THE CLASSIC CORNER FRACTURE OF CHILD ABUSE: A PROPOSED MECHANISM OF INJURY.

Introduction: Corner fractures and bucket-handle fractures have been characterized by Caffey and later by Kleinman et al. as long bone fractures highly specific for child abuse[1,2]. Radiographically, Kleinman and Marks have described the typical morphological pattern as "a fracture extending through the primary spongiosa adjacent to the chondro-osseous junction. As the fracture line approaches the cortex, it veers away from the growth plate cutting a fragment of bone that is thicker peripherally than it is centrally." Histologically, they also showed that this peripheral fragment of bone included the subperiosteal bone collar[2]. In suggesting a biomechanical mechanism for these fractures, Kleinman and Marks indicate that "Metaphyseal lesions in infants occur from indirect forces. Shearing forces are applied to the metaphysis when the extremity is pulled, pushed, or twisted or when the infant is shaken[2]. Although the radiographic and histologic appearance of these fractures has been conclusively described in abused infants, the biomechanical loading mechanism that produces these fractures has not been clearly delineated. The purpose of this study was to evaluate the resultant injury seen in a neonatal porcine hind limb model under applied tensile, torsional, and bending (4-point) loads. We hypothesized that tension is the biomechanical loading mode responsible for bucket handle and corner fractures.

Materials and Methods: The pig hind limb model was chosen since the limbs are similar in size and anatomy, and since physical closure in pigs does not occur until about 6 months.[3] 30 hind limbs were harvested from 6-8 week old recently deceased neonatal pigs (IACUC exempt). Soft tissues of the knee joint were left intact. Soft tissues superior to the mid-shaft of the femur and inferior to the mid-shaft of the tibia were removed. Ten limbs were tested in tension. An additional ten were tested in torsion. The remaining 10 were tested in four-point bending. For both tension and torsional loading modes, calcium sulfate dental cement was used to pot the mid-shaft of the femur superiorly and the mid-shaft of the tibia inferiorly in custom made jigs. After the cement set, the jigs were placed in a materials testing machine and tested in the following manner. For tensile loading, the specimens were loaded under displacement control at a rate of 3.0 inches per second to simulate the rapid loading of trauma. For torsional loading, the specimens were loaded at an angular rate of 85 degrees per second. Four-point bending was performed with the knee in hyperextension at a rate of 3 inches per second to simulate the rapid loading of trauma. In torsional loading, the specimens were loaded at an angular rate of 85 degrees per second. Following biomechanical testing, high resolution radiographs (Faxitron radiography unit and Kodak EM-1 film) were made of the failed specimens to determine the fracture type. Specimens were then immediately fixed in 10% formalin. After fixation, specimens were trimmed, rinsed in tap water, dehydrated in graded alcohols, cleared in xylene, infiltrated and embedded in paraffin, and sectioned on a rotary microtome. Sections were then stained with H&E as well as several special stains to histologically differentiate the growth plate from surrounding bone. These specimens were then viewed with an optical microscope to evaluate the location of the fracture with respect to the growth plate and surrounding bone.

Results: Radiographically, all 10 of the limbs tested in tension showed classic corner fractures through the growth plate and subchondral bone of the distal femur. Fragments of subperiosteal metaphyseal bone were found anteriorly, posteriorly, and laterally, with no predominant location of the fragments. If radiographs were made obliquely, bucket handle fractures were observed. One limb which was tested in tension showed a partial corner fracture through the posterior growth plate with a fragment of bone that is thicker peripherally than it is centrally. In tension, the mean failure load was 258 pounds with a standard deviation of 87 inch-pounds. Histologically, the corner fractures had a morphology consistent with those seen in abused infants, the biomechanical loading mechanism that produces these fractures has not been clearly delineated. The purpose of this study was to evaluate the resultant injury seen in a neonatal porcine hind limb model under applied tensile, torsional, and bending (4-point) loads. We hypothesized that tension is the biomechanical loading mode responsible for bucket handle and corner fractures.

Discussion: Corner fractures are rarely seen in infants and children as a result of accidents. They are felt to be diagnostic of child abuse. A tensile mechanism of injury is unusual in normal falls and blunt trauma. In this model, a tensile loading mechanism has consistently produced the typical corner fracture of child abuse. Torsional loads did not result in corner fractures. In one of the ten specimens tested in four-point bending, a corner fracture was observed, perhaps because bending loads can be resolved into tensile and compressive components. Therefore, a tensile load is the proposed mechanism of injury for the corner fracture of child abuse.

Conclusion: Tensile loading produced the classical corner fracture of child abuse in a porcine neonatal model.

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Figure: Sagittal histological section through the distal femur of one of the porcine hind limbs tested in tension demonstrating the classical appearance of a corner fracture (Fx) and attached metaphyseal subchondral bone fragment (BF). The growth plate (GP) and articular cartilage (AC) are also observed in relation to the fracture line. (Hematoxylin and Eosin, original magnification × 8 X)