H72 Determination of Impact Direction Based on Fracture Patterns in Human Long Bones

Todd W. Fenton, PhD, Michigan State University, Department of Anthropology, 354 Baker Hall, East Lansing, MI 48824; Ashley E. Kendell, MA, 721 North Capitol Avenue, Apartment 4, Lansing, MI 48906; Trevor S. DeLand, BS, Michigan State University, East Fee Hall, East Lansing, MI 48824; and Roger C. Haut, PhD, A407 East Fee Hall, Orthopaedic Biomechanics, Michigan State University, East Lansing, MI 48824*

After attending this presentation, attendees will have a better understanding of how to determine the direction of impact on long bones based on fracture pattern. The main goal of this research is to show that under controlled laboratory conditions, fracture patterns in human long bones display consistent characteristics that allow the determination of impact direction.

This presentation will impact the forensic science community by clarifying the relationships between characteristic features of fracture patterns and directionality of impact on human long bones.

The current forensic literature suggests that the direction of blunt force trauma to human long bones can be determined by the presence and orientation of a butterfly fracture. However, a recent study by Thomas and Simmons (2010) using a sheep bone model suggest that the butterfly pattern was an inconsistent finding. They then conclude that blunt force direction should not be assumed based on the presence or orientation of a butterfly fracture pattern. A series of experimental studies using 550 human long bones (Kress, 1996) also generated various patterns of fracture, including the typical butterfly, inverted wedges, oblique and transverse fractures. However, a variety of impact loading conditions and devices were used. Therefore, it remains unclear whether a butterfly wedge is a consistent finding during blunt force trauma, or, when present, if its orientation accurately predicts direction of loading.

Based primarily on the mechanics literature, this study hypothesized that under controlled laboratory conditions of impact loading and defined constraint of the bones, a consistent set of fracture features will result that can be used to predict impact direction on human long bones. While previous research typically focuses on the presence of butterfly fractures to determine impact direction, the current study examined the presence of complete as well as incomplete fracture characteristics to determine directionality of blunt force trauma to a long bone. Since it is believed that human long bone fracture initiates on the tension side and then propagates along lines of shear on the compression side to form a butterfly fracture, the current study also examined the location of fracture initiation and the pattern of fracture propagation.

In this study, 15 dry human femora were impacted with a rounded 2.5-inch cylinder perpendicular to the long axis of the bone. The anvil was connected to the hydraulic actuator of a material's testing machine (MTS, model 810). The ends of the bones were potted in room-temperature curing epoxy resin and inserted into cylindrical cups that allowed translational and rotational motions. The femora also had an axial load of 100 lbs. applied during the three-point bending tests. Impact loads transverse to the long bone axis were applied in the anterior-posterior and posterior-anterior directions by controlled displacement of the anvil at 0.2 m/s. In numerous experiments, fracture initiation and propagation were captured with a high-speed camera at 10,000 fps.

Results indicate that on a gross scale, 9 of 15 (60%) fractures were oblique, 4 of 15 (27%) fractures were transverse, and 2 of 15 (13%) were comminuted. But the gross fractures did not tell the whole story. A lesson learned is that one must also inspect the incomplete fractures. Closer examination of the bones revealed four common long bone fracture patterns: (1) incomplete butterfly fractures (tension wedges) in 80% of the cases; (2) transverse fractures on the tension (initiation) side in 80% of the cases; (3) failure angle shifts from approximately 45° to parallel (to the long axis) in the oblique gross fractures in 87% of the cases; and, (4) breakaway spurs on the compression side in 73% of cases. These common fracture patterns represent criteria that enabled us to determine the blunt force impact direction in 14 of 15 experiments.

In summary, the current study indicated that in a controlled laboratory setting, examination of distinct fracture characteristics help determine impact direction on human long bones. Specifically, a set of four criteria, outlined above, can be evaluated and used to quite accurately determine the direction of traumatic forces on tubular bone. The results also show that fracture consistently initiated on the tension side of the bone, opposite to the side of blunt force trauma, and that fracture propagation typically followed theoretical lines of maximum shear stress.

Fracture Pattern, Blunt Force Trauma, Directionality of Force