Sliding of Two Lag Screw Designs in a Highly Comminuted Fracture Model

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Abstract

A fracture construct, representing a worst-case model of a comminuted intertrochanteric fracture, was created in order to compare the fixation stability of two different cephalomedullary nails: one where the lag screw can telescope within itself to achieve displacement of the head-neck fragment, and the other where the solid lag screw slides only. After nail fixation, the models were loaded and then cycled, and positions of the head-neck fragment and lag screw were determined. Both nails similarly acted to limit motion of the head-neck fragment by the sliding of their lag screws, causing impingement of the fragment against the nail. Fragment movement was achieved with significantly less force with the telescoping lag screws, which also showed no final lateral projection from the nail. This was in contrast to the solid lag screws that demonstrated lateral projection in all cases.

Sliding of the lag screw in hip fracture fixation devices enables fracture consolidation and transmission of forces through the fracture site and, by this mechanism, enhances healing. The lack of sliding (or jamming) of a lag screw within the nail, here used in this application of fracture care, may lead to fracture nonunion or device failure. Previous studies of lag screw sliding have shown that in the case of sliding hip screws\textsuperscript{1} material of the device and the lag screw angle were the most important determinant factors; whereas for intramedullary nails,\textsuperscript{2} nail-design factors, such as proximal bowing and the internal hole diameter of the nail, were most important in affecting lag screw sliding. An interest has grown in cephalomedullary nails having new lag screw designs that enable sliding within themselves (telescoping) for fragment consolidation and that do not project laterally from the nail; this projection potentially can cause soft-tissue irritation.

In this study, nails of similar material design and lag screw angle were used in an attempt to focus on lag screw design and its effect on sliding, by comparing telescoping and non-telescoping lag screws. We previously conducted an experiment on lag screw sliding in intramedullary nails when used to fix unstable four-part intertrochanteric fractures.\textsuperscript{3} Although in this previous study where we did not lock the set screws within the nails to prevent sliding, only a minimal amount of sliding was observed. We attributed this finding to the stability of the osseous impingements (typically, the head-neck fragment against the remaining proximal femur and occasionally against the superior portion of the nail).

The current study essentially repeated the prior experimental testing but modified the approach in the following two ways: 1. elimination of the major osseous impingement of the head-neck fragment against the proximal femur fragment and 2. utilization of the setscrews to affix the lag screw to the nails, as would be clinically done to prevent excessive screw movement.

Materials and Methods

The test specimens used were recovered from a prior study of lag screw sliding that compared the telescoping lag screw design with a standard sliding lag screw design (Fig. 1). Six nails and lag screws of each type were removed from 12 femurs, and the nails and lag screws were then reassembled,
with the head-neck fragment reattached to the lag screw. For both nail types, the lag screws were locked to the nails by fully tightening the internal setscrews within the nails. The Gamma 3™ trochanteric nail (Stryker®, Mahwah, New Jersey) set screw was then backed-off a 1/4-turn, as recommended in the surgical protocol. The telescoping Biomet® Peritrochanteric Nail (PTN, Biomet®; Parsippany, New Jersey) lag screw was used in the keyed version to minimize rotation.

The nails were placed in an angle vise such that the femur axis was at 25° and the anteversion of the neck was neutral. The vise was held to a platform attached to the actuator of a mechanical tester (MTS Systems, Inc., Eden Prairie, Minnesota). This nail angulation enabled the joint reaction force in single-legged stance to be simulated by a single vertical load to the femoral head. The heads were loaded using an aluminum annulus for the distribution of the loads over a major portion of the superior head. The other side of the annulus was coated with Teflon® and rode against a Teflon® platen to ensure free movement of the head during testing. The lateral position of the lag screw and the distance of the head-neck fragment from the nail were measured with calipers.

The femurs were then loaded vertically to 1200 N. The lag screw position and the inferior and lateral head displacements were recorded before and after loading. The femurs were then cyclically loaded to 1200 N for 1000 cycles in a sinusoidal manner at 3 Hz. After cycling, the lag screw position and head displacements with respect to the nail were remeasured.

**Results**

During the initial loading to 1200 N, the telescoping lag screws began telescoping at less than 40 N, as evidenced...
by lateral translation of the head-neck fragment and no displacement laterally of the lag screw sleeve (this load is insufficient to advance the screw within the head). The specimens with the telescoping design showed various amounts of movement of the head-neck fragment toward the nail, and usually this motion was limited by impingement of the head-neck fragment against the nail (Fig. 2). This did not occur in two specimens where motion of at least 1.5 cm of the head-neck fragment was achieved due to the telescoping feature. One of the two telescoping design specimens in which impingement of the fragment on the nail did not occur when fully telescoped showed initial penetration of the lag screw through the femoral head.

During the initial loading to 1200 N, the solid lag screws were observed to translate laterally in the nail at an average load of 140 N (range, 100 N to 185 N). This movement was again limited by the head-neck fragment impingement on the nail. One specimen exhibited 2 cm of motion of the lag screw laterally from the nail (Fig. 3).

After cycling, a minor amount of further movement of the head-neck fragment was observed (< 2 mm) for both nail types, due to compressive fatigue and fracture of the bone at the impingement point on the nail. This was also reflected in a small amount of additional lateral motion of the solid lag screws; none of the telescoping design lag screws exhibited lateral movement.

**Discussion and Conclusion**

It is well-established in the literature that a solid sliding lag screw provides adequate fixation in the treatment of unstable intertrochanteric fractures. Trochanteric bursitis, a type of lateral hip pain, is sometimes increased with greater fracture compression and is a recognized complication of solid sliding lag screws.

The telescoping feature of the lag screw can accommodate approximately 1.5 cm of movement before motion of the screw within the head occurs, leading to penetration of the head. Movement of the standard sliding lag screw is achieved at the expense of lateral projection of the screw from the nail, as seen clinically when the implant backs out into the iliotibial band. The “free” length of the locking slot and initial position of the set screw in the slot limit the amount of sliding (2.5 cm is the maximum achievable). It was observed that movement with the standard sliding lag screw was more constrained than with the telescoping design nail. This has been noted previously with a non-telescoping version of this lag screw design.4

This study represents a worst-case scenario, in which there is so much comminution of the proximal femur that it is unable to provide support, and thus movement of the head-neck fragment is limited by its impingement against the nail. A similar situation would occur if the neck was comminuted, but a greater movement of the head would be required to achieve its impingement against the nail.

There are several factors that limit the direct comparison of these findings to expected clinical behavior. The initial loading assumptions1,2 were based on a two-dimensional, static case of one-legged stance, whereas actual loads are three-dimensional and dynamic. There was no lubrication, although this does not appear to be a significant factor in lag screw sliding.3 The testing loads that were used are lower than the loads that are observed by the hip joint during typical activities of daily living. However, we did not incorporate muscle forces or soft tissue forces that cross the joint to counteract the forces placed on the head of the femur. This may affect lag screw sliding differently than what is observed clinically. However, fracture collapse and compression are affected by two very different implant mechanisms. Fracture compression using a solid lag screw occurred at the expense of lateral protrusion of the screw into the iliotibial band and surrounding soft tissues. In contrast, fracture compression using a telescoping lag screw resulted in far less lateral screw protrusion.

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