Original Research

Femoral Neck Fracture Fixation: A Biomechanical Study of Two Cannulated Screw Placement Techniques

Kevin C. Booth, MD*
Thomas K. Donaldson, MD†
Qiang G. Dai, PhD†

A B S T R A C T

This biomechanical study evaluated two different methods of femoral neck fracture fixation. Ten pairs of embalmed femora were used. A standardized midcervical osteotomy was performed. One side from each pair was fixed with either conventional (central) or calcar (cortical adjacent) screw placement. The femora pairs then were subjected to cyclic and load to failure biomechanical testing. The results demonstrated significant improved stability, load, stiffness, and displacement in all tested parameters for the group with calcar screw fixation. Grossly, the conventional fixation group tended to fail in an excessively varus position, while the calcar fixation group failed with impaction of the head on the calcar, a potentially stable position.

More than 250,000 hip fractures occur per year in the United States, and with the increasing elderly population, this number is expected to double by the year 2050.¹ Medical management of these fractures is disappointing. Thus, in patients who are able to tolerate it, surgery with internal fixation has become standard care.² ³ This is especially true in the elderly patient with a nondisplaced femoral neck fracture.

The traditional method of fixing femoral neck fractures involves driving three parallel cannulated screws or pins up the center of the femoral neck into subchondral bone. This pattern of placement is generally a jig-directed equilateral inverted triangle.² This places the screws in the weak, osteoporotic, trabecular bone of the femoral neck, and in some cases, the femoral head-screw complex subsides in the neck and settles into an unstable varus position. There is a definite correlation with fracture nonunion and failure of internal fixation manifesting in a downward migration of the pins and femoral head without plastic deformation.³

This study was undertaken with the premise that in osteoporotic fractures, the adjacent calcar could be used as high-quality bone to enhance fixation and improve the strength of the hip fracture construct. A biomechanical model was used to compare the conventional inverted triangle central neck placement with the proposed modified calcar buttress position.

MATERIALS AND METHODS

Ten pairs of elderly embalmed proximal femora were used. Radiographs verified the lack of osseous disease. Specimens were cut with a band saw to create a standardized midcervical osteotomy perpendicular to the cervical neck.⁴ ⁵ The osteotomy then was fixed with either a conventional inverted triangle (central) method or a comparative calcar buttress method (Fig 1). Right and left specimens were randomized for each test group.

In the conventional inverted triangle method, the minimum distance between the adjacent cortex and screw side was 5 mm. In the calcar fixation group, screws were placed essentially subcortical. Fixation was achieved with three parallel 6.5-mm cannulated screws (Depuy-ACE, Warsaw, Ind) in each group. The screws were placed under direct vision by first retrograding double-tipped guide pins down the femoral neck and then reducing the "fracture" (Figs 2 and 3). A neck shaft angle of
135° was used for all specimens. Screw length was determined by depth gauge and confirmed with radiographs.

Following fixation, each specimen was mounted in a testing jig in single stance phase at approximately 25° of adduction and 15° of flexion, and biomechanical testing was performed on an Instron 8521 (Instron, Canton, Mass). Specimens were subjected to a 30-N axial preload, and initial displacement of the osteotomy was measured with a vernier caliper as well as by axial piston position. Specimens then were subjected to an axial cyclic loading test of 100 cycles at 1500 N. Displacement was recorded at initial preload and the specimens were subjected to load to failure tests (Fig 4).

Statistical analysis was performed using a paired $t$-test. A $P$ value of $<.05$ was considered statistically significant.

**RESULTS**

Results are summarized in the Table. A statistically significant advantage was found for the calcar-buttressed configuration in all tested parameters. Testing specifically included:

- gap displacement of the osteotomy after 100 cycle loading,
- gap displacement at mechanical failure,
- axial (piston) displacement after 100 cycle loading (1500 N),
- stiffness at yield,
- stiffness at failure,
- load at yield point, and
- maximum load at failure.

Gross observation of failed specimens showed the femoral head impacting on the femoral neck in the calcar fixation group, while the conventional fixation group failed with toggling of the femoral head over the neck into increasing varus (Figs 5-7). No specimens in either group developed subtrochanteric fractures.

**DISCUSSION**

The elderly patient with a femoral neck fracture is at elevated risk from multiple surgical procedures. If the initial fixation procedure fails, more complex solutions such as conversion to hemiarthroplasty are required, increasing patient mortality. Activities of daily living may produce forces of 1500 N across the hip joint, and improving the hip fracture construct strength (maximum load at failure) to more than twice this force may avoid catastrophic failure.

Other studies have demonstrated the efficacy of cannulated screw fixation in femoral neck fractures and also have elaborated on the principles of optimal technique. However, the study described here is unique in that it demonstrates improved construct strength with the varied position of three otherwise ideally placed screws.

This experiment was designed with specific internal controls to minimize individual specimen variation. Matched femurs were used, and each side was randomized. This should have reduced the effect of side, embalming technique, desiccation, and bone density. Both groups used the same 135° neck shaft angle for screw placement. Embalmed specimens were used, and other studies have shown that embalming results in only slight decreases in ultimate tensile strength, maximum strain, and modulus of elasticity.
Enthusiasm for the conventional (central) method of pin placement stems primarily from two sources. In situ pinning of the pediatric slipped capital femoral epiphysis often necessitates placement of the screw quite anterior. Central placement is critical to avoid "extending" the femoral neck. Also, the risk of subchondral penetration and chondrolysis is reduced with central placement.

Studies by Crowell et al. and Benterud et al. have demonstrated increased subchondral bone density in the superior central quadrants of the femoral heads. Fixation in these quadrants demonstrated increased pull-out strength compared with inferiorly placed screws. However, these situations do not reflect the elderly femoral neck fracture. Pediatric trabecular bone within the femoral neck is dense and supportive, while elderly osteoporotic trabecular bone is fatty and provides minimal structural support. Increased screw pull-out strength may potentially correlate with decreased cutout, but femoral neck fractures often settle with the screws losing interfragmentary compression by sliding through the lateral cortex.

Clinical failures typically show loss of fixation, migration of the hardware, fracture displacement, progressive varus, and screw cutout (erosion of the screw threads through the superior femoral head). Our gross observations of the failed specimens showed all of these in the conventional fixation group; however, the calcar fixation group was noted to settle in a position of impaction of the femoral head onto the calcar with bony apposition. This gave the appearance of impacted bone-on-bone contact, even at biomechanical failure (Fig 7). It is reasonable to conclude that this impaction may allow healing and that the progressive varus gapping observed in the central specimens would be unlikely to promote union.

These results indicate that it is critical to prevent varus settling to optimize healing potential. Screw cutout was not appreciated in any failed specimens, suggesting that this probably represents a biologic response to movement in a loose construct. While this biomechanical study cannot yield clinical results, the observations are nonetheless encouraging, and a clinical review of this fixation method is ongoing.

**Conclusion**

Significantly improved construct strength is achieved with the use of three cannulated screws placed peripherally in the femoral neck. Optimal screw position is achieved with the first screw placed along the femoral calcar (inferior in the coronal [anteroposteri-
important as it is in tension during loading and is placed approximately two thirds up the anterior femoral neck (superior in the coronal plane and anterior in the sagittal plane).

REFERENCES


