Age Effects on Bending Fracture Patterns in Ovine Femora

*Patrick E. Vaughan, BS*, Michigan State University, Orthopaedic Biomechanics Laboratories, E Fee Hall, Rm 407, East Lansing, MI 48824; Feng Wei, PhD, Michigan State University, 965 Fee Road, Rm A-414B, East Lansing, MI 48824; and Roger C. Haut, PhD, Michigan State University, Orthopaedic Biomechanics, A407 E Fee Hall, East Lansing, MI 48824*

After attending this presentation, attendees will better understand the effects of age on fracture patterns in controlled, concentrated four-point bending tests on fresh ovine femora.

This presentation will impact the forensic science community by utilizing ground-truth experimental data and simple Finite Element (FE) analyses to aid in the interpretation of fracture patterns under concentrated four-point bending of ovine femora.

Most research in forensic biomechanics of long bones has focused on the failure pattern from three-point bending and how tension wedges are consistently produced. This involves a transverse crack that initiates on the tensile surface of the bone and forms a Y-shaped fracture pattern from the tensile to the compressive sides of the bone. From these data, many forensic practitioners claim to cite impact direction based on the three-point model as noted.[1] This becomes problematic because cases of compression wedge fractures under non-controlled impact testing have been reported where the typical Y-shaped fracture pattern has become inverted.[2] Furthermore, reports cite a consistent pattern of compression wedge fractures under a slow, concentrated four-point bending configuration.[3] Recently, 40% of ovine femur failures have been reported to be compression wedge fractures.[4] Also, it has been shown that under torsion, age and rate effects influence spiral fracture patterns of long bones.[5] It is therefore forensically relevant to determine how compression wedges in long bone fractures might be produced under a concentrated four-point loading configuration, and what effects, if any, specimen age may have on the production of these compression wedge fracture patterns.

The objectives of the present study were to: (1) execute controlled, concentrated four-point bending tests of ovine femora; (2) identify fracture patterns in association with specimen age; and, (3) study the fracture patterns with the help of FE modeling.

Fourteen freely supported ovine femora were failed under a concentrated four-point bending configuration.[3] Five femora (one day to one week old) were classified as young and nine femora (one to two years old) were classified as old. In this test configuration, the distance between the two outer supports was 60% of the specimen length, while the distance between the two inner loading probes was 10% of the specimen length. A servo-hydraulic testing machine was used to fracture the bones. Failure was achieved at a rate of 2Hz over an 8mm and 10mm displacement of the loading probes for young and old bones, respectively. All bones were loaded on the posterior surface of the bone. The experiments were filmed with a high-speed camera at 40,000fps. After experimentation, specimens were examined for gross fracture morphology.

Prior to mechanical testing, a whole-bone Computed Tomography (CT) scan was taken of an old ovine specimen. These 3D images were reprocessed using volumetric techniques in Mimics®, given a tetrahedral mesh in 3-matic®, then imported into Abaqus 6.11 where loads and boundary conditions were applied to simulate the above-mentioned four-point bending tests.

In the young group, 60% (3/5) of the specimens failed with a tension wedge. The remaining specimens exhibited complete transverse fractures; however, in the old group 67% (6/9) of the specimens produced compression wedge fractures, while the remaining specimens showed oblique fractures located slightly outside an inner probe where compression wedges initiated. High-speed footage confirmed fracture initiation occurring on the tensile side of the bone in all cases. All experimental measures (i.e., initial bone stiffness, bone displacement at failure, energy input during failure, and failure loads) have shown significant differences between groups at a level of $p<0.001$.

The observed experiments demonstrated that under concentrated four-point loading, young bones produced transverse or tension wedge fractures while older bones produced compression wedge fractures. The direction of compression wedge fracture was perpendicular to the line of maximal principal stresses generated from the FE model of the older bone, slightly outside the inner probes. To date, FE analyses of younger bones have not been completed to help explain the production of the transverse and tension wedge failures in the young bones. The premise is that changes in the structural and material descriptions of these bones will help in these explanations.

**Reference(s):**

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**Forensic Biomechanics, Long Bone Fracture, Four-Point Bending**