A96 Fracture Characteristics of Fresh Human Femora Under Controlled Three-Point Bending

Mariyam I. Isa, BS, Michigan State University, Dept of Anthropology, 354 Baker Hall, East Lansing, MI 48824; Todd W. Fenton, PhD, Michigan State University, Dept of Anthropology, 354 Baker Hall, East Lansing, MI 48824; Trevor S. DeLand, BS, E Fee Hall, 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 relationship between controlled, experimental loads and fracture outcomes in long bone bending tests on fresh human femora.

This presentation will impact the forensic science community by contributing ground-truth data linking a specific, consistent set of loading conditions under three-point bending with bone behavior and fracture morphology.

Current literature associates long bone bending failure with tension wedge fractures, in which a transverse crack initiates at the tensile surface of a bent bone and branches as it propagates toward the impacted surface of the bone; however, numerous experimental studies of long bone bending have reported variability in gross fracture outcomes. Wedge fragments have not always been presented and in some cases researchers have reported compression wedges with the transverse crack on the impacted surface of the bone.[1-3] Martens reported a high frequency of compression wedges under a four-point bending configuration and Kress reported some cases of compression wedges under uncontrolled loading situations.[1,2]

Fenton et al. performed controlled three-point bending experiments on dry human femora and consistently documented incomplete tension wedge-type fractures.[4] Within this set of experimental impacts, the orientation of the incomplete wedge could be used to reliably determine the direction of the applied load.

The objectives of the present study were to: (1) execute controlled three-point bending tests of axial loaded, fresh human femora; (2) describe the mechanical behavior of the specimens; and, (3) identify fracture outcomes, including characteristics of the complete and incomplete fractures and gross fracture surfaces.

Six pairs of unembalmed human femora were mounted into a three-point bending fixture in a servohydraulic materials testing machine. Static axial loads simulating standing posture were applied with a spring-mounted fixture. Failure was achieved via controlled displacement of a steel anvil at midshaft, inducing three-point bending. Right femora were loaded on the posterior surface and left femora were loaded anteriorly. Following each failure experiment, specimens were grossly examined for complete and incomplete fractures and fracture surface morphology.

These controlled bending tests demonstrated variability in mechanical behavior between human subjects. Failure load ranged from 4.0 to 9.2kN. The displacement of the bone to failure ranged from 5.8 to 13.2mm and the energy to failure ranged from 15.0 to 66.3J; however, there were no significant differences in failure load, displacement, or energy between the paired anterior and posterior loaded specimens. The variation in mechanical behavior did not appear to affect the consistency of fracture characteristics.

The controlled bending tests produced consistent fracture outcomes across specimens. In each case, a short transverse crack was initiated on the tensile surface of the bone. Thus, the crack occurred on the anterior surface in all posteriorly loaded femora and on the posterior surface in all anteriorly loaded femora. Upon gross examination, the transverse fracture surface was consistently mottled and billowy. Complete and incomplete fractures branched off the transverse crack and angled toward the compressed surface of the bone, producing an incomplete tension wedge. In each case, the branch point occurred on the tensile side of the neutral axis. After the branch point, the fracture surface appeared jagged and sharp. No complete wedges presented. Complete fractures were either primarily oblique (42%) or transverse (58%). All specimens exhibited at least one incomplete fracture that curved from the branch point to parallel with the bone's long axis.

This study demonstrated that bone failure occurred in a predictable manner under controlled, experimental loading conditions. Three-point bending with axial compression produced consistent fracture characteristics, although the mechanical behavior was variable between human subjects. For each specimen, the specific orientation of fracture reliably reflected the direction of the applied load.

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This work is in response to the Scientific Working Group for Forensic Anthropology (SWGANTH) Gap Analysis Report, which calls for collaborative work with biomechanists to improve current methods in trauma analysis. To this end, the Michigan State University Forensic Anthropology and Orthopedic Biomechanics Laboratories are pursuing a joint research initiative investigating the effects of specific, experimentally controlled loading conditions on fracture outcome; this presentation communicates the latest work on three-point bending of human femora. The data contributed here will help experts determine the specific loading conditions that lead to a specific set of long bone fracture characteristics.

References:

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Three-Point Bending, Blunt Force Trauma, Long Bone Fracture

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