Abstract

In order to determine the effects of two different headless screw designs on fixation of simulated capitellum fractures, six matched pairs of embalmed humeri had simulated capitellum fractures created. Fixation with Acutrac compression screws was compared to Herbert screws in a matched pair experimental design. All specimens were cyclically tested with simulated physiologic loading. Both displacement of the capitellum as a function of the number of cycles and failure loads were determined. Fixation by the Acutrac screws was significantly more stable than Herbert screws at 2000 cycles, 0.17 mm versus 1.57 mm (p < 0.02). The Acutrac fixation also had a higher failure load, 154 N versus 118 N (p < 0.05). The Acutrac screws tested in this biomechanical study provided more stable fixation of simulated capitellum fractures than Herbert screws. This appears to be related to the design of these screws.

Isolated fractures of the capitellum are rare, accounting for 1% of all fractures about the elbow. Reports have described treatment by closed reduction, fragment excision, and open reduction with and without internal fixation. When open reduction and internal fixation is performed, techniques include the use of partially threaded cancellous lag screws, Kirschner wires, and headless screws. The authors have previously reported on the stability of simulated fractures of the capitellum secured with Acutrac screws (Acutrac, Acumed, Beaverton, OR) compared to 4.0-mm cancellous lag screws inserted in both the anterior to posterior direction (AP) and the posterior to anterior direction (PA). We concluded that the Acutrac screw provided the more stable fixation. The purpose of this current study was to compare the fixation stability achieved by two different headless compression screw designs: Acutrac screws inserted in the AP direction to Herbert screws (Zimmer, Warsaw, IN) inserted in the AP direction.

Materials and Methods

Six matched pairs of embalmed cadaveric humeri were used. All specimens were radiographed in the anteroposterior and lateral views to evaluate osteopenia and check for osseous defects and pathologic lesions. Simulated capitellum fractures were created by osteotomies in the coronal plane at the posterior edge of the articular surface and in the sagittal plane at the lateral edge of the trochlea. The lateral third of the trochlea was not included in the osteotomized fragment of the capitellum. The osteotomies were performed with a diamond wire saw at the periphery and completed with an osteotome to simulate a fracture surface by creating interdigitiation. This method reproduced similar osteotomies for all samples. Two Acutrac or two Herbert screws were used for fixation of the capitellum of each pair. The Acutrac screw is a fully threaded, self-tapping, tapered, variable pitch headless screw. The leading tip measures 3.3 mm in diameter and widens to 4.6 mm for a 30-mm screw. The Herbert screw was introduced in the 1980s as an alternative to AO lag screws. It has threaded proximal and distal ends separated by an unthreaded shaft. The finer pitch of the proximal end advances more slowly than the coarser threads at the distal end thereby achieving compression. All screws were inserted in the AP direction perpendicular to the articular surface according to the respective manufacturer’s recommendations. All specimens were radiographed prior to testing to check for the appropriate placement of the hardware (Figs. 1 and 2).

Cyclic loading of the specimens was performed using
a custom loading device attached to a servohydraulic materials testing machine (MTS, Eden Prairie, Minnesota). Each specimen was secured to the MTS by a Sawbones bone holder (Vashon, WA) at 20° of flexion. The angle was chosen because biomechanical testing has shown that the greatest amount of force transmitted from the radial head to the capitellum occurs between zero and thirty degrees of elbow flexion. A load applicator was designed to make flush contact with the capitellum (Fig. 2).

Sinusoidal cyclic loading using a maximum loading force of 75 N at 3 cycles per second was applied to each specimen. This value was chosen from biomechanical analysis of force transmission through the elbow. Displacements of the MTS actuator were recorded with a strip chart recorder at 90, 180, 360, 900, and 2000 cycles. Initially, an intact specimen was tested and found to produce less than 0.01 mm of displacement at 75 N. Since this was a rigid construct, it was assumed that all displacement took place at the simulated fracture site. After cyclic loading, the specimens were loaded to failure at a rate of 50 N/sec. The load to failure was defined as the maximum of the load displacement curve. All specimens were inspected and radiographed after testing to ascertain the mechanism of failure. Data were analyzed using a Student’s matched-pair t-test. The level of significance used was p < 0.05.

Results
Specimens stabilized with the Acutrac compression screws exhibited less displacement than those stabilized with the Herbert compression screws at each cyclic measurement interval (Table 1). At 2000 cycles, the Acutrac samples displaced an average of 1.40 mm less than the Herbert screw specimens; this was statistically significant (p < 0.02). The Acutrac specimens had a mean failure load of 154.67 N versus 118.67 N for the Herbert specimens. This difference in load to failure was statistically significant (p < 0.03).

All specimens failed by shear displacement of the capitellum fragment. No articular splits were noticed between the screw insertion sites after cyclical loading or loading to failure. Radiographs showed radiolucency around the proximal end of the Herbert screw. This indicated screw toggle as the mechanism of failure of fixation.

Discussion
The Herbert screw and the Acutrac screw are headless screw designs that were developed to allow interfragmentary compression while eliminating articular or soft tissue impingement on the exposed screw head. Furthermore, both designs obviate the need for countersinking and the subsequent removal of subchondral bone that is necessary
for adequate purchase in small fragments.

In this study, the Acutrac headless compression screw design provided more stable fixation than the Herbert headless compression screw design in both cyclical loading and loading to failure. This can be explained by the difference in screw design. In contrast to the Herbert screw, the fully threaded design of the Acutrac screw creates a larger cross-sectional area of bone-screw interface along the entire screw track. This allows for greater resistance to loading in shear, less toggle, and ultimately greater holding power.

We recently published a laboratory study on the use of Acutrac screws for the fixation of capitellum fractures. We concluded that the Acutrac compression screw provided more stable fixation than 4.0-mm cancellous lag screws inserted in the AP or PA direction. Toby and colleagues compared the fixation of matched pair scaphoids with Herbert screws to cannulated 3.5-mm screws, Acutrac screws, Herbert-Whipple screws (Zimmer, Warsaw, IN), or a Universal Compression screw (Howmedica, Rutherford, New Jersey) in cyclic bending loads. Acutrac screws required greater loads to produce displacement compared to the Herbert screw. Wheeler and associates compared AO 4.0-mm cancellous screws, Acutrac screws, and Herbert screws in scaphoids. They concluded that both the Acutrac and AO screws provided greater compression than the Herbert screw in both bone and in foam. After cyclic loading, the Acutrac screw maintained compression better than both the AO screws and the Herbert screws.

Limitations of this investigation include the use of embalmed specimens; however we do not feel that this was a significant problem as matched pairs were used and other studies have shown that embalming specimens does not significantly alter the mechanical properties of bone. In addition, the study used a maximum load of 75 N at a constant 20 degree angle of contact which does not duplicate the varying loads and angles seen clinically. Morrey and coworkers showed that maximal force transmission through the radial head to the capitellum occurs at 0 to 30 degrees of elbow flexion. While loading the specimen along this vector does not produce maximum shear, the angle is within the range where maximal force is transmitted to the capitellum. Furthermore, this study does not take into account varus and valgus positioning of the elbow as may occur during daily activities. However, Markolf and colleagues showed that with varus positioning, there is an increase in force transmitted from the radius to the ulna via the interosseous membrane and subsequent increased loading of the ulnohumeral joint and decreased loading of the radiocapitellar articulation. Although specimens were subjected to only 2000 cycles, the rate of displacement decreased as a function of the number of cycles.

**Conclusion**

It is often difficult to draw absolute clinical recommendations based on an isolated biomechanical study. The Acutrac screws tested in this biomechanical study provided more stable fixation of capitellum fractures in cadaveric specimens than Herbert screws and may do so in the clinical setting.

**References**