INTRODUCTION
Flexible intramedullary (IM) nails are used with increasing frequency to internally fix stable and unstable pediatric femoral shaft fractures. This method of fixation with either stainless steel (Richards) or titanium (Synthes) nails is popular because avascular necrosis of the femoral head develops in some adolescents treated with adult reamed IM rods. Flexible nails do not provide entirely rigid fixation and their use in comminuted fractures remains in question. 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 implant material for greater fixation stability may improve clinical decision making and outcomes.

PURPOSE
This study evaluated the biomechanical differences in simulated transverse and comminuted femoral fracture stability after flexible IM nailing with stainless steel (SS) and titanium (Ti) implants.

METHODS
Ten adolescent sized (length 38 cm, canal diameter 9 mm) composite epoxy femoral models (Sawbones, Inc., Vashon Island, WA) simulating cortical and cancellous bone were assigned to two groups (n=5). Two flexible SS or Ti nails (3.5 mm diameter) were placed through medial and lateral insertion sites at the distal femoral metaphysis in a divergent ‘C’ configuration. Transverse fractures were simulated with a hand-held power saw in the mid-diaphysis and tested in 10 cycles of torsion between ± 1 Nm at 0.05Hz and in ramped axial compression to 50N at 1 N/s with an MTS 858 testing machine (Eden Prairie, MN) in line with the femoral mechanical axis (Figure 1). Nail placement was confirmed for each model using fluoroscopy (Figure 2).

Simulated comminuted fractures were then created by removing a 2 cm segment of bone, and identical biomechanical testing was repeated. Finally, these specimens were tested in ramped axial compression at
0.5mm/s until 5 mm of gap closure (failure). Displacment (mm), force (N), angle (deg) and torque (Nm) data were sampled at 10Hz. Differences in axial rotation, stiffness and failure load between nail types (SS vs. Ti) and fracture types (trans vs. comm) were analyzed with a two-way ANOVA.

RESULTS AND DISCUSSION
Titanium nails had significantly less angular motion between ±1 Nm when stabilizing comminuted fractures (18.50º ± 3.24) compared to SS nails (24.31º ± 4.78) (p=0.012). Transverse stability was not different between nail types (Ti=18.40º ± 3.71 vs. SS=22.74º ± 3.96) (Figure 3).

Axial compression stiffness was significantly greater for Ti compared to SS in the simulated transverse fracture pattern (892±138 N/mm vs 463±218 N/mm, p=0.007) (Figure 4). This was also true for comminuted fractures (792±110 N/mm vs 447±209 N/mm, p=0.031). There was no statistical difference between nail types for load required to produce 5 mm of gap closure (Ti=247±134 N vs. SS=182±101 N) (Figure 5).

The goal of this study was to determine which nail type best stabilizes comminuted femoral shaft fractures and has the greatest torsional and axial stiffness. Elastic moduli differences in Ti (E=110 GPa) and SS (E=200 GPa) alloys exist. Despite the lower modulus of elasticity for Ti, the increased structural stability may be related to the ability of the Ti nails to bend and conform to the intramedullary canal of the femur increasing contact compared to the SS nails. Both nail types stabilized all simulated fractures at levels beyond physiologic non-weight bearing axial loads (>40% body weight of average adolescent) without permanent deformation.

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