

The Influence of Retrograde Intramedullary Nail Length on Interfragmentary Strain in Distal Femur Fractures

Anish Raju¹, Gregory R. Roytman^{1,3}, Steven M. Tommasini^{1,3}, Daniel H. Wiznia^{1,4}, Brianna R. Fram¹

¹Department of Orthopaedics and Rehabilitation, Yale School of Medicine, Yale University, New Haven, CT, ²VA Connecticut Healthcare System, Veterans Health Administration, West Haven, CT, ³Department of Biomedical Engineering, Yale School of Engineering and Applied Sciences, Yale University, New Haven, CT, ⁴Department of Mechanical Engineering and Materials Science, Yale School of Engineering and Applied Sciences, Yale University, New Haven, CT
anish.raju@yale.edu

Disclosures: Nothing to disclose.

INTRODUCTION: Retrograde intramedullary nail (rIMN) fixation is an important technique for treating distal femur fractures, a major and increasingly common injury with an estimated annual incidence of 27.4 per 100,000¹. This method of internal fixation has advantages over surface implant fixation, including reduced surgical footprint and stabilization in line with the anatomic axis of the bone. Surgeons select the rIMN length and anatomic termination level based on biomechanical principles, patient anatomy and fracture pattern. However, the relationship between rIMN length and interfragmentary strain, an important and heavily studied factor in distal femur fracture healing, is poorly characterized. We aimed to investigate this relationship using finite element analysis (FEA) computer modeling.

METHODS: Using finite element analysis, we loaded 8 different 9 mm diameter rIMNs ranging from 200mm to 380mm in length within a 3D model of a synthetic osteoporotic femur. Each nail was stabilized with 2 proximal lateral to medial screws and 4 distal interlocking screws. The corresponding rIMN tip terminations relative to the lesser trochanter ranged from 170 mm below to 10 mm above (Figure 1). Material properties were defined per manufacturer specifications for the rIMN, interlocking screws, and cortical and trabecular layers of the femur. For all rIMN length scenarios, a 3 mm-wide distal transverse fracture was modeled 45 mm proximal to the intercondylar notch of the femur. Each rIMN length scenario was tested in FEA simulation under the same single-leg stance loading conditions. The femoral head was loaded axially with force from 80 kg of body weight (784 N) while the femoral condyles were fixed in place. Strain was then calculated by measuring the average displacement across the fracture site.

RESULTS SECTION: The average fracture site strain decreased as the rIMN length increased (Figure 2). There was no notable change in strain between rIMNs ending 10 mm above and 30 mm below the lesser trochanter, but the strain differed sharply for shorter rIMN lengths. An outlier for this relationship was present in the rIMN ending 70 mm below the lesser trochanter. Failure was minimal (0-0.1% failed elements) and only occurred around the proximal screw entry and exit points.

DISCUSSION: These results suggest a relationship in which increased rIMN length is associated with decreased distal femur fracture site strain, the opposite of the effect seen with lateral locking plate fixation in which longer plates with larger screw spread correspond with increased fracture site strain. This effect plateaued once rIMNs were long enough to engage in the femoral diaphysis. While our computational testing reveals important information, we recommend further *in vivo* investigation to understand this effect in real patients.

SIGNIFICANCE/CLINICAL RELEVANCE: This finding has important implications for surgeons aiming to achieve optimal healing of these increasingly common injuries, which remain prone to delayed healing and nonunion.

REFERENCES: 1. DeKeyser, G., Thorne, T., Martin, B. I., & Haller, J. M. (2024). Changing Epidemiology of Distal Femur Fractures: Increase in Geriatric Fractures and Rates of Distal Femur Replacement. *The Journal of the American Academy of Orthopaedic Surgeons*, 32(24), e1289–e1298. <https://doi.org/10.5435/JAAOS-D-24-00007>

IMAGES AND TABLES:

Figure 1. Distance of Retrograde Intramedullary Nail Termination Below Lesser Trochanter

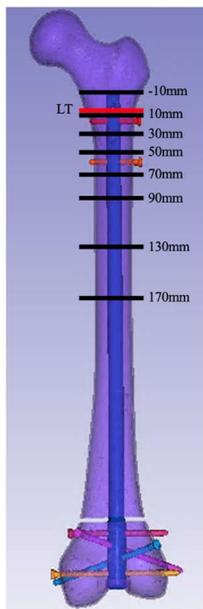


Figure 2. Strain at 3mm fracture site decreases as rIMN Length is increased in FEA

