Dynamic Hip Screw Hole Placement vs Bone Strain

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Introduction: Stability after bone healing and removal of hip screws are of concern due to clinical failures in the femur. Removal of compression hip screws occurs when there are clear needs such as Necrosis, infection, implant failure or severe lateral pain. Femoral neck failures can be greater than 9% depending on anatomy factors [1]. Another study shows that 7 spontaneous neck fractures occurred from a total of 20 patients after implant removal [2]. Biomechanical testing shows that intact femurs have greater fracture strength than femurs with removed trabecular bone [3] and fracture strength is correlated to bone mineral density [4]. Studies based on Finite Element (FE) models have shown that bone failure can be predicted based on bone strain while correlating bone constitutive models from bone density [5]. The objective of this study was to compare the bone strain distribution of an intact femur versus the same femur with voids due to implant removals. The implant removals were based on a standard dynamic hip screw placement, a dynamic hip screw placement with more proximal screw holes, and a dynamic hip screw with a single more proximal screw hole.

Methods: A CT scan femur (Donor data: 72 years, 64 inches, 231 lbs, female, Caucasian) was segmented and used to build an assembly of the femur with a DePuy Synthes Dynamic Hip Screw (LCP DHS, 130°, with Ø5mm locking screws, and appropriate blade - not available for sale in the US) using Creo Parametric 2.0 (PTC, Needham, MA). Voids were defined in the bone representing the removal of the DHS implant. Four scenarios were considered; intact, standard DHS placement, DHS placement with more proximal screw holes, and DHS with a single more proximal screw hole as shown in Figure 1. The femur was cut at the mid shaft location and the analysis focused on the proximal end. ANSYS Workbench (ANSYS, Canonsburg, PA) was used to create an FE model. The constitutive model of the femoral bone was defined for each element in the mesh by spatially mapping each element to the CT scan in Mimics 16.0 (Materialise, Belgium) using the following relationships: r=-0.1 + 0.0004(Gray scale Value), E=6850r^{1.49}, n=0.3 [5][6].

The loads were defined for standard gait loads and an oblique fall backwards. The gait loads were defined from Bergmann et al. The mid shaft cut surface was fully constrained while a load was applied to the center of the femoral head based on an anatomically defined coordinate system using constraint equations. The oblique fall backwards was defined from Keyak. Again, the mid shaft cut surface was fully constrained and the greater trochanter was constrained from displacement in the direction of the applied load. A load was applied to the center of the femoral head at 60° to the shaft and 70° to the major axis of the femoral neck using constraint equations. Figure 2 shows the geometry definition, material mapping, and boundary conditions. A strain of 0.0061 was used as a failure criterion for the femur [9]. The volume of bone greater than the failure strain was measured for each geometry configuration and for each loading case.

Results: The volume of strain was determined for the entire proximal bone and also for a more proximal bone volume to focus on the local behavior near the implant voids. In all cases for gait, the volume greater than 0.0061 strain were zero or very close to zero. The greatest detectable volume was
0.04\text{mm}^3. However, there was significant volume of bone greater than 0.0061 strain based on the oblique fall backwards load. Figure 3 summarizes these results. The trend shows that as the holes become more proximal the volume of strain greater than 0.0061 becomes smaller and gets closer to the intact bone.

**Discussion:** Supporting screws holes for a Dynamic Hip Screw plate tend to create lower strain in the femur, after implant removal, as the hole becomes more proximal. There are many other factors to consider for the design of a Dynamic Hip Screw, such as stability during healing and stress on the implant.

**Significance:** Supporting screws holes for a Dynamic Hip Screw plate tend to create lower strain in the femur, after implant removal, as the hole becomes more proximal.
Figure 3: Strain Volumes vs. Configurations