Enhancing Fatigue Performance of Bridge Plate Constructs

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INTRODUCTION
Empty screw holes over the zone of comminution in plate-screw constructs is recommended to create relative stability and encourage secondary bone healing via callus formation, the goal of bridging. However, stress is localized to that region of the plate. Empty screw holes represent a weak link in the construct, and with delayed healing can lead to permanent plate deformity or failure. It has been shown that placing locking screw heads (shaft of standard screw cut off) into open holes improves fatigue properties, but screw heads are prone to loosening. The purpose of this investigation was twofold: first to evaluate fatigue performance of locking plates instrumented with new locking hole inserts (LHIs), and to determine if increased insertion torque improves performance.

METHODS
New LHIs were designed specifically to reduce the likelihood of loosening. Their engagement with plate screw hole threads results in an increased friction over normal screw heads, while still allowing for ease of removal. The fatigue performance of both 3.5 mm and 4.5 mm 8-hole locking plates (Peri-Loc, Smith & Nephew) instrumented with new LHIs was evaluated using four-point bend per ASTM standards. All plates were positioned in a worst-case configuration during loading such that the far-bone side of the plate was in tension. For each size, plates instrumented with six LHIs were compared to plates with all holes open. Four LHIs were located within the loading span and two were outside the loading span (Figure 1). The 3.5 mm LHIs were inserted to either 1.70 N-m or to 3.96 N-m of torque. The 4.5 mm LHIs were inserted to either 1.70 N-m or to 3.96 N-m of torque. Upon failure (defined as plate fracture), the amount of LHI loosening was evaluated by measuring removal torque. Statistical analyses for means were performed on test results using an F-Test for variance and a Student’s t-Test assuming equal variance.

RESULTS

Effect of fillers and insertion torque: At the 1.70 N-m insertion torque, 3.5 mm plates with LHIs survived an average 114,300 cycles, which was 52% more cycles (p = 0.01) than plates without LHIs (average 75,487 cycles). Increasing insertion torque to 3.96 N-m led to a further increase in 3.5 mm plate fatigue life (p = 0.02) to an average 153,177 cycles. This represented a 106% increase compared to plates without LHIs (p << 0.05). The 4.5 mm plates with LHIs survived 48% more cycles (average 74,369 cycles) than plates without LHIs (average 50,214 cycles) (p = 0.001).

Loosening of inserts: At the 1.70 N-m insertion torque, all 3.5 mm LHIs inside the loading span had nearly completely loosened (removal torque < 0.2 N-m) upon failure. Increasing insertion torque to 3.96 N-m reduced loosening as 3.5 mm LHIs retained an average 63% of their insertion torque despite a higher cycle count at plate failure. The 4.5 mm LHIs retained an average 64% of their insertion torque at failure.

DISCUSSION
Locked plating technology has expanded the versatility for meta-diaphyseal fractures by providing angularly stable fixation of the distal segment. However, with the advances in fixation of the plate to bone, the failure mode clinically has largely shifted to plate fatigue. This is most evident in segmental defects of the distal femur and proximal tibia. These defects take a long time to heal and many need delayed grafting procedures. Holes that are within the defect region of the plate become stress risers and are the most common region for fatigue failure of the plate. In theory, inserting a LHI will make the region over the defect stronger since LHIs are mechanically fit into a threaded hole. The goal of these inserts is to increase the fatigue life of the implant in the face of a defect. The results of this study indicate substantial improvement in the cycles to failure for both 3.5 and 4.5 plates. Their use in regions that span bony defects, particularly in patients in whom delayed fracture healing may be present, may be advantageous.

Figure 1 – Locking Compression Plate with and without Locking Hole Inserts as tested (3.5mm plate shown with approximate location of loading rollers and spans indicated).

Figure 2 – Typical Fracture of the Locking Compression Plate with and without locking screw hole fillers (4.5mm plate shown here).