H73 Bone Fracture Mechanics: *In Vitro* Strain Gauge Analysis of the Ribs and Mandible During Failure

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The goal of this project is to employ *in vitro* strain gauge analysis to better understand the mechanism of two types of fractures which are commonly seen in forensic cases: (1) rib fractures secondary to thoracic compression and/or blunt force, and (2) indirect mandibular fractures secondary to high velocity gunshot wounds of the cranial vault.

This presentation will impact the forensic community and/or humanity by helping to understand how bone responds to particular loading conditions. This information will allow investigators to more accurately reconstruct how rib and mandibular fractures occur, thus better understand their forensic importance.

Understanding the mechanism of trauma to the skeleton is vital if forensic anthropologists are to address issues of cause and manner of death. In this paper, the authors utilize *in vitro* strain gauge analysis, a technique used by biomechanists and anthropologists to examine the relationship between morphology and function of bone, to explore two different types of fractures for which the mechanism is unclear. Strain gauges measure the amount of bone deformation, i.e. strain, at the specific sites to which the gauges are bonded. The skeletal material for this project consists of teaching specimens that were re-hydrated in a saline solution. For both projects, the specimens were secured beneath the transducer of an MTS mechanical testing system so that they could be placed under a load along an axis simulating the direction of force under investigation (i.e., for the ribs, an anterior-posterior compression of the thorax, and for the mandible, lateral expansion of the condyles). The strain gauges were bonded along several locations where the greatest loads were anticipated, based on common fracture locations.

The first research problem is a buckling fracture of the ribs as noted by Symes *et al.* (2005). Long bones fail initially on the side experiencing tension, but Symes and colleagues have provided evidence that curved structures such as ribs can fail in compression. This has been noted during autopsy and is contrary to currently understood biomechanical beam theory. Initial experiments confirmed the findings of Symes and colleagues, that is, the authors were able to load a rib and reproduce a buckling fracture with the side in compression failing before the side in tension. This phenomenon was further explored experimentally by attaching strain gauges to several ribs along various locations (inner angle, outer angle, inner shaft, and outer shaft). The strain gauges allow the local bone deformation, i.e. strain, to be measured quantitatively. Each rib was loaded individually until failure. Both load cell forces and types of fractures are reported.

The second problem is a type of lesion best described as a secondary fracture of the mandible, often produced by a single gunshot wound to the cranial vault. This fracture is particularly well-documented among victims of genocide killed with 7.62 mm. projectiles, as well as in domestic homicide cases in which a relatively high velocity and/or high energy projectile is the cause of death. The fracture is known as a Kolusayen fracture among Turkish human rights investigators. In many of these cases, blunt trauma to the face and mandible can be ruled out on the basis of lack of associated fractures to the fragile bones of the face, alveolar bone, and dentition. These mandibular fractures can occur in the corpus at the canine alveolus, the gonial angle, the mental foramen, or the mental symphysis and they are often unilateral. The fractures are rarely found in the ramus or neck of the condyle where many blunt force fractures occur. Because the fracture is associated with uniformly fatal gunshot lesions of the cranial base and vault, it has been of little clinical interest and is therefore not referenced in the clinical literature. Since the mandibular fracture is secondary to the primary cause of death, this lesion is most likely underreported in autopsy protocols and is only discovered during examination of remains that have become skeletonized. Reconstruction of the events surrounding the death of the victim would be erroneous should these mandibular fractures be interpreted as being the result of direct blunt force trauma.

These experiments sought to record the amount of force needed to cause a mandibular fracture via lateral displacement of the condyles and test whether rapid glenoid expansion secondary to basilar fracture or temporary cavitation of a passing projectile can generate sufficient strain forces to produce a Kolusayen fracture. The condyles and superior rami were embedded in a resin compound and then one condyle was restrained. The contralateral condyle was then pulled away from the restrained condyle, simulating a spread of the glenoid fossae and the temporo-mandibular joint capsules. Initially a manual load was applied to gain a better understanding of how much strain the mandible experienced. After the manual application of load the mandibles were positioned beneath the transducer and the mandible was pulled until the bone failed. Preliminary data confirm that when the mandibular condyles are distracted, the corpus fails in tension and a fracture occurs in the most vulnerable part of the mandible. Again, both load force and fracture type is reported.

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