INTRODUCTION:

Successful application of plate and screw fracture fixation requires a stable construct with proper stiffness for the entire fracture healing period [1-2]. It is known that plate working length, i.e. the distance between the first screws on either side of the fracture site, is one of the most important surgeon-controlled factors determining the flexibility of the construct especially when a bridging technique is used. It is less clear how working length is related to the fatigue characteristics of a given construct. Furthermore, it is of interest to understand how the plate working length will influence construct stiffness and fatigue stability with osteoporotic bone stock as compared with a healthy bone condition.

The purpose of this study was to evaluate the fatigue performance and construct stiffness of locked plate constructs for different plate working lengths, using a cyclical physiologically relevant loading condition, in a human cadaveric distal metaphyseal femoral fracture model. As the first step, the study was performed with non-osteoporotic human cadaveric femora. Specifically, differences in construct stiffness at various cycle counts, fatigue endurance, screw loosening, and failure mode were evaluated for two different plate working lengths.

METHODS:

Seven (7) matched pairs of fresh-frozen non-osteoporotic (T-score ≥ -1.5 based on bone mineral density screening evaluation) human cadaveric femora were used for this study. An oblique distal metaphyseal defect that was 1 cm on the medial side and spanning 3 screws distances on the lateral side was created and bridged, with either 1 or 5 screw holes unfilled (i.e. “short” or “long” working lengths), using a distal femur locking plate system (Smith & Nephew, Memphis, TN) (Figure 1). The left and right femurs of each pair were randomly assigned to either a short or long working length group. Each plate was provisionally secured to the bone so that no gap existed between the plate and bone upon instrumentation. Screws were then inserted and tightened to approximately 4 N-m of torque. Distal fixation in all specimens was with five 5.7 mm bicortical cannulated locking screws. The remaining fixation was with six (6) or four (4) 4.5 mm locking self-tapping cortex screws for the short and long working lengths, respectively. After instrumentation, the femora were resected below the lesser trochanter 36 cm above the knee joint line and were potted in a pair of custom-made loading fixtures through which a physiological combined loading configuration per ISO 7266-4 (2002/E) was applied. All specimens were subjected to a staircase axial cyclical load (starting at 445 N with an increased load increment of 111 N every 25,000 cycles) at 1 Hz until failure. During the entire period of testing, fracture gap closure was monitored through a pair of contact sensing plates. Failure was defined as fracture gap closure or a loss of maintenance in load. Construct stiffness was evaluated initially and after each subsequent 12,500 cycle interval. After fatigue failure, screw removal torque was measured using a torque meter. Statistical analyses were conducted using paired Student’s t-tests.

RESULTS:

Failure Modes: Testing of all of the fourteen constructs stopped due to closure of fracture gap on the medial side. The modes of failure for short working length constructs were most commonly plate fracture (6 of 7) with only one construct failure due to failure of a screw. The modes of failure for long working length constructs were more mixed, indicating stress concentration was less focused on the plate. Plate fracture occurred in four constructs but the plate/screw/bone interface failed in the other three. The short working length constructs survived higher loads levels (1,001 N (1), 890 N (4), and 779 N (2)) when compared to the long working length constructs (890 N (1), 779 (4), and 668 N (2)). This corresponded to a significantly higher fatigue life for the short working length constructs (103,734 ± 17,623 cycles) compared to the long working length constructs (86,090 ± 12,792 cycles), (p=0.04).

DISCUSSION:

Results from this study show that the short and long working length constructs fail in different modes. The short working length constructs tend to fail by plate fracture whereas long working length constructs, in lieu of their more diverse stress concentration, have a less predictable mode of failure that is likely sensitive to other construct parameters such as bone quality, screw purchase, etc. The higher stiffness seen with the short working length constructs is intuitive. These short working length constructs had a faster rate of stiffness decline, but surprisingly, had an average higher average rate (2.8 times, p=0.009) than the long working length constructs (Figure 2 dotted line).

Screw Loosening: For the short working length constructs, the two screws nearest to the fracture gap in the proximal fragment loosened the most. For the long working length constructs, the two screws nearest to the fracture gap on the distal fragment loosened the most. The most proximal screw for both the short and long working length constructs loosened the least.

REFERENCES: