Should Inter-prosthetic Screws Be Placed When Prophylactically Plating a Femur?

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INTRODUCTION: Apposing intramedullary femoral implants create a stress riser, which can increase the risk of an inter-prosthetic femur fracture. To mitigate this risk of fracture, surgeons may choose to prophylactically plate the lateral aspect of the femur. However, the optimal prophylactic plating construct, especially where to place screws, is not well understood. Accordingly, our objective was to determine how adding a prophylactic lateral plate with and without screws between femoral implants altered fracture risk based on failure load and energy-to-failure of the construct.

METHODS:

This biomechanical study included 20 osteoporotic Sawbones femurs (PN 3503). Under fluoroscopic guidance, we placed intramedullary steel dowels antegrade and retrograde to create a 2-cm (n=8) or 10-cm (n=9) inter-prosthetic distance (IPD) at the mid-diaphysis of the femurs. We prophylactically plated 11 of these femurs with broad curved 18-hole 4.5 mm plates. One subgroup of the prophylactically plated femurs had one (IP-1) intra-prosthetic screw placed, and the other subgroup did not have any intra-prosthetic screws (IP-0). Femurs without intramedullary steel dowels and femurs with intramedullary steel dowels, without prophylactic plates were used as controls.

To assess fracture risk, we performed lateral 4-point-bending mechanical testing. Prior to placing each construct in the Mechanical Testing Systems (MTS) loading rig, we applied a speckle pattern to the surface of the femur. We then loaded each construct to failure and recorded applied force and crosshead displacement measured by the MTS. Synchronously with the recorded MTS data, we recorded videos of the speckle pattern using a pair of cameras. Using the MTS data, we computed both the failure force as the maximum load during the trial, and the energy-to-failure as the area under the lateral force-displacement curve (Figure 1). We performed a one-factor analysis of variance with a post-hoc Tukey test to compare the failure force and energy-to-failure from each of the 7 different construct conditions (i.e., No Implant, 2-cm, 2-cm IP-0, 2-cm IP-1, 10-cm, 10-cm IP-0, 10-cm IP-1). To further investigate the mechanisms of failure, we also post-processed the recorded videos using digital image correlation (DIC) to determine the surface strain distributions throughout testing.

RESULTS:

The energy-to-failure was greatest in the constructs with a 10-cm IPD, and 2-cm and 10-cm IPD with a prophylactic plate without intra-prosthetics screws (24.4±1.7 J, 20.5±0.8 J, and 23.6±4.1 J, respectively) (Figure 2). The energy-to-failure was lowest in the femurs with a 10-cm IPD and a 2-cm IPD with an intra-prosthetic screw (5.9±0.9 J and 7.8±2.6 J, respectively).

Similarly, the failure force was greatest ($p<0.002$) for the constructs with a 2-cm and 10-cm IPD with a prophylactic plate and no intra-prosthetics screws (4936±157 N and 4437±234 N, respectively) (Figure 3). The failure forces for the other constructs were similar to that of the femur without any intramedullary steel dowels (No implant = 3050±243 N, 2-cm IPD = 2690±368 N, 10-cm IPD = 3273±102 N, 2-cm IPD P-1 = 3080±384 N, 10-cm IPD P-1 = 2545±251 N).

DIC analysis of the strain distributions demonstrated concentration at the screw/s between the implants for each condition (Figure 4).

DISCUSSION AND CONCLUSION: Our key finding is that lateral prophylactic plating of the femur with apposing intramedullary implants increases the energy-to-failure and the failure force under lateral four-point bending (Figures 2 and 3). The strongest construct for femurs with either a 2-cm or a 10-cm IPD was a bridging construct without a screw between the intramedullary implants. Based on our biomechanical test results, we recommend adding a lateral prophylactic plate to femurs when the IPD between apposing intramedullary implants is less than 10 cm and avoid placing screws within the intra-prosthetic gap because these add additional stress risers to the construct (Figure 4).