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Biomechanical comparison of long, short, and extended-short nail construct for femoral intertrochanteric fractures

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ABSTRACT

Objectives: Short and long cephalomedullary (CM) nails are commonly used construct for fixation of intertrochanteric (IT) fractures. Each of these constructs has its advantages and its shortcomings. The extended-short (ES) CM nail offers a hybrid between long and short nail design that aims to combine their respective benefits. The goals of this study were to (1) biomechanically evaluate and compare construct stiffness for the long, short and ES constructs in the fixation of IT fractures, and to (2) investigate the nature of periprosthetic fractures of constructs implanted with these various designs.
Methods: Eighteen synthetic femora were used to evaluate three types of fracture fixation constructs. Axial compression, bending, and torsional stiffness were reported for both stable and comminuted IT fracture models. All comminuted fracture constructs were loaded to failure in axial compression to measure failure loads and evaluate periprosthetic fracture patterns.
Results: Stiffness were similar among constructs with few exceptions. Axial stiffness was significantly higher for the short nail compared to the long nail for the comminuted model ($p = 0.020$). ES nail constructs exhibited a significantly higher failure load than short nail constructs ($p = 0.039$). Periprosthetic fractures occurred around the distal interlocking screw in all constructs.
Conclusions: Nail length and position of interlocking screw did not alter the biomechanical properties of the fixation construct in the presented IT fracture model. Periprosthetic fractures generated in this study had similar patterns to those seen clinically. This study also suggests that if a periprosthetic fracture is to occur, there is an increased probability of it happening around the site of the interlocking screw, regardless of nail design.

Introduction

Proximal femur fractures represent a public health problem affecting more than 266,000 US Medicare beneficiaries annually, with an estimated annual cost of $2.9 billion [1,2]. About 50% of femoral fractures occur in the intertrochanteric (IT) region [3,4]. Given the impending boom in the geriatric population, developing more efficient ways to treat these fractures, and their complications, is a necessity. While both nail and plate constructs can be used for the fixation of stable IT fractures [5], it has been shown that proximal femoral nails may be superior to plates for certain unstable fracture patterns [6,7]. In the USA, there has also been a sharp increase in use of nails for the more stable IT fracture patterns [8–10].

Currently, nailing of femoral IT fractures can be performed with either a short or long cephalomedullary (CM) nail construct [11]. The short CM nail offers simplicity in insertion and distal interlocking, but is associated with complications such as thigh pain or femur fracture at the distal tip or just distal to the nail [5,12,13]. Although the canal-spanning length of long CM nails offers potential mechanical benefits, targeting distal locking screws can increase both operative time and radiation exposure [14]. These issues have led some surgeons to prefer short CM nails or long distally unlocked CM nails [15], which can be easier and faster to use [16].

The extended-short nail (ES nail; Advanced Orthopaedic Solutions, Torrance, CA) is a novel nail design that attempts to combine the mechanical characteristics of a long CM nail with the

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simplicity and ease of use offered by a short CM nail [16]. In this system the interlocking screw is inserted using a jig similar to the one used by short nails in the middle section of the nail. To date, there is no study comparing the biomechanical characteristics of the three available nail designs. The goals of this study were to (1) biomechanically evaluate and compare construct stiffness for the long, short and ES constructs in the fixation of IT fractures, and to (2) investigate the nature of periprosthetic fractures that may occur surrounding these constructs.

Materials and methods

Intact construct preparation

Eighteen standard, medium left synthetic femora (Fourth Generation, model 3403; Sawbones Worldwide, Vashon, WA) were used to biomechanically evaluate construct stiffness of three different CM nail constructs for the fixation of intertrochanteric fractures. Failure testing was also performed to investigate the patterns of periprosthetic fractures in the different fixation constructs. The canals of the Sawbones femora were reamed by the manufacturer with an 18 mm bit to thin the cortex along the entire diaphysis. This resulted in a 2 mm cortical thickness at the thinnest region of the femoral diaphysis. Previous studies have used a similar preparation as a surrogate for osteoporosis [17]. Each femur was oriented vertically in the sagittal plane with both condyles contacting the base of a potting mold. This resulted in 8° of adduction in the coronal plane. The distal 4 cm of the each femur was potted with a casting resin (Smooth-Cast 300; Smooth-On, Easton, PA).

Construct preparation

Femora were assigned to three groups ($N = 6$ per group) implanted with one of the following: a short (SN), long (LN), or extended-short (ES) CM nail (all implants supplied by Advanced Orthopaedic Solutions, Torrance, CA; Fig. 1). All implants were inserted by the same orthopaedic surgeon (SM) according to standard surgical technique with the use of fluoroscopy (BV Pulsera, Philips, Andover, MA). All constructs consisted of an 11 mm distal diameter nail with a 130° neck angle and 10.5 mm × 95 mm lag screw. The LN and ES were 39 cm in length, and the SN was 20 cm in length. A locking screw (5 mm × 50 mm) was inserted in the static locking hole for the SN and LN. The locking screw was inserted in the central midshaft femur hole for the ES nail.

The implanted intact femora were used as a surrogate for a healed IT fracture. After biomechanical testing of the implanted intact femora, a stable trochanteric fracture model (AO Type 31-A1) was created in each of the femora using a surgical reciprocating saw (SYSTEM 6; Stryker Instruments, Kalamazoo, MI). An oblique osteotomy was created from the central lateral aspect of the greater trochanter to the pinnacle of the lesser trochanter. This fracture condition is referred to as the *stable fracture model* throughout this manuscript. Following biomechanical testing of the stable fracture models, a comminuted trochanteric fracture model (gap model) was created in each femur using the same surgical reciprocating saw. A 1 cm bone gap was created by widening the stable fracture model distally. A triangular wedge consisting of the lesser trochanter was also removed (3 cm along the medial aspect of the femur at the lesser trochanter). This fracture model is referred to as the *comminuted fracture model* throughout this manuscript (Fig. 2).

Biomechanical testing procedure

Eighteen intact femora were tested in axial compression, bending, and torsion to obtain baseline stiffness values. All tests were conducted in a servohydraulic testing system (858 Mini Bionix; MTS Systems Corporation, Eden Prairie, MN). Following construct implantation and stable fracture creation, each femur was again tested in all three modes. After comminuted fracture creation, each femur was evaluated once more in all three modes. Finally, all femora were loaded to failure in axial compression. The models used in this study were specifically designed to test the fracture construct and not the fracture patterns themselves. Bending and compression forces in the stable fracture construct tested the nail–screw junction with point-contact of the fracture fragments. In the unstable fracture construct, and in all torsional testing, the proximal screw–nail junction and distal nail-interlocking screw junction were tested. This study design was implemented in order to simulate the various fixation constructs in the early (prior to bone healing) post operative phase. In this stage the load experienced by the implant is maximized [18] and potential difference between fixation constructs would be accentuated.

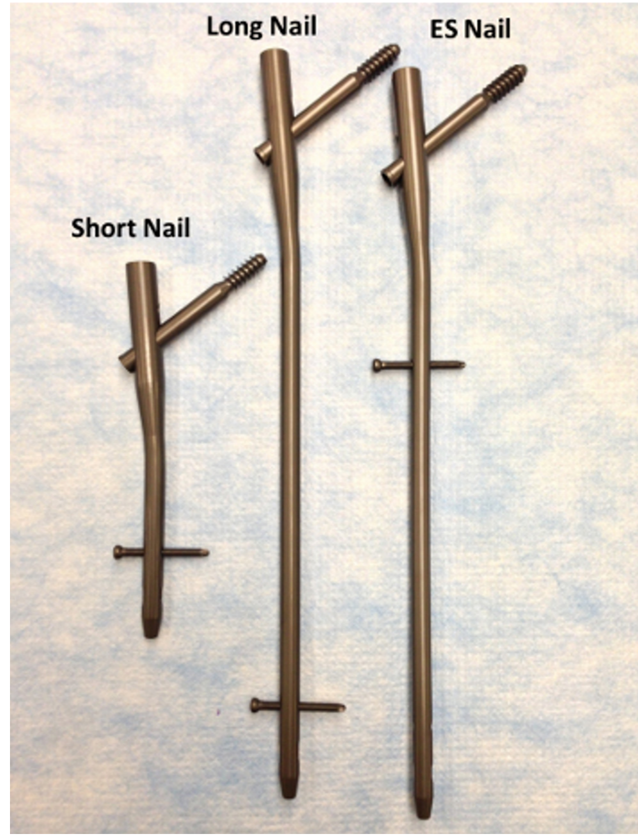

Fig. 1. Nail types

Axial compression

The potted distal end of each construct was secured to an X–Y bearing system. The bearing system allowed for self-alignment of the femur and minimized shear forces. The femur orientation was at 8° of adduction in the coronal plane and vertically aligned in the sagittal plane. The femoral head was seated and free to rotate in a hard resin cup (47 mm diameter) which modeled the acetabulum (Fig. 3A). Intact and stable fracture model constructs were cyclically loaded (sinusoidal waveform) from 100 N to 1000 N of compression at 0.2 Hz for ten cycles. The same loading parameters were used for the comminuted fracture model, except that the peak load was reduced to 500 N to prevent permanent deformation of the construct.