Basic Science

Percutaneous Pinning of Proximal Humerus Fractures: A Biomechanical Study
Sanjiv H. Naidu, MD*†
Brian Bixler, MD*
John T. Capo, MD*
Mark J.R. Moulton, MD*
Alex Radin, PhD†

ABSTRACT

Mechanical testing of two-part surgical neck fractures fixed with four different pin configurations was performed. Ten fresh, frozen, unembalmed humeri stripped of all soft tissues were used; the surgical neck was osteotomized perpendicular to the humerus long axis. Terminally threaded 2.5-mm AO pins were used to fix the fracture. Humeri then were tested in both torsion and bending on a custom-made jig using Instron 1331 to assess the rigidity of pinning constructs. In torsion, two lateral pin construct was significantly less rigid than all other pin configurations. The addition of an anterior pin to two lateral pins did not increase bending rigidity, but significantly increased torsional stiffness. The addition of two bicortical tuberosity pins or two bicortical tuberosity pins and one anterior pin to two lateral pins significantly increased rotational and bending rigidity. Results confirm clinical data, and the authors conclude that multiplanar pins are needed to augment torsional stiffness, and that the addition of two bicortical tuberosity pins enhances bending rigidity.

Nearly 80% of proximal humeral fractures can be treated nonoperatively.1 At times, however, the reduction may be unstable, particularly for displaced surgical neck fractures. Open reduction and internal fixation (ORIF) then is indicated.1 ORIF with plates and screws, tension band wiring, or suture repair are all viable options to obtain a stable reduction; however, complications include avascular necrosis, joint stiffness, and neurovascular injury.2

Unlike other open procedures, percutaneous pinning circumvents extensive soft-tissue stripping. Several authors support the use of percutaneous pins as a means to hold the reduction of unstable, two-part surgical neck fractures.3,4 Some recommend inserting pins from the lateral aspect of the humerus into the humeral head. Others have suggested that additional pins inserted from the anterior cortex of the humeral shaft, or from the greater tuberosity, may enhance fixation.5

Review of the English literature showed no biomechanical data concerning percutaneous pinning of the surgical neck of the humerus. In the following in vitro biomechanical study, the rigidity of percutaneous pin constructs is evaluated, both in torsion and in cantilever bending.

MATERIALS AND METHODS

Mechanical testing was performed on 10 fresh, frozen, unembalmed humeri from which all the soft tissues had been removed. The specimens were paired humeri from five donors, two men and three women ranging from in age 72 to 77 years. All specimens were radiographed prior to testing to confirm the absence of preexisting pathology. All specimens had been stored and frozen at −70°C until testing.

The humeri were thawed overnight at room temperature, and then potted in a copper cylinder using polyester
autobody cement. A two-part fracture was simulated by making a complete transverse osteotomy at the surgical neck of the humerus. The fracture then was reduced, and terminally threaded 2.5-mm AO pins were used for fixation. A 2-mm comminution was made using an oscillating saw to assure that bony interdigitiation did not confound the stiffness values measured.

The pins were classified by insertion into three groups, as described by Jaberg et al. (Fig 1). Group A consisted of two lateral pins placed from the lateral shaft of the humerus into the humeral head. Group B consisted of one pin placed from the anterior cortex into the humeral head. Group C consisted of two pins inserted in a retrograde fashion from the greater tuberosity into the medial cortex of the shaft.

Pins in groups A and B were inserted at a 30° angle from the shaft. The entry point was 2 cm from the fracture site, and pins were advanced to lie in the subchondral bone 5 mm from the articular surface. Group C pins were inserted to gain bicortical purchase. All pins were inserted 1 cm apart using an adjustable Synthes guide (Synthes, Paoli, Pa) with a power drill without predrilling, and pin placement was confirmed with radiographs. The humeri then were mounted on a specially designed jig (Figs 2-4), which was secured to the base of Instron 1331 (Instron Corporation, Mass).

Two loading regimens were used to mimic in vivo deforming forces. Torsion was used to simulate the relative rotation that would occur at the fracture site due to the action of the external rotators inserted on the humeral head and the internal rotators inserted on the humeral shaft. In addition to torsional forces, cantilever bending would occur at the fracture site due to adduction moment of the pectoralis major.

Using predetermined loading rates and total displacements required to determine stiffness without causing specimen failure, each humerus was used to test each of four pin configurations in the following order by the same surgeon: (Group 1) A pins; (Group 2) A and B pins; (Group 3) A, B, and C pins; and (Group 4) A and C pins. This order was selected so that no pin was removed and then reinserted. After the humerus was tested in all four configurations, the specimen was discarded and the series was repeated on a new specimen.

The torsion test is illustrated in Figure 3. The head is fixed in the jig so that the distance from the point of fixation to the fracture site was constant at 2 cm. The humeral shaft, potted in cement, then was placed in the cylindrical drum; the distance between the fracture site and the point of fixation in the drum was consistently maintained at 15 cm. A uniaxial force was applied to the cylindrical drum on the jig to simulate a torsional load. The radius of the cylinder was 1 in., and therefore, the torque moment arm was 1 in. as well.

The left humeri were loaded in a clockwise direction, and the right loaded in counterclockwise direction to mimic internal rotation of the shaft by the pectoralis major and the latissimus dorsi. Torsional torques of 0 to 20 lbs/in. were applied at the loading rate of 1 in./min to obtain load displacement curves. The test was stopped when the total displacement reached 0.5 in., and the resultant slope of the load displacement curve was used to
calculate torsional stiffness.

In the bending test, the head was fixed in the jig at a constant distance of 2 cm from the fracture site. A transfraction pin was placed in the shaft 3 cm distal to the fracture site to simulate pectoralis major insertion. The humerus was oriented so that the applied uniaxial load would mimic medially directed bending forces generated by the pectoralis major contraction. Loads from 0 to 20 lbs were applied at 0.3 in./min. The test was stopped when the total displacement reached 0.1 in., and the resultant slope of the load displacement curve was used to calculate bending stiffness.

The stiffness values for various pin configurations were compared using one-way ANOVA. Post-hoc Student Neuman Keul's test determined statistically significant differences among the groups.

**RESULTS**

None of the pins were plastically deformed, and none of the specimens failed. In torsion, the pin constructs in Groups 2, 3, and 4 were all significantly stiffer than those in Group 1 ($P < .01$). There were no differences in pin construct stiffness among Groups 2, 3, and 4 (Fig 5).

In bending, pin constructs in groups 3 ($P < .05$) and 4 ($P < .01$) were significantly stiffer than those in Group 1 (Fig 6). The pin construct in Group 2 was not significantly different from those in Group 1, and there were no differences in bending stiffness between pin constructs in Groups 3 and 4.

**DISCUSSION**

AO principles of internal fixation dictate that to achieve primary bone healing, rigid internal fixation is necessary in long bone fractures. However, proximal humeral fractures pose a different problem. They usually occur in the older osteoporotic population. Hardware purchase in such weak bone poses a major problem.

Surgical neck fractures of the proximal humeri heal readily due to excellent blood supply and good soft-tissue envelope; however, fracture fragments must be aligned to achieve bony union. Although surgical neck non-unions are rare, they can occur in displaced and unstable fractures.

Percutaneous pinning allows the surgeon to maintain fracture alignment without resorting to ORIF. Various pinning configurations have been advocated by several authors, but mechanical stability data on such pinning constructs are not presently available. Four different pin constructs were studied to address these issues.

The results show that none of the pins were plastically deformed, and none of the specimens failed. Stability or strength of fixation were not measured; the above reported values represent the rigidity of pin constructs. Increasing the rigidity of fixation decreases motion at the fracture site, and therefore enhances primary bone healing. Because the deforming forces for the surgical neck fractures have yet to be quantitated, one must assume that the most rigid construct will provide for optimal bony union. Increasing rigidity may allow for early motion, but this supposition would require further research.

Pin construct stiffness was related to both the number of cortices engaged with the pins, and also the number of mutually intersecting planes along which the pins are oriented. In torsion, the pin constructs in Groups 2, 3, and 4 were significantly more rigid than those in Group 1. There were no significant differences in pin construct stiffness among Groups, 2, 3, and 4, even though Group 3 showed the most stiffness. Biplanar fixation was used in Groups 2 and 4, whereas triplanar pinning was used in Group 3. The data suggest that for torsional stability, multiplanar fixation is more important than the number of cortices engaged.

While torsional stiffness increased with multiplanar fixation, bending stiffness depended more on the number of cortices purchased. Pin constructs in Groups 1 and 2 were not significantly different in terms of bending stiffness. Group 1 had two cortices engaged, whereas Group 2 had three cortices engaged. Pin constructs in Groups 3 and 4 were significantly
stiffer than those in Group 1. Group 3 had seven cortical bites, whereas group 4 had six cortical bites.

To stabilize an unstable proximal humerus fracture, a rigid pinning configuration is needed to overcome the deforming forces. The above biomechanical study confirms the clinical results in that at least a multiplanar pin construct was needed to optimize torsional stiffness, and that additional tuberosity pins augmented the bending stiffness of percutaneous pin constructs.

REFERENCES