BIOMECHANICAL ANALYSIS OF ANTEGRADE AND RETROGRADE FLEXIBLE INTRAMEDULLARY NAIL FIXATION OF SIMULATED FEMORAL FRACTURES

A.T. Mahar*, K.B. Fricka^, S.S. Lee^, P.O. Newton*
* Orthopedic Biomechanics Research Center, Children’s Hospital – San Diego, San Diego, CA, USA
^Department of Orthopedic Surgery, University of California – San Diego, San Diego, CA, USA

INTRODUCTION
Understanding of optimal fixation materials and techniques for mid-shaft femoral fractures remains unclear. Titanium appears to have improved biomechanical performance over stainless steel, but the ideal location for insertion of these nails has not been reported. Improved stability can be determined by examining the stiffness of a fixation during torsional and compressive loads. It may be inferred that greater initial stability will reduce the likelihood of refracture while increasing the likelihood of early callus formation and return to partial weight bearing. Therefore, a biomechanical evaluation of insertion site for greater fixation stability may improve clinical decision making and outcomes.

PURPOSE
To evaluate the biomechanical stability of simulated transverse and comminuted femoral fractures after retrograde or antegrade flexible titanium(Ti) intramedullary(IM) rod fixation (Synthes, Inc., Paoli, PA).

METHODS
Ten adolescent sized (length 38 cm, canal diameter 9 mm) composite epoxy femoral models simulating cortical and cancellous bone were utilized (Sawbones, Inc., Vashon Island, WA). Five underwent retrograde IM fixation with two 3.5mm Ti rods placed in a divergent “C” pattern through medial and lateral insertion sites at the distal metaphysis (Figure 1A). The other five underwent antegrade IM fixation with two 3.5mm Ti rods placed using one “C” and one “S” shape rod through two insertion holes just inferior to the greater trochanter (Figure 1B). Placement of the nails simulated the ‘clinical feel’ and location of nails within the femur models was confirmed with fluoroscopy.

Transverse fractures were created at the mid-diaphysis using a saw. Specimens were tested using a MTS 858 machine (MTS, Co., Eden Prairie, MN) in torsion at ±1Nm at 0.05Hz and in ramped axial compression to 50N at 1N/sec. Comminuted fractures were then created by removing the 2cm segment of bone proximal to the transverse fracture. They underwent identical testing and were also tested in ramped axial compression to failure(5mm of shortening) at 0.5mm/sec. Testing was performed in line with the mechanical axis of the femur (Figure 2).

Figure 1: Fixation methods showing retrograde insertion (A) and antegrade insertion (B).

Figure 2: Testing configuration in-line with mechanical axis (yellow) rather than anatomical axis (red).
Displacement (mm), force (N), angle (deg) and torque (Nm) were sampled at 10Hz for all tests. Axial rotation and stiffness over the 50N load were analyzed with two-way ANOVA. Failure load was analyzed using one-way ANOVA. A Tukey’s post—hoc correction was used where necessary.

RESULTS AND DISCUSSION
Retrograde rods had significantly less angular motion between the applied torque in stabilizing both transverse(T) and comminuted(C) fractures (T=18.4°±3.7; C=18.5°±3.2) when compared with antegrade fixation (T=30.9°±8.3; C=32.1°±7.6), (p<0.0005).

Axial compression stiffness in both fracture patterns was significantly greater for retrograde rods (T=892.2+138.7N/mm; C=792.0+110.2N/mm) compared to antegrade rods (T=485.8+220.1N/mm; C=622.6+63.1 N/mm), (p<0.0005).

There was no statistical difference in axial load to failure between antegrade (416.8+127.5N) or retrograde (247.4+134.3N) fixation (p=0.08). However, there appeared to be a trend of greater load to failure for antegrade fixation.

Retrograde Ti flexible IM rod fixation of simulated femur fractures is more stable under torsional physiological loading than antegrade Ti flexible IM rod fixation. The “C” and “S” patterns of the antegrade nails appear to offer less fixation since the two insertion sites mechanically function as a single entrance hole which then allows for greater angular rotation and lesser stiffness. Although initial stiffness in compression was greater in the retrograde group, the antegrade group required a greater compressive load to shorten 5mm. Both failure levels exceed force levels encountered during partial
weight bearing. It appears that retrograde nailing may offer the best fixation for torsional control and small axial loads. For larger children or adults, the antegrade insertion may be considered to prevent segment shortening since that method required approximately 250N of force to generate 1mm of shortening (Figure 5).

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