A95 An Analysis of Butterfly Fracture Propagation

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After attending this presentation, attendees will have a clear understanding of the initial fracture mechanism and subsequent fracture propagation of butterfly fractures (a.k.a. wedge fractures). This presentation will clarify how butterfly fractures form and where, in regard to the applied loading force, this fracture pattern initiates in moderate- to high-speed blunt impacts. Attendees will gain a greater understanding of the fundamental failure mechanisms associated with butterfly fracture patterns. Attendees will also gain knowledge on the potential use of biomechanical bone surrogates in forensic anthropological studies of blunt force trauma.

This presentation will impact the forensic science community by providing clarification on how butterfly fracture patterns are formed using an interdisciplinary approach. Combining biomechanics and forensic anthropology, this study conducted dynamic three-point bending tests on surrogate tibias to determine whether butterfly fracture patterns initiate in tension or compression. The results of the tests and analyses allowed conclusions regarding the initial fracture mechanism and the subsequent fracture propagation. This information can assist pathologists and forensic anthropologists in determining the direction of force when trauma has resulted in the formation of a butterfly fracture pattern.

Purpose**:** This research addresses the issue of applied loading direction, initial fracture mechanism, and subsequent fracture propagation of butterfly fractures. The purpose of this research is to identify and analyze the propagation of butterfly fractures in lower limbs initiated through blunt force trauma. The scope of this research is limited to ten surrogate tibias.

Materials and Methods**:** Sawbones® composite tibias were utilized for this study. These models have previously been shown to display similar biomechanical properties (stiffness, fracture toughness, and ultimate strength) as real human tibial bone. All Sawbones® tibias were medium-sized left fourth generation, which have a foam core, 9mm canal, and an overall length of 37.5cm. Tests were conducted using a dynamic three-point bending impactor designed to simulate blunt force trauma applied in a Lateral-Medial (L-M) direction to the surrogate tibias. The applied loading direction of L-M was chosen to simulate a pedestrian vs. vehicle accident, which is a common source of butterfly fractures. Each test performed was documented using a high-speed video camera at 5,000 frames-per-second. Motion analysis was performed using a marker affixed to the impactor to determine dynamic deformation of each specimen. Video was also analyzed to determine where the fracture initiated and the path of fracture propagation. A triaxial accelerometer array was affixed to the impactor for determining impact force using Newton's 2nd law. Accelerometer data were collected at 20,000 Hz and filtered using Channel Frequency Class (CFC) 1000. A photogate was used to measure impactor velocity just prior to impact with the tibia. Photographs and measurements were taken before and after each test to document resulting trauma.

Results and Conclusions**:** All specimens tested resulted in complete fractures. All fractures initiated on the convex side of the bending bone and were the result of tensile failure of the material. The fracture(s) then propagated toward the concave side of the bending bone on an angle of approximately 45 degrees from the long axis of the bone. This angled fracture pattern is consistent with shear failure of the material within an area of the bone experiencing high compressive stress. Completion of the propagation resulted in the classic "wing shape" seen in butterfly fracture patterns. The current study is in agreement with prior biomechanical studies, which demonstrate the initial bony failure occurs as a result of high tensile stress in the material followed by shear failure on the compressive side of the bending bone. Contrary to some previous studies, none of the butterfly fractures in this study initiated on the compressive side of the bending bone and no compressive wedge fracture patterns were observed.

Fracture Propagation, Butterfly Fractures, Composite Bones