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

Anish Raju, Gregory Ronald Roytman, Steven Tommasini, Daniel Wiznia, Brianna Fram

INTRODUCTION:

Retrograde intramedullary nail (rIMN) fixation is an important technique for treating distal femur fractures. This method of biological internal fixation has many advantages including reduced surgical footprint and providing stabilization in line with the anatomic axis of the bone. Surgeons select the rIMN length and termination level in the fracture based on biomechanical principles, patient anatomy and fracture pattern. However, the relationship between rIMN length and interfragmentary strain, an important factor in fracture healing for plate and screw-based fixation constructs for distal femur fracture, is poorly characterized. We aimed to investigate this relationship using finite element analysis (FEA).

METHODS:

We loaded 8 different 9 mm diameter rIMNs from 200mm to 380mm in length into a 3D model of a synthetic osteoporotic femur with distinct cortical and trabecular layers. The corresponding rIMN tip terminations relative to the lesser trochanter ranged from 170 mm below to 10 mm above (Figure 1). Material properties corresponding to titanium for the rIMN and interlocking screws, epoxy for cortical bone, and foam for trabecular bone were defined based on manufacturer specifications. 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 an FEA simulation under a single-leg stance scenario. The femoral head was loaded axially with force from 80 kg of body weight (784 N) while the femoral condyles were fixed in place without distal rotation or translation. Strain was then measured by computing the average displacement across the fracture site.

RESULTS:

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 and only occurred around the proximal screw entry and exit points.

DISCUSSION AND CONCLUSION:

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. This finding has implications for surgeons aiming to achieve optimal healing of these increasingly common injuries, which remain prone to delayed healing and nonunion. Future validation with real-world synthetic and cadaver bones will further elucidate the biomechanical relationship between rIMN length and strain.

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

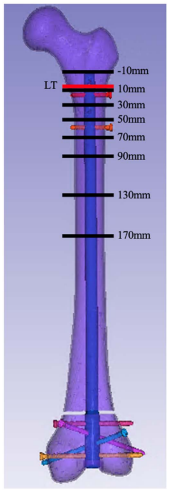

Figure 2. Strain at 3mm fracture site decreases as rIMN Length is increased in FEA