SECOND GENERATION INTRAMEDULLARY NAILING OF COMPLEX FRACTURES OF THE PROXIMAL FEMUR: A BIOMECHANICAL STUDY OF FRACTURE SITE MOTION

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Purpose: Second generation intramedullary nails (so-called “reconstruction nails”), that traverse the femoral neck and shaft, have become a popular method of treating complex, complex femur fractures. The proximal dimensions of these implants appear to be an important factor in determining the biomechanical characteristics of these nails. Most studies have merely looked at implant failure to compare various designs. In order to better understand the role of implant design in fracture stability, fracture site motion under physiologic loading conditions must be investigated. The purpose of our study was to compare fracture site motion in a progressively unstable fracture model under simulated physiologic loading conditions. Our hypothesis was that nails having larger proximal nail dimensions and stiffer materials would allow less fracture site motion in unstable fractures.

Methods: Four femoral intramedullary nails were tested: Russell-Taylor Delta recon (Smith & Nephew, Memphis, TN), Alta (Howmedica-Osteonics, Rutherford, NJ), Long Gamma (Howmedica-Osteonics), and Uniflex (Biomet, Warsaw, IN). A total of twenty fiberglass composite femurs (Pacific Research Laboratories, Vashon Island, WA) were instrumented, five for each nail type. All femurs were reamed and nails of nominal size 11 x 380 mm were placed following the individual technique guide for each device. Nails were proximally locked and radiographed to ensure proper placement of the proximal screws in the femoral neck, as well as proper nail position in the intramedullary canal. Two distal locking screws were placed using fluoroscopic guidance. Finally, all femurs were fluoroscopically examined to verify adequate final nail and screw placement.

A servohydraulic load frame (MTS 858 Bionix, Eden Prairie, MN) was used for nondestructive loading of the specimens to simulate both single-leg stance and double-leg stance. Four fracture patterns were tested: A) nondisplaced transverse (classification 32.A3.1), B) medial cortex wedge comminution (32.B3.1), C) one centimeter segmental loss (32.C3.2), and D) one centimeter segmental loss with a nondisplaced femoral neck fracture (32.C3.2 + 31.B2). A standardized pattern for the cuts was utilized.

In our single-leg stance model, femurs were loaded proximally through a hinged fixture with a rotating axis at the point of load application located 8-cm medial to the center of the femoral head. Rotation of the fixture was balanced by a double cable attached lateral and superior to the femoral head in a location simulating the origin of the abductor group on the ilium. The cable crossed the greater trochanter and continued distally parallel to the femoral shaft, attaching ultimately to the fixture upon which the distal femur was supported. Specimens were also tested in double-leg stance by locking the rotating proximal fixture and disengaging the cable. The femurs were preloaded to 50 N and then cycled for ten full load cycles at 0.1 Hz with data collected on the last cycle. Single-leg stance was tested using load cycles up to 720 N simulating one-body weight. Double-leg stance used 360 N to simulate one-half body weight.

A custom-designed two-dimensional motion system was used to quantify the amount of fracture site motion in the coronal plane. The relative fragment rotation, the lateral (shear) translation, and the axial translation across the distal fracture site were calculated. Vertical displacement of the femoral head (MTS actuator displacement) in double-leg stance was also recorded and analyzed. ANOVA and post hoc t-tests were used to determine statistically significant differences between groups (p<0.05).

Results: Single-leg stance: There were significant differences in coronal plane rotation, shear, and axial translation across the proximal femur fracture site between the different nail types and the different fracture patterns (p<0.001). The least rotation (0.80 ± 0.35 deg), shear (0.19 ± 0.08 mm), and axial motion (0.66 ± 0.30 mm) occurred with the Long Gamma nail in fracture pattern A. The most rotation (4.46 ± 1.33 deg) and shear (3.18 ± 2.23 mm) occurred with the Alta nail in fracture pattern C. The most axial motion (4.81 ± 2.35 mm) occurred with the Uniflex in fracture pattern D. Double-leg stance: Coronal plane rotation demonstrated significant differences in between the different nail types and the different fracture patterns (p<0.001). There were significant differences in shear and axial translation between the different fracture patterns (p<0.001) but not the different nail types (p>0.05). The least rotation, shear, and axial motion generally occurred in fracture pattern A with the Long Gamma nail. The most rotation (2.02 ± 0.87 deg) and shear (0.87 ± 0.60 mm) occurred with the Alta nail in fracture pattern C. The most axial motion (0.82 ± 0.90 mm) occurred with the Alta in fracture pattern A. The vertical translation of the femoral head was significantly different between nail types (p<0.001) and between fracture patterns (p<0.001). The least motion was allowed by the Long Gamma nail in fracture pattern A. The most rotation (4.46 ± 1.33 deg) and shear (3.18 ± 2.23 mm) occurred with the Alta nail in fracture pattern C. The most axial motion (4.81 ± 2.35 mm) occurred with the Uniflex in fracture pattern D. The least motion was allowed by the Long Gamma nail in fracture pattern A (1.08 ± 0.11 mm) and the most was allowed by the Alta nail in fracture pattern D (2.55 ± 0.65 mm).

Discussion and Conclusion: For simple, well-reduced fractures, the four nails we tested allow similar amounts of fracture site motion, indicating that the choice of implant is not critical in these fractures. As the fracture severity increases (lack of cortical contact, gap, and comminution), the proximal nail dimensions and implant materials (stainless steel versus titanium) are significant factors in reducing fracture site motion. Therefore, for unstable fractures in the proximal femur, implant selection is critical.