Mechanical Effects of Off-Axis Insertion of Locking Screws – Should we do it?
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Introduction
Orthopaedic bone screws have proven strength when placed orthogonal to the plate, but certain fracture lines and/or poor bone quality have led some to intentionally cross-thread bone screws in a non-orthogonal manner in order to capture offside bone fragments. It is thought that conventional non-locking screws, since they rely on friction between plate and bone for primary stability, can be placed in this manner with little loss in rigidity. However, the biomechanical consequences of this practice when locking screws are used have not been addressed. The purpose of this study was to evaluate the cantilevered bending strength of locking screws inserted at various angles in relation to the plate.

Methods
Twenty-five (25) 3.5 mm Locking Cortex Screws (Smith & Nephew, Inc.) were inserted into round holes through a straight plate via hand-powered insertion using a standard screwdriver while measuring insertion torque. Screws were inserted to 1.7 N-m at various angles in relation to the longitudinal axis of the plate (ie, cross-threaded) and parallel to the transverse axis of the plate (Figure 1).

Upon insertion, the achieved angle of insertion and its prominence protruding from the far-bone side of the plate was measured using optical luminescence (Figure 2). Each screw was then until failure in a cantilevered bending scenario that simulated near cortex fixation. Prototype screws were especially designed with thread modifications in the loading region to ensure uniform loading and no slippage during testing (Figure 1). This modification did not affect the strength of the screw.

Peak cantilevered bending strength was measured and the moment at failure was calculated. Failure was defined as screw deformation or screw head disengagement. Failure modes were noted. Linear regression analyses were implemented to assess biomechanical data trends with significance declared at \( p < 0.05 \) at 95% confidence.

Results
There was a positive correlation between increasing insertion angle and increasing prominence; a higher screw insertion angle yielded greater prominence (\( p < 0.05 \)). Prominence values ranged from negligible up to 3 mm. As screw insertion angle increased, the bending moment at failure decreased (\( R^2 = 0.67 \), Figure 3). Screws inserted to 3-degrees or below primarily failed via screw deformation at the minor diameter below the head (95% of the time), whereas screws inserted to greater than 3-degrees primarily failed via locking mechanism disengagement (83% of the time).

Figure 3: Cantilevered bending strength of screws inserted off-axis.

Discussion
Cross-threading locking screws results in decreased mechanical strength when evaluated in cantilevered bending. As angulation increases upon insertion of a single screw into the plate, the potential for having less screw head threads engaged into the plate becomes greater, which leads to decreased fixation strength, greater prominence, and a change in failure mode.

It could be extrapolated that clinical construct failure mode may also shift to screw head toggle in the plate hole – since the screws inserted to greater than 3-degrees of off-axis insertion in this study resulted in locking mechanism disengagement. Future work would need to confirm this theory. Greater screw head prominence may lead to post-operative irritation in some anatomical areas where little soft tissue coverage exists. These findings indicate that the practice of cross-threading locking screws may not be biomechanically advantageous.

Significance
The cross-threading of bone screws to capture offside bony fragments is a common practice that has not been biomechanically assessed. These findings indicate that cross-threading may not be biomechanically advantageous and change screw mode of failure.