Intramedullary nails with distal interlocking screws locked to the nail may have higher fatigue strength in comminuted supracondylar femur fractures

INTRODUCTION:
Supracondylar femur fractures represent 6% of all femur fractures [1]. The surgical treatment of supracondylar femur fractures remains challenging especially when associated with comminution due to high rate of failure of fixation, more commonly in the setting of osteoporosis. Currently, periacetabular distal locking plates have been preferred over the retrograde intramedullary nails (IMN) in case of severe comminution. Recently, a new IMN with distal interlocking screws locked to the nail has been developed in order to improve distal fixation; however biomechanical fatigue performance has yet to be investigated. The goal of this study is to determine the in situ fatigue strength of the new distal locking screw IMN for comminuted supracondylar femur fracture model (AO/OTA type 33A3) simulating 8 weeks of full weight bearing gait loading.

METHODS:

Specimen Preparation
Three pairs (N=6) fresh frozen cadaveric females, age=86±9 years femurs were repaired with a new IM nail which has four distal interlocking screws. The distal locking screws can be locked to the IMN as a locking plate, or left unlocked as in conventional IMN (Biomet Trauma, Parsippany, NJ). One femur from each pair was locked while the contralateral pair was unlocked. Then, a gap was created simulating a metaphyseal fracture with comminution (AO/OTA type 33A3) [2] (Fig. 1). The proximal and the distal fragment were potted in a rigid plastic pipe and a polymer casting agent (Smooth-On, Easton, PA) leaving the fracture site and distal interlocking screws unaffected.

Biomechanical Testing
The loading conditions simulated forces along the length of the femur during walking [3]. Specimens were cyclically loaded from 0.1 to 1.5 times body weight (BW) axially, 0.1 to 0.5 BW laterally, and 0 to 0.02 BW-m of external rotation for 100,000 cycles at 4 Hz [3]. These loads were applied via a custom-designed test jig mounted to an axial-torsional test frame (MTS Mini-Bionix 858) (Fig. 2). This jig consisted of a torsional-locking bearing that converted the axial displacement of the test actuator into combined axial and shear loading. The testing set-up were validated on anatomical models (4th generation composite femur, Sawbones) and an in-line mounted multi-axial load cell (AMTI MC5-6-5000).

The integrity of the repair construct was assessed at regular intervals during fatigue testing. 16 cycles of data were recorded every 2500 cycles using the in-line load cell and the relative 3-D motion across the fracture site was also recorded (Optotrak 3020 with First Principles Software, Northern Digital, Inc) (Fig. 2). AP and lateral planar radiographs were also acquired every 2500 cycles using a full-scale c-arm (Philips BV Pulsera) to document failure of the construct. If the specimen survived fatigue loading, it was loaded to failure in gait at the quasi-static loading rate of 4 mm/min and 2 deg/min. X-rays were acquired at 500N intervals throughout destructive testing to monitor the method of failure.

The fatigue strength of the new distal locking IMN was compared to the traditional non-locking IMN using the following outcome measures: 1) changes in the axial and torsional stiffness of the repair construct with fatigue loading; 2) number of cycles to acute failure; and 3) in the case of survival of the construct to fatigue run-out, quasi-static load-to-failure strength.

RESULTS:
All locking and non-locking IMN repairs survived until fatigue run-out at 100,000 cycles and were subjected to load-to-failure testing. There were no statistically significant differences in either axial or torsional stiffness between the two construct types at any fatigue cycle interval (Fig 3 & 4). However, the locking IMN did trend towards having a higher stiffness than the non-locking design - particularly in torsion (Fig. 4) - for loading durations greater than 15,000 cycles.

The ultimate axial and torsional loads during load-to-failure testing were not statistically different between the locking and non-locking IMN designs. The average ultimate load was 4121±619N and 4032±272N for the locked and non-locked IMN, respectively. Both the locked and non-locked nails failed via screw bending during the load to failure portion of the test.

DISCUSSION:
This study reports the preliminary results of a study that compares IMN with interlocking screws locked to the nail (similar to a locking plate) and interlocking screws unlocked to the nail (conventional interlocking) in the setting of an extra-articular comminuted supracondylar femur fracture using a novel multiaxial testing protocol. The testing conditions of this study simulates the forces while walking i.e weight bearing and for 6-8 weeks of postoperative period in osteoporotic specimens. Although, both constructs survived the fatigue test, there is a trend towards higher stiffness with locked nails when compared to non-locked nails. While these results imply that locked nail may provide superior fixation, thus sustain longer before failure, current sample size did not allow us to perform a statistical analysis. As the sample size is increased, this difference may reach statistical significance.

REFERENCES: