Can Fatigue Strength of Locking Plates be Improved by Plugging the Unfilled Screw Holes in Comminuted Supracondylar Femur Fractures

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INTRODUCTION:
Locking plates have improved the fatigue life and helped to avoid failures of fixations at the bone-screw interface. Comminuted supracondylar femur fractures are commonly fixed with periacicular locking plates. The comminuted area is usually bridged i.e. the screw holes on the plate are unfilled. Clinically, fixation usually fails with plate bending and breaking at the level of unfilled screw holes [1]. We hypothesized that plugging the unfilled screw holes will improve the fatigue strength of the fixation. The purpose of this study was to investigate how the fatigue life of a plate with combination locking/compression holes would be affected by plugging the holes.

METHODS:

Specimen Preparation

18 fourth generation Sawbones femurs were instrumented with a locking/compression plate (Synthes). Once the femurs had been repaired, a defect was created which exposed the three most distal shaft screws in order to simulate severe comminution (Fig. 1). The specimens were then potted in a two part epoxy resin (Smoothcast, Smooth-On). The distal portion was potted to the just cover the condyles and the proximal portion was potted to 4 cm below the simulated fracture. The specimen were then randomly divided into the following three treatment groups (N=6 per group): 1) plugged holes (Fig. 1, top); 2) screw only (Fig. 1, middle); and 3) unplugged (Fig. 1, bottom).

For the plugged group, a three dimensional scan of the complex hole in the plate was obtained and used to produce a plug which was manufactured out of 316SS using selective laser sintering. The plug was designed to be a tight press fit with the screw in place such that every portion of the hole was filled.

Biomechanical Testing

Following instrumentation, the specimens were loaded onto a servohydraulic testing machine (MTS Mini-Bionix 858) which was outfitted with custom designed pivots which allowed for variable offset and unconstrained rotation in the sagittal plane (Fig. 2). The center of rotation of the pivots was set such that the proximal pivot rotated through the femoral head and the distal pivot rotated through the center of the intercondylar notch.

The specimens underwent a stepwise fatigue loading scenario of 100N to 660N of compression and 0 to 13Nm of external rotation which increased by 110N of compression and 2Nm of external rotation every 25,000 cycles. Following testing of the initial groups, it was suspected that the stepwise loading scheme was inducing non-fatigue failures in the specimen, so an additional 5 specimen per group were run-out at the initial loads until failure.

RESULTS:

Stepwise Loading

There were no significant differences in any outcome metric between any of the comparison groups (Fig. 3). The mean number of cycles to failure for the run-out specimen was 29,500±2,700 cycles, 29,300±5,500 cycles, and 27,200±2,900 cycles for the plugged, screw only, and unplugged configurations, respectively.

Run-out Loading

There were no significant differences in any outcome metric between any of the comparison groups (Fig. 3). The mean number of cycles to failure for the run-out specimen was 39,500±13,500 cycles, 36,600±7,200 cycles, and 43,400±9,700 cycles for the plugged, screw only, and unplugged configurations, respectively. The mode of failure for the plugged configuration was fracture at the proximal shaft (1/5), the proximal gap hole (1/5), the middle gap hole (1/5), and the distal screw (2/5). The mode of failure for the screw only configuration was the proximal gap hole (5/5). The mode of failure for the unplugged configuration was the proximal shaft (2/5), the proximal gap hole (2/5), and the middle gap hole (1/5) (Fig. 4).

REFERENCES:

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