THE DEFORMATION OF SUPRACONDYLAN FEMORAL NAILS WITH INSERTION:  
THE EFFECT OF LENGTH ON AIMING ARM ACCURACY

+*Miclau, T; *Hymes, R; *Holmes, W; **Raabe, N; **Krettek, K  
++University of California, San Francisco, CA; **Hannover Medical School, Hannover, Germany  
miclaut@orthosurg.ucsf.edu

Materials and Methods

For this study, the amount and direction of insertion-related implant deformation at the proximal most interlocking hole of supracondylar femoral nails were recorded. A three-dimensional coordinate system was devised to determine motion in the three planes and three axes of rotation (1). This was measured using a three-dimensional magnetic motion tracker system (3space® Pastrac:S® System Polhemus Navigation Sciences Division, McDonnell Douglas Electronic Company, Colchester, Vermont, USA) which consists of two field sensors and a magnetic source connected to a microprocessor. The position of each sensor is monitored in three planes and three axes in relation to the magnetic source. Previous work has shown the spatial accuracy of the system to be 0.5 mm in translation and 0.3 degrees in rotation and angulation, with a sensitivity of 0.1 mm and 0.2 degrees between the sensors. The supracondylar femoral nails used for this study were stainless steel (Smith & Nephew Richards, Memphis, TN, USA). Six measured 11 mm in diameter and 150 mm in length and six measured 11 mm in diameter and 250 mm in length. The stainless steel supracondylar femoral nails had 5.5 mm proximal interlocking holes that were designed to accept 5.0 mm cortical bone screws. The centers of the two proximal interlocking holes were 15 mm and 30 mm from the nail tip. A plexiglass mounting that attached the magnetic sensors to the proximal end of the nail was constructed. A plastic extension was designed to decrease the interference of the implants on the magnetic sensors. The implants were then mounted vertically on the testing frame. The coordinate system was calibrated after attaching the sensors to the nails. Zero position was established and reconfirmed after removing and remounting the nail.

Intact femurs were used to maximize nail deformation. Six paired, cadaveric femora, devoid of soft tissues and stored at -25°C, were thawed at room temperature for 24 hours prior to usage. Both nail groups were inserted in the same manner. An entry hole was made just anterior to the femoral attachment of the posterior cruciate ligament using a sharp awl and the entry site wasreamed. The selected nails (11 x 150mm-right side, 11 x 250mm-left side) were attached to the targeting jig. Prior to nail insertion, a trochar and standard drill bit were placed through the aiming jig to confirm alignment with the proximal interlocking holes. All nails were advanced by hand or gentle taps with a mallet. A single distal and two proximal interlocking screws were then placed using the distally based aiming jig in accordance with the manufacturers' recommendations. The distal interlocking screws were placed initially, followed by placement of the proximal interlocking screws (the distal-most screw first). Accuracy of the jig was defined as success or failure of interlocking screw placement. The femurs were cut with an oscillating saw transversely, just proximal to the tip of the nail, and the proximal portion of the bone was resected. The bone-nail complex then was remounted onto the testing frame in its initial position. The sensor was reattached to the tip of the nail and the position of the nail was recorded. A right-handed rectangular coordinate system, with the center at the nail tip was used to determine the three dimensional change in position. The positive x-axis pointed distally, in the longitudinal axis of the nail; the positive y-axis pointed in the sagittal direction ventrally, and the positive z-axis of a left femur pointed medially (right femur directed laterally). Rotation about the x-axis is the angle γ, about the y-axis is the angle β, and rotation about the z-axis is angle α. The groups were evaluated using a Wilcoxon test.

Results

For the 11 x 15 and 11 x 25 mm stainless steel nails respectively, the mean deformation was: 0.3±0.3 mm (range 0.6mm) and 0.3±0.6 mm (range 1.4mm) in the proximal direction (x-axis; p<0.08); 0.2±0.3 mm (range 0.7mm) and -0.9±2.8 mm (range 7.7mm) in the ventral direction (y-axis; p<0.03); and -0.6±0.07 mm (range 3.3mm) and 2.4±2.0 mm (range 5.6mm) in the medial direction (z-axis; p<0.05). The rotational deformations averaged: -0.4±0.8 degrees (range 2.3mm) and 0.0±0.4 degrees (range 1.1mm) of rotation around proximal-distal axis (angle γ; p<0.03); 0.7±0.7 degrees (range 1.8mm) and -0.9±1.2 degrees (range 3.0mm) of rotation around the dorsal-ventral axis (angle β;p<0.05); and 0.02±0.1 degrees (range 0.3mm) and 1.7±2.5 degrees (range 6.9mm) of rotation around the medial-lateral axis (angle α; p<0.01). The accuracy of the distal interlocking screws for nails of both lengths was 100% (6/6) each. The accuracy of placement for the proximal interlocking holes was 10/12 (83%) for the 11 x 150 mm nail and 3/12 (25%) for the 11 x 250 mm nail.

Discussion

In this study, longer implants demonstrated significantly more deflection than shorter implants of the same diameter. This deflection affects the accuracy of proximal interlocking screw placement. Therefore, it would appear that manufacturer changes in aiming arms alone would be limited in improving the accuracy of proximal interlocking screw placement. In addition, in order to minimize operative delay during surgery or potential damage to both the nail and interlocking screw, surgeons should be aware that aiming jigs are more inaccurate with longer nails. This study also illustrates that an interlocking screw aiming jig, one of the most attractive features of the short retrograde nail, becomes less accurate with increasing lengths of implants and degrees of deformation. In the future, quantification of nail deformation and its relationship to implant design may facilitate strategies for the development of more successful aiming arms.

References