A Biomechanical Comparison of Two Patterns of Screw Insertion

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Abstract

Inserting a screw into a long bone introduces a stress riser that can predispose the bone to fracture. Where multiple screws are inserted this vulnerability may be increased. It is thought that the pattern of screw insertion plays an important part in determining the susceptibility of the bone to stress fracture. In order to study the importance of pattern of screw insertion, third generation composite femora with cannulated screws inserted in two different patterns were tested to failure by a servohydraulic materials test system. The vertical pattern of screw insertion is less apt to predispose a long bone to subsequent fracture than a horizontal pattern.

Some fractures of long bones are treated by internal fixation with screws. A prime example would be certain fractures of the hip. The introduction of a screw into a long bone, however, carries with it the risk of introducing a stress riser that may make the bone more vulnerable to subsequent stress fracture. In cases of multiple screw insertion, the risk of subsequent fracture may be increased. How much of a part the pattern of screw insertion plays has not been thoroughly investigated. The following study was designed to test the concept that a transverse pattern of screw insertion weakens a long bone more than an alternative pattern where the screws were not placed at the same level transversely.

Methods

Whole femur surrogates (N = 25) (third Generation Composite Femurs, Pacific Research Laboratories, Vashon, WA, USA) were purchased and prepared for testing. Femora were divided into two groups based on the relative position of three 6.5 mm diameter and 95 mm long cannulated screws (Stryker Orthopedics, Mahwah, NJ, USA) (Fig. 1). In the first group (N = 11), screws were placed in a triangular pattern with the two most distal screws placed in the same horizontal or transverse plane. Samples with this configuration were designated the horizontal group. In the second group (N = 9), screws were placed in a triangular pattern, however the triangle was tilted so that no two screws were placed in the same transverse plane. The configuration approximated a vertical pattern, and therefore samples with this configuration were designated the vertical group. A control group (N = 5) without any screws was also included. In all the screw insertions, an attempt was made to maintain uniformity of location of the screws within each group and to start the most distal screw no lower than the level of the middle of the lesser trochanter.

Femora were cut transversely 175 mm from the lesser trochanter (225 mm from the most proximal point of the greater trochanter). For each specimen, the diaphysis of the proximal portion was potted in square aluminum tubing (50 x 50 x 50 mm) using a low-melting point alloy (Cerro Metal Products, Bellefante, PA, USA). The bone was rotated with respect to the pot about the stem axis in order to provide 15° of femoral neck anteversion. Femora were tested in an upright position using the methods of Cody and colleagues. The femoral-pot construct was positioned in a custom fixture so the diaphysis was tilted medially at 25° from vertical in the coronal plane. Each femur was loaded through the femoral head using a spherical cup with a 23 mm radius to simulate the acetabulum. All samples were loaded to failure under displacement control at 5 mm/sec using a servohydraulic materials test system (Instron, Canton, MA, USA). Load and actuator displacement were digitized and recorded (LabVIEW, National Instruments Inc., Austin, TX, USA).
Maximum load and structural stiffness were determined from the load and displacement curves. At completion of mechanical testing, the samples were classified as having either a subtrochanteric or femoral neck fracture.

**Results**

No significant difference was found for stiffness or failure load among the vertical, horizontal, and control groups (Table 1). However, there was a significantly higher proportion of samples in the horizontal group that failed in the subtrochanteric region (Table 2). For these samples, the fracture passed through the screw holes in 6 of the 11 specimens (chi-squared, p < 0.042). Failure occurred through the femoral neck for all of the specimens in the vertical group, as well as in the control group.

**Discussion**

The proximal femur was chosen as the representative for this investigation because historically, when a triangular pattern of nail insertion\(^2\)\(^-\)\(^4\) was used to fix femoral neck fractures, there was a significant incidence of the subtrochanteric fractures through the lower screws.\(^5\)\(^-\)\(^9\) There is a disagreement in the orthopaedic literature as to whether the location of the lower screws\(^10\) or the pattern of screw insertion\(^3\) was responsible for the susceptibility to the stress fracture. Although clinically the practice of fixing these fractures using a triangle pattern has changed, and an inverted triangle pattern is now recommended, the influence of the pattern of insertion has not been adequately biomechanically tested.

Selvan,\(^11\) by means of mechanical testing, showed that a triangular configuration of screws was superior to a vertical configuration for fixation of femoral neck fractures. The triangular pattern has a higher peak load, higher ultimate load, and more energy absorption before failure.

Oakey\(^12\) indicated that a triangular pattern with the base distally makes the femur more vulnerable to fracture around the distal screws. The method used to test the specimens involved potting the femur across the femoral neck to concentrate the force to the subtrochanteric region. Our study tested the femoral specimens in a more anatomically correct position by potting the diaphysis and applying the force to the femoral head. The results confirm the importance of pattern of placement in affecting the way bone fails. Although stiffness and failure load were not affected by pattern, a greater number of failures occurred through the two screws placed in a horizontal configuration. This suggests that two screws placed at the same level may lead to an increased risk of fracture in a long bone.

It should be noted that the vertical pattern recommended in this study eliminates the disadvantages of horizontal screws but still maintains the strength of a triangular configuration (Fig 1).

In this study, to eliminate the role played by the location of the distal screws being placed at or below the cortical cancellous bone transition, no screw was inserted below the middle of the lesser trochanter. In this way, the influence of improper location of the lower screws was removed.

We note some obvious weaknesses of our study:

1. Results of studies of fracture failure in the proximal femur may not necessarily translate to other long bones;
2. The materials used for specimens of femora, while designed to replicate the strength and morphology
of normal femora, do not reproduce the trabecular architecture and possibly behave differently from osteoporotic bone;

3. The specimens were tested in only one mode (i.e., direct weight bearing); torsion and transverse stress application were not tested; and

4. No attempt was made to test for the effects of repetitive loading at subfracture levels.

All the above inadequacies of this study would probably give rise to quantitative differences rather than qualitative differences, and do not compromise the validity of the study.

Conclusion
A biochemical testing of two different patterns of screw insertion confirms that vertical pattern of screw insertion is less apt to predispose a long bone to subsequent fracture than a horizontal pattern. This study emphasizes the importance of avoiding the use of screws at the same level transversely in the internal fixation of a long bone.

Disclosure
The authors acknowledge the generosity of Stryker Orthopedics, Mahwah, NJ, for supplying the equipment used in these experiments.

Reference


