An Original Study

Helical Blade vs Telescoping Lag Screw for Intertrochanteric Fracture Fixation

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Abstract

The purpose of this study was to compare fixation stability and lag screw sliding characteristics between 2 different hip-nail lag screw designs, a telescoping screw-barrel and a solid helical blade.

Simulated, unstable, 4-part intertrochanteric hip fractures were created in 6 pairs of cadaveric femurs. Each nail type was randomly assigned within each femur pair. Lag screw sliding and inferior and lateral head displacements were measured following an applied static load of 750 N. Measurements were obtained before, during, and after cyclical loading with 750 N for 105 cycles. Ultimate failure strength was determined.

After considering inferior head displacements, no significant differences between the 2 screw designs were found. Mean head displacement for the helical screw was 2.18 mm, compared with 1.87 mm for the telescoping screw ($P = .731$). A significant difference in the amount of lateral movement of the lag screws was found, however. The helical lag screws had mean lateral sliding of 2.68 mm, compared with 0.25 mm for the telescoping screws ($P = .007$). Neither of the lag screw constructs failed by screw cutout from the head.

Both screw designs provide similar fixation strength for stabilization of 4-part intertrochanteric fractures. Both the telescoping lag screw and the helical blade facilitate fracture collapse, but the telescoping lag screw also minimizes lateral projection of the screw from the nail. This advantage may help minimize postoperative lateral soft-tissue impingement.

Successful return to preinjury level of function is the goal in treating patients with unstable intertrochanteric hip fractures. Intramedullary (IM) sliding hip screw nails have become the device of choice for fixation of unstable intertrochanteric hip fractures.[1-5] IM nails are inserted within the femur, typically with a single large-diameter lag screw extending from the lateral femoral cortex, securing the head-neck fragment. The lag screw component in these implants is designed to slide within the nail for compression while maintaining load-sharing characteristics at the fracture site.

Femoral head implant cutout remains a significant complication.[6] Difficulty in sliding may lead to device failure, nonunion, and lag screw cutout of the head. Excessive sliding may lead to symptomatic lateral protrusion of the screw. Previous studies have shown that implant material and lag screw angle are the most important factors in sliding hip screw failure,[7] whereas nail design and superomedial orientation of the channel for a large-diameter proximal lag screw are the most important factors in IM implant failure.[7] Attempts have been made to modify lag screw design to maximize sliding characteristics and minimize screw cutout from the femoral head. One recent modification in lag screw design is telescoping the lag screw within a fixed barrel, which allows the lag screw to slide within itself during fracture collapse, thereby potentially minimizing lateral protrusion from the nail (Figure 1). The helical blade design is inserted by impaction without predrilling; tapping this design was shown to provide stronger purchase in the femoral head by radial compaction of the cancellous bone around the flanges of the blade during insertion.[9]

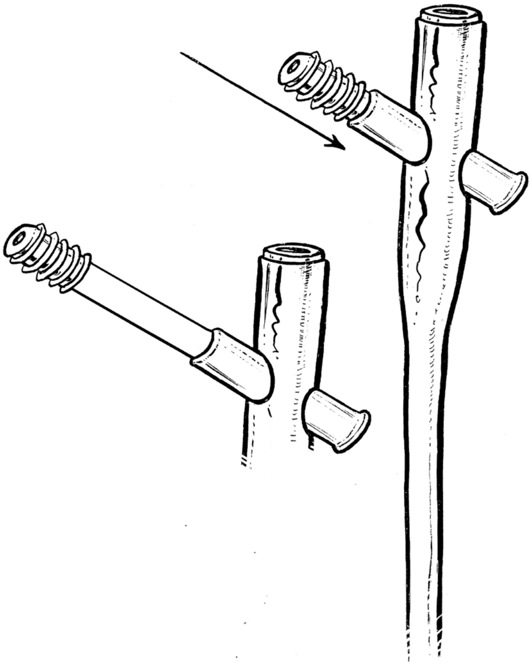

Figure 1. Schematic of telescoping mechanism of peritrochanteric nail lag screw.

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Am J Orthop. 2011;40(9):452-456.

Figure 2. Peritrochanteric nail with telescoping lag screw (left) and trochanteric fixation nail with helical solid sliding lag screw (right).

We conducted a study to evaluate and compare amount of lag screw sliding, head fragment stability, and ultimate strength of fixation of 2 new trochanteric hip nail lag screw designs. Two different lag screw designs were used to stabilize a simulated 4-part intertrochanteric fracture. Our hypotheses were that there would be no significant difference between the 2 implant designs with respect to sliding characteristics and ultimate strength of fixation, and that head fragment stability would be similar between screw designs.

METHODS AND MATERIALS

Six matched pairs of osteopenic embalmed cadaver femurs were used. Specimens were selected on the basis of biplanar radiographs (taken to exclude samples with morphologic abnormalities) and bone density measurements, which were made with dual-energy x-ray absorptiometry (DXA) (Hologic Scanner QDR-2000 Supine Lateral X-Ray Bone Densitometer; Hologic, Waltham, Massachusetts). The femurs were stripped of all soft tissues, and the femoral condyles were removed at equal lengths from the lesser trochanter.

The distal femoral shafts were then potted with acrylic cement in 5×5-cm^2 aluminum tubes. A ring stand was used to support femurs during mounting to ensure correct orientation. Throughout the experiment, desiccation was avoided by keeping the specimens wrapped in saline-soaked gauze and sealed in airtight double bags when not in use.

A peritrochanteric nail (PTN) made by Biomet (Warsaw, Indiana) and a trochanteric fixation nail (TFN) made by Synthes (West Chester, Pennsylvania) were randomly assigned within each femoral pair. The PTN is 17 cm long and has a 7° proximal bend and a 15.8-mm outer proximal diameter. In contrast, the TFN is 17 cm long and has a 6° proximal bend and a 17-mm outer proximal diameter (Figure 2). The lag screws of each nail are angled at 128° and 130°, respectively, to the main longitudinal axis of the nail. Both nails have a distal slot for a distal interlocking screw.

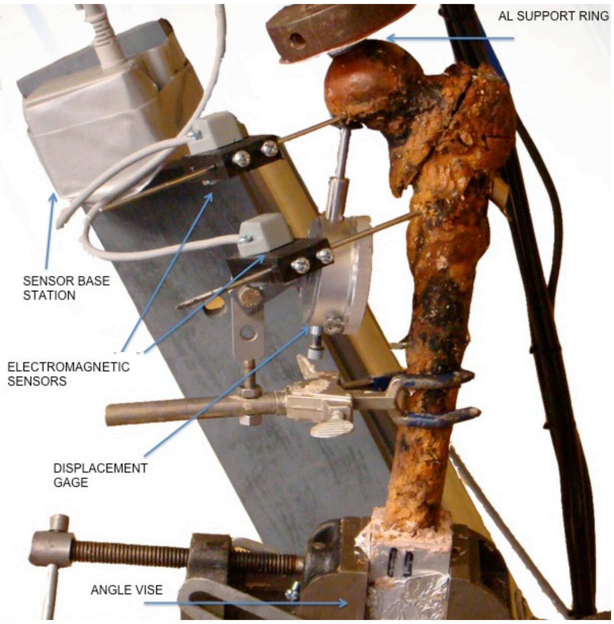

Figure 3. Testing apparatus mounted with specimen shows position of displacement transducers used to measure fracture displacement.

One specimen from each matched pair was randomly selected to undergo fixation with the TFN helical blade. The other specimen was fixed with the PTN lag screw. Starting holes for the nails were first drilled in the greater trochanter as appropriate for each nail. Flexible reamers were used to ream the femurs to 11 mm. The nails were then inserted with the alignment jig. The lag screws were inserted over a guide pin to ensure the end of the screw would be centered in the head. Nails were removed, and an experimental unstable intertrochanteric fracture was simulated in each femur. The fracture was made with a thin-blade oscillating saw. First, a fracture line was created through the intertrochanteric line. Next, a secondary fracture line was created around the lesser trochanter, and the posteromedial buttress and lesser trochanter were removed. Finally, a transverse fracture line was created at the base of the greater trochanter.[10-13] The fractures were reduced, and the instrumentation was reinserted under direct vision. The lag screws were placed using the appropriate alignment jig and ended less than 10 mm from the femoral head articular surface. During guide pin insertion, lengths were measured to ensure proper lag screw placement. In a clinical setting, lag screw lengths are selected to prevent soft-tissue irritation. To help minimize our screw inventory, we used only 100-mm lag screws. The result was that they projected laterally by various lengths. The set screws of both nails were fully engaged according to manufacturer protocols—onto the groove of the TFN helical blade or onto the outer shell of the PTN screw. Distal interlocking screws were used to control nail rotation, even though they are not needed to stabilize this fracture pattern.[13] After final implantation, specimens were radiographed to ensure component positioning and tip apex distances. The specimens were placed on a platform attached to the actuator of a material testing system (MTS Systems, Eden Prairie, Minnesota) in an angle vise so that the femur was at 25° and the anteversion of the neck was neutral. This testing setup is shown in Figure 3.

Single-legged stance joint reaction force was simulated by the femoral angulation and a vertical load on the femoral head.[14-16] The femoral heads were loaded using an aluminum annulus, which distributed the loads over a large region of the superior head. The other side of the annulus was coated with Teflon and rode against a Teflon plate to ensure free movement of the head during testing. A standard spring displacement gauge with an oversized contact plate, enabling horizontal head movement, was attached to the femur below the fracture lines to measure inferior head displacement. Two 3-mm end-threaded Steinmann pins were then placed; one was inserted 2 mm below the osteotomy perpendicular to the shaft and parallel to the neck, and the other was affixed to the inferior head and parallel to the first pin. A drop of cyanoacrylate glue was added to both pins for further stabilization. Both pins were affixed with a Patriot sensor (Polhemus, Colchester, Vermont) 4 cm from their insertion. These sensors, in conjunction with a base unit mounted adjacent to the femur, enabled additional 3-dimensional measurements of displacement, as well as angulation and rotation of the head fragment. Calibers were used for measurement of the lateral position of the lag screws.

Testing began with vertical loading of the femurs to 750 N. Head fragment movement, lag screw position, and inferior head displacement were recorded before and after loading. After completion of vertical loading, cyclical loading was done to 750 N for 10, 100, 1000, and 10,000 cycles in a sinusoidal manner at 3 Hz. After each cycle interval was completed, permanent lag screw position, inferior head displacement, and position measurements were recorded with the 750 N loads removed. Last, the femurs were loaded to failure. Vertical loads at a rate of 1.0 cm/min were applied to the femoral heads. Load and displacement parameters were recorded until specimen failure or a maximum load of 2500 N. Failure was defined as fracture of the femoral head, neck, or shaft; extension of the prior created fracture; screw cutout through the head; or implant deformation. Amount of helical blade sliding and lag screw telescoping was directly measured and calculated from the sensors. Radiographs were obtained of all specimens on completion of the biomechanical testing.

Results were statistically analyzed with paired *t* tests and regression tests.

RESULTS

DXA of the intact specimens from patients older than 60 years showed generally osteoporotic femurs with a mean Ward triangle bone density of 0.532 g/cm^3. There were no differences between left and right bone mineral density between the 2 treatment groups (solid helical design, telescoping screw design) ($P = .426$).

No significant differences in lateral or inferior head displacement or screw sliding were found between the solid helical and telescoping screw designs when an initial static load of 750 N was applied. However, some variance was attributed to differences in osteotomy sites, mating of cut surfaces, and amount of manual fracture consolidation before testing.

During cyclical loading, minor variable displacements occurred after the initial static loading test, within the first 10 cycles secondary to the incongruity between the head and shaft pieces. However, these appeared to resolve after the first 10 loading cycles, and thus the displacement data were analyzed as changes between 10 and 10^5 cycles (Table).

There was significantly ($P = .007$) less lateral lag screw sliding in the telescoping screw design group (0.25 mm) than in the solid helical design group (2.68 mm). The designs had similar inferior head displacements. Calculations based on postloading radiographs imply that additional compression occurred through the telescoping feature of the telescoping screw design.

None of the specimens failed during cycling. Two of the solid helical design specimens and 3 of the telescoping screw design specimens resisted loading to 2500 N. The specimens that failed typically split the proximal femur longitudinally. For the 7 femurs that failed at less than 2500 N, there was a correlation between bone mineral density (DXA), with lower failure values having the lowest bone density ($r = .873$). None of the specimens exhibited cutout of the screw from the femoral head.

DISCUSSION

In this investigation, we found that both nail designs demonstrated adequate fixation strength for managing unstable 4-part intertrochanteric fractures with respect to inferior head displacement and ultimate load to failure. Although the total amount of lateral lag screw sliding was low (~0.25 mm) for both screws, the telescoping screw design showed

Table. Comparison of Head Displacement, Lag Screw Sliding, and Failure for the 2 Nail Designs

Design[a]	Head Displacement Inferiorly, mm			Sliding of Lateral Lag Screw, mm			No. of Specimens Sustaining 105 Cycles, Then at Least 2500 N
	Mean	SD	Range	Mean	SD	Range	
Trochanteric fixation nail, helical blade	2.18[b]	1.75	0.18-5.13	2.68[c]	1.69	0.25-5.55	2
Peritrochanteric nail, telescoping	1.87[b]	1.24	0.27-2.57	0.25[c]	0.29	0.05-1.76	3

[a] Six of each design were tested. [b] $P = .731$. [c] $P = .007$.

significantly less lateral screw sliding (measured from lateral projection of nail) than the solid helical design did. IM nail screw implants slide less than plate and screw designs do because the nail acts as a lateral buttress and prevents lateral migration of the proximal fragment.[11] In our study, although both designs allowed for fracture collapse and compression, posttesting radiographs showed that, with the telescoping screw design, nail compression occurred at the fracture site because the design telescoped within itself. The telescoping feature of the lag screw is designed to eliminate lateral impingement, but lateral impingement occurred nevertheless. We believe the telescoping property was partially inhibited by lack of comminution in our model and resulted in some lateral projection. In a more unstable fracture model, such as a gap model, we may have been able to observe a larger amount of screw barrel telescoping and less lateral projection.

In other biomechanical studies, Sommers and colleagues,[9] Strauss and colleagues,[17] and Al-Munajjed and colleagues[18] showed the helical blade lag screw to be superior to the conventional solid lag screw because of the stronger purchase in the femoral head by radial compaction of the cancellous bone around the flanges of the blade during insertion.[19] We found no such difference in fracture displacement or femoral cutout between the helical blade and the telescoping lag screw. One reason for this could be our chosen fracture model, which under low loads achieved relative stability for both telescoping and helical blade screws. The relative stable fracture interface limited the downward translation of the head-neck fragment. Thus, we did not observe the biomechanical advantages of the solid helical design over the conventional lag screw, as previously demonstrated.[9,17-19] We speculate that the telescoping mechanism in the telescoping screw design can compensate for a possible increased head purchase achieved with the solid helical blade design, but a more comminuted fracture model may be needed to prove that aspect.

The effects of the telescoping feature of the telescoping screw design can be explained by mathematical calculation and deductive reasoning. For a 45° nail-screw angle, the head inferiorly translates about 70% of the amount the lag screw slides. In this case, the lag screw types showed similar inferior head translation. In previous comparisons of the helical blade screw with the conventional lag screw, the helical blade demonstrated significantly less inferior head translation.[9,17,18] Our study results showed that the telescoping screw design and the solid helical design had similar inferior head translation, which can be explained only by the ability of the telescoping screw design to telescope within itself, thereby compensating for the biomechanical advantage of the helical blade screw. Because the telescoping screw design lag screw projected laterally significantly less than the solid helical blade design lag screw did, the head movement of the telescoping screw design lag screw could have occurred only by telescoping.

Femoral head cutout and failure of the lag screw to stabilize a fracture did not occur in our study. However, several femurs failed because of diaphyseal splitting. This finding appeared unrelated to lag screw design, but may have been secondary to an aspect of the trochanteric nail design, such as radius of curvature or proximal bend of the nails.[11] The solid helical blade design incorporates a 6° bend in the proximal nail, the telescoping screw design a 7° bend—not a significant difference. Failure by diaphyseal splitting is not clinically relevant, as it is not a common complication in patients with hip fractures stabilized with IM nail fixation.

Our investigation had several limitations, including use of a simulated unstable intertrochanteric fracture using standard ex vivo techniques. These fracture models, however, may not have been as unstable as those observed clinically, but the ability to study a construct with no fracture fragment interdigitation allowed us to assess fracture fixation in its purest form. Absence of fracture comminution accounted for the overall minimal sliding of both lag screws. A gap model, representing a larger degree of fracture comminution, may have served as a better model for evaluating larger differences between sliding and telescoping in the 2 screws. Another limitation was the use of cadaveric specimens with their inherent variability, though the treatment groups were standardized by DXA and radiographic evaluation.

The femurs tested in our study were loaded only in the coronal plane, and our testing parameters represent the forces across the hip joint during a single-leg stance of the gait cycle.[20] During the normal gait cycle, multidirectional forces act on the hip joint. The tested femurs were not loaded in the anteroposterior plane, which more closely simulates the forces across the hip joint when rising from a seated position. These forces represent a significant amount of the joint reactive forces observed across the hip joint during the course of a day but they occur much less frequently during gait than the single-leg stance, which was tested in this study.

The testing loads we used are lower than the loads placed on 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 be the reason for failure at a load smaller than what is observed clinically. The electromagnetic sensors detected no appreciable "tilt" that would have represented femoral head collapse over the end threads or blades of the lag screws.

All values were less than 5°, probably because of ruggedness in the head-neck fragment interface consolidating during cycling. Some tested specimens from both design groups exhibited anterior rotation of the head-neck fragment of 10° to 20°. The observed anterior rotation of the head-neck fragments was not associated with a particular device and was attributed to variation in the angle of cuts. Measurement of head rotation around the lag screw was difficult because of sensor locations. Calculations would have required that precise biplanar radiographs establish sensor locations with respect to the lag screw axis.

CONCLUSION

In this biomechanical evaluation and comparison of PTNs and TFNs, no differences were found in femoral head fixation achieved by the telescoping dual-diameter design of the PTN and the helical blade design of the TFN.

Both telescoping dual-diameter lag screws and solid single-diameter helical blade lag screws—different mechanisms and designs—are strong and capable of stabilizing unstable intertrochanteric hip fractures in vivo, and both allow for compression across the fracture site.

Fracture compression using a solid single-diameter helical blade lag screw occurs at the expense of lateral protrusion of the screw into the iliotibial band and surrounding soft tissues. Fracture compression using a dual-diameter telescoping lag screw, which uses a combination of sliding and telescoping, results in far less screw protrusion into the lateral soft tissue. Further study of the clinical results of patients who undergo fixation of these fractures with these devices is warranted.

AUTHORS' DISCLOSURE STATEMENT

This research was supported by a grant from Biomet. Implants were donated by Biomet and Synthes. Dr. Egol receives research funding from Biomet, Stryker, and Synthes and reports being a paid consultant to Biomet and Synthes. The other authors report no actual or potential conflicts of interest in relation to this article.

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