Finite Element Analysis of IM Nail Femur Fracture Fixation for Surgical Decision Support
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Introduction: Intramedullary (IM) nails are commonly used to stabilize proximal femur fractures. Surgical considerations such as implant size, implant position, medullary canal reaming, and screw configuration influence biomechanics and the healing process. However, surgeon intuition and precedent are currently the primary drivers for how these decisions are made. With computational modeling of fracture fixation, construct design variables can be adjusted to isolate their independent and interaction effects on biomechanical outcomes. We have generated a large model library that includes hundreds of variations of fracture and construct-related variables for IM nail fixed proximal femur fractures (AO/OTA types 31-A), providing a comprehensive picture of resulting mechanics.

Materials and Methods: A femur model was adapted from previous work (biomedtown.org). Bone was divided into trabecular and cortical with elastic moduli 155MPa and 16GPa, respectively. Fractures were modeled based on the AO/OTA classification system. For each model an IM nail was aligned within the femur in SolidWorks (Dassault Systemes). A canal was then reamed and bone and implant models were exported to Abaqus (Dassault Systemes) for meshing and simulation. Hard contact with Coulomb friction was modeled between implant and bone ($\mu=0.42$), implant and fixation screws ($\mu=0.20$), and bony fragments at the fracture site ($\mu=0.46$).[1] A load of 2kN was applied to the proximal femur with loading orientation and femur boundary conditions to simulate the heel strike phase of gait.[2] Previously described simplified muscle loads were used.[3] Simulations were performed for all configurations varying nail length, diameter, material properties, and presence of distal fixation screws. The model was validated through comparison to previously reported biomechanical testing data.[1] Outcomes were maximum nail stress, interfragmentary motion in the axial and shear directions, and maximum fixation screw stress.

Results and Discussion: Gapped fractures showed larger maximum implant stresses, axial, and shear interfragmentary motions than their reduced counterparts. Increasing nail diameter decreased maximum implant stress and both axial and shear interfragmentary motions, or had minimal effects in all fracture shapes. Nail length was not predictive of shear interfragmentary motion in multiple linear regression analysis for most fracture shapes.

Translational Impact: The results of this study can be used to educate training surgeons as well as for presurgical planning. The data suggest surgeons use the largest fitting IM nail diameter for fixing proximal femur fractures and that both short and long nails are likely appropriate for stabilizing shear interfragmentary motion.

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