Effect of Plates in Proximity to Empty External Fixation Pin Sites on Long Bone Torsional Strength

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Introduction: A cortical defect, or stress riser, in a long bone concentrates loads at that point, and, ultimately, weakens the bone. A defect that constitutes 20% of the bone diameter is associated with a 34% decrease in bone strength (Edgerton). High energy long bone fractures often require provisional external fixation prior to definitive internal plate and screw stabilization. Empty bicortical external fixation pin sites typically lie outside of the confines of the plate, and may have an effect on plated long bone strength. The purpose of this study was to determine the effect of an empty bicortical external fixation pin site in proximity to a compression plate on torsional long bone strength.

Methods: Thirty medium, left, fourth-generation composite tibias were used in this study. The composite tibias were divided into six groups of five bones each. In each group an empty bicortical external fixation pin site was created by the anterior to posterior placement and removal of a 5.0 mm Shanz pin at varying longitudinal levels in reference to a the distal aspect of the plate. Six-hole compression plates (4.5 mm x 121 mm) were placed in a standard mid-diaphyseal position on the medial aspect of the mid-diaphysis of the tibia. The control group, Group I, consisted of an intact bone without a plate, and an empty bicortical pin site placed 3.0 cm distal to the standard plate position. All subsequent groups consisted of a standard positioned plate with the defect located 3.0 cm distal to the plate in Group II, 2.0 cm distal in Group III, 1.0 cm distal in Group IV, between the two most distal screw holes of the plate in Group V, and between the 4th and 5th distal holes in Group VI. The composites were rigidly clamped into an 858 Mini-Bionix materials testing system equipped with a 100 Nm torsional load cell for torsional failure testing. The constructs were preconditioned by rotating the superior end internally up to 15 Nm at a rate of 0.25 Nm/sec for two complete cycles. The constructs were axially preloaded 20 N, and then rotated internally at 0.25 degrees/sec until failure. The mode of failure was noted and failure load, displacement, and stiffness were determined and analyzed for differences with one-way analysis of variance with Tukey adjustment for multiple comparisons and alpha set at 0.05.

Results: The mode of failure for all specimens that failed was a spiral fracture that bisected the axis of the defect. Group II and Group III specimens (empty pin sites 3 cm and 2 cm distal to the plate, respectively) failed at lower loads than the Group I controls, although these differences were not significant; the altered torsional mechanics of these long bones could be attributed only to the presence of the plate. Groups V and VI specimens (empty pin sites within the plate) resulted in significantly higher loads to failure versus Group II (p < 0.024) and Group III (p < 0.007). Group III specimens also displayed significantly less displacement than Groups V and VI (p < 0.008), and Group VI specimens were significantly stiffer than Group I and Group II (p < 0.036).

Discussion: Decreased long bone torsional strength secondary to a bicortical pin defect has been established, but the effect of a plate in proximity to an empty bicortical pin site has yet to be reported. This study suggests that an empty pin site outside the confines of a plate lowers the long bone torsional
strength as the defect moves more distal to the plate, but increases for empty pin sites closer and/or within the confines of the plate. In this composite study, the greatest risk for fracture due to an empty pin site stress riser occurred at 2 cm distal to the plate. Long bone plates in proximity to an empty external fixation pin site should ideally be placed inside or within 1 cm of the plate.

**Significance:** This biomechanical study sought to determine the effect of an empty external fixation pin site in proximity to a plate on the torsional strength of long bones. Long bone plates in proximity to an empty external fixation pin site should ideally be placed inside or within 1 cm of the plate.

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