Effect of Plate-Bone Contact on Stresses in Periarticular Locking Plates

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Introduction: Since compression between a locking plate and underlying bone is not required to achieve stability, locking plates can be designed to limit contact with underlying bone to further preserve bony vascularity[1,2]. The hypothesis is that a locking plate will experience the most stress under a given load when its contact with the underlying bone is minimal. The stresses in the locking plate will be reduced if the contact between the plate and bone increases when the construct is subjected to prehealing loads of sufficient magnitude. The purpose of this study was to examine the effects of contact between a locking plate and bone, using finite element analysis (FEA) models of a biomechanical test set-up.

Methods: Two periarticular locking plates (Zimmer, Inc., Warsaw, IN) were used in this study, namely, a distal radial dorsal T-plate and a proximal lateral humeral plate. The plates incorporate locking screw holes in the plate head and alternating locking (circular) and compression screw (oval) holes in the shaft. Locking screws were used to secure the dorsal T-plate (holes 1 through 6) and humeral plate (holes 1 through 5) to their respective bone blocks.

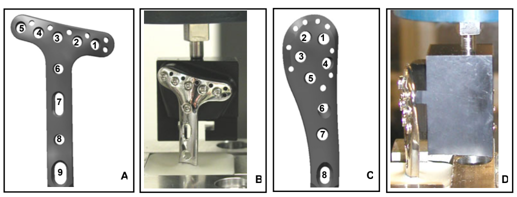

Figure 1: *Dorsal T-plate -[A] Hole numbers [B] Fatigue test set up; Humeral plate -[C] Hole numbers [D] Fatigue test set up*

The dorsal T-plate shaft was cut between holes 8 and 9. The resulting face at the proximal end was constrained to resemble the use of a locking screw secured in hole 9. Similarly, the humeral plate shaft was cut between holes 7 and 8 and the resulting face at the distal end was constrained to resemble the use of a locking screw secured in hole 8 (Fig. 1). FEA models T0 and T1 were created for the dorsal T-plate and models H0 and H1 were created for the humeral plate. It was assumed that for models T0 and H0, the plate will not come in contact with the bone block. For models T1 and H1, frictionless contact was defined between the plate and the bone block to allow the plate to come in contact with the bone block when loaded. A force of 89 N and 338 N was applied on the radial and humeral bone blocks respectively, at clinically relevant worst-case locations. For simplification, the threads were not modeled for the plate locking holes and locking screws. The locking plates and screws were modeled with linear elastic properties of forged 22Cr-13Ni-5Mn Stainless Steel [E=206,843 MPa, ν=0.27]. Bone blocks were modeled with linear elastic properties of acetal copolymer [E=3,103 MPa, ν=0.35]. Nonlinear static FEA with large deflection option were performed using ANSYS version 9.0 (Ansys, Inc., Canonsburg, PA) software. Fatigue tests were performed to demonstrate that the plate designs are sufficiently strong to satisfy design requirements.

Results: The discussion is focused on the comparison of stress results between the models rather than on absolute stress values, since the purpose of this study is to examine the effects of contact between the plate and block. The contact between the plate and bone block in the metaphyseal area reduced the vertical displacements at the load point in models T1 and H1 by 20% and 17% respectively, when compared to models T0 and H0. Consequently, significant reductions in locking plate stresses were obtained in the metaphyseal area. No significant change was observed in the stress values predicted in the shaft area of the locking plates.

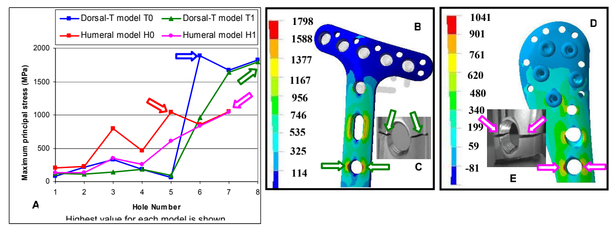

Figure 2: *[A] Maximum principal stress(MPa) Summary; Dorsal T-plate model T1- [B] FEA Stress plot [C] Fracture at hole 8; Humeral plate model H1– [D] FEA stress plot [E] Fracture at hole 7*

The highest stress location predicted in model T1 (hole 8) and H1 (hole 7), matched the fracture location obtained in fatigue testing. (Fig. 2) Dorsal-T Plate: The highest maximum principal stress value in model T0 at hole 6 was significantly reduced (by 49%) in model T1 due to its contact with the bone block. Humeral Plate: The highest maximum principal stress value in model H0 at hole 5 was significantly reduced (by 45%) in model H1 due to its contact with the bone block.

Conclusions: Contact between the locking plate and the matching bone can potentially influence the highest stress location in the locking plate. FEA predicted the highest stress values in the metaphyseal area of the plate (hole 6 for model T0; hole 5 for model H0) when the plate did not come in contact with the bone block. In fatigue testing, no fractures were obtained in the metaphyseal area. When the plate was allowed to come in contact with the bone block, stresses in the metaphyseal area of the locking plate were significantly reduced. The highest stress values were recorded only in the plate shaft area (hole 8 for model T1; hole 7 for model H1), matching the fractures obtained in fatigue testing. The precontoured shape of the locking plate, its proximity to the matching bone and the magnitude of prehealing loads are some of the factors that may affect the resulting plate-bone contact and consequently locking plate stresses. FEA models and assumptions should be validated by physical testing.

References: [1] Egol et al, J Orthop Trauma 2004;18:488-493 [2] Haidukewych et al, J Am Acad Orthop Surg 2004;12:205-212.