A119 The Application of Fractography in Trauma Analysis of Complex Long Bone Fractures

Mariyam I. Isa, MA, Michigan State University, East Lansing, MI 48824; Todd W. Fenton, PhD, Michigan State University, East Lansing, MI 48824; Lillian Antonelli, Michigan State University, East Lansing, MI 48823; Patrick E. Vaughan, MS, Michigan State University, East Lansing, MI 48824; Feng Wei, PhD, Michigan State University, East Lansing, MI 48824*

Learning Overview: After attending this presentation, attendees will have learned about the utility of fractography in identifying point of failure and direction of crack propagation in complex long bone fractures.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by adding to a growing body of research on the application of fractography to skeletal trauma analysis. This current study contributes new data from concentrated four-point bending experiments in which fractographic features were compared directly to high-speed video of fracture propagation.

Fractography refers to the study of fracture surface features and the relationship of these features to crack propagation.[1] Fractographic methods have been applied to a variety of materials to interpret the causes of failure. Recently, Christensen et al. proposed a method for applying fractography to the analysis of skeletal trauma in forensic anthropology cases.[2] They described and investigated several fractographic features, including bone mirror, bone hackle, arrest ridges, and cantilever curl, in a sample of human femora that failed in three-point bending experiments. Using these features, they reported low inter- and intra-observer error identifying fracture initiation and estimating fracture propagation in cortical bone.

While these results are promising, there is a need to clarify the strengths and limitations of fractography in skeletal trauma analysis through additional research. In the previous study, each specimen under three-point bending exhibited only one primary fracture. This allowed for a relatively straightforward assessment of one of two complementary fracture surfaces. However, it is of interest to assess whether fractography can help resolve fracture initiation and propagation in more complex cases of skeletal trauma.

The current study investigates the use of fractography in a sample of femora fractured under another set of controlled loading conditions: concentrated four-point bending. Unlike three-point bending, specimens fractured under concentrated four-point bending exhibited complex, “compression wedge” fracture patterns involving multiple fragments.

The goals of this study were: (1) to assess the presence/absence of fractographic features in this sample; and (2) to assess whether these features could be used to interpret fracture propagation. The materials assessed in the current study include six whole, biomechanically fresh human femora failed in concentrated four-point bending experiments as a part of a previous replication study of the work of Martens et al.[3,4] All experiments were filmed with a high-speed camera at 40,000 frames per second (fps) in order to capture fracture initiation and propagation.

The fracture surfaces of each bone fragment were examined macroscopically using oblique lighting and a low power microscope. The presence or absence, anatomical locations, and orientations of four fractographic features were noted: bone mirror, bone hackle, arrest ridges, and cantilever curl. These features were used to interpret the location of initial failure and direction of crack propagation. Finally, fractographic interpretations were compared to the real sequence of fracture events captured on video.

Twenty-eight bone fragments were examined across the six specimens in the study (mean=4.66 fragments per impact). At least one fractographic feature was present on each of the 28 fragments. In each specimen, bone mirror occurred only in the area corresponding to initial failure near the tension surface. As fracture initiated from exactly one location in each experiment, only fragments with a fracture surface corresponding to that location exhibited bone mirror.

Arrest ridges and/or cantilever curl were present where fractures terminated. All six specimens exhibited multiple termination sites; these features were therefore observed in more fragments than bone mirror. Bone hackle was the feature most commonly observed across fragments, although it was subtler in appearance than bone mirror, arrest ridges, and cantilever curl.

In all six specimens, the fractographically inferred direction of fracture matched to the actual fracture propagation direction observed on high-speed video. These results indicate that the fractographic features described by Christensen and colleagues are informative of initial failure and crack propagation even in cases involving complex, compression wedge fractures.[2]

In forensic anthropology, trauma analysis is moving beyond simple descriptions and fracture typologies. Instead, investigators are generating more nuanced interpretations of sequential failure modes, from fracture initiation to fracture termination. Fractography demonstrates promise as one tool to aid in such interpretations. For cases involving complex fractures, reconstructing crack development provides an important foundation for subsequent interpretations, such as bending direction of a long bone in blunt force trauma.

Reference(s):

1. Hull D. *Fractography: Observing, Measuring and Interpreting Fracture Surface Topography*. Cambridge: Cambridge University Press; 1999.
2. Christensen A.M., Hefner J.T., Smith M.A., Webb J.B., Bottrell M.C., Fenton T.W. Forensic fractography of bone: A new approach to skeletal trauma analysis. *Forensic Anthropology* 2018; 1(1):32–51.
3. Isa M.I., Fenton T.W., Vaughan P.E., Wei F., Haut R.C. Concentrated Four-Point Bending and Fracture Behavior in Human Femora. *Proceedings of the American Academy of Forensic Sciences*, 69th Annual Scientific Meeting, New Orleans, LA. 2017.
4. Martens M., van Audekercke R., de Meester P., Mulier J.C. Mechanical behaviour of femoral bones in bending loading. *Journal of Biomechanics* 1986; 19(6):443-54.

Trauma Analysis, Fractography, Blunt Force Trauma

*Presenting Author