Effect of Daily Living Activities on the Stability on Pertrochanteric Fracture Fixation Devices

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Statement of Purpose: Osteoporosis is the leading cause for proximal femoral hip fractures in the elderly. The two major implants used for rigid fixation in these cases are sliding hip screws and intramedullary (IM) nails. The latter was introduced because of limitations of the side-plate construct. It is currently up for debate as to which implant is more effective for osseous stability for repairing complex fractures. In this study, both fixation methods were modeled in an effort to determine the optimal implant for the common pertrochanteric simple fracture through the greater trochanter (Orthopaedic Trauma Association - 31-A1.2).

Finite element analysis (FEA) models comparing both implant systems developed by others are limited due to the lack of muscle forces incurred during daily living activities and critical in determining the stability of the bone-implant system [1]. Inputs in this study include muscle forces in addition to other loading parameters essential to determine the most stable implant system for both normal and osteoporotic bone.

Methods: The Trochanteric Femoral Nail® (TFN®) and Dynamic Hip System® (DHS®) (Synthes, Paoli, PA) were used as target implants. A lag blade, instead of a screw, was used in the TFN system as it has been shown to provide greater rotational stability, increase bone compaction, and increase load-bearing capacity [2]. A 50th percentile European female subjected to four daily living activities (gait/walking, lunging, cycling, and egress) was modeled in the AnyBody Modeling System™, a software simulating the mechanics of the live human body working in concert with its environment. were broken down into 100 intervals of equal duration. Motion and force data generated in AnyBody including 1) spatial positions, 2) muscle forces and joint reaction forces and moments, and 3) velocities and accelerations of the hip, were exported in a FEA package (ABAQUS). Osteoporotic bone was simulated by decreasing bone density by 2.5 standard deviations and decreasing the Poisson's ratio from 0.3 to 0.25. Both implants were modeled as anisotropic linear-elastic/ideal plastic Ti-6Al-7Nb. The TFN® system was modeled as being fixated statically distally, and the DHS® was modeled as having its four screw holes filled. Perfect fastening and alignment of the blade and screws were assumed. Contact surfaces and "penalty-type" contact algorithms were employed to prevent bone/implant interpenetration. Contact pressure was measured by a set of contact springs. For each of the 100 intervals and for each activity case, a quasi-static structural finite-element analysis of the fractured femur/implant assembly was carried out using ABAQUS/Standard.

Results: To analyze the data, appropriate fracture fixation and bone healing promotion criteria had to be developed. Fracture fixation (f_{ff}) was assumed to be a measure of relative translation and rotation of the two bone fragments. As translation was insignificant, only degree of rotation, as computed using the Rodrigues formula subtracted from and then divided by its maximum acceptable value, was considered. Bone healing (f_{bh}) was quantified with the fraction of the fracture surfaces over which the two surfaces are in contact. A single objective function was defined as a weighted average of the two criteria ($f_{comp}=w_{ff}f_{ff}+w_{bh}f_{bh}$). An additional function was used to combine the weighted averages for each daily living activity. An active patient was assumed to engage in 5% lunging and cycling each, and the ratio between walking and egress activity was set to be .95/.05 (having a higher slope of two with other otherwise identical parameters in the graphs in Figure 1) and .85/.15 (having a lower slope in the graphs in Figure 1).

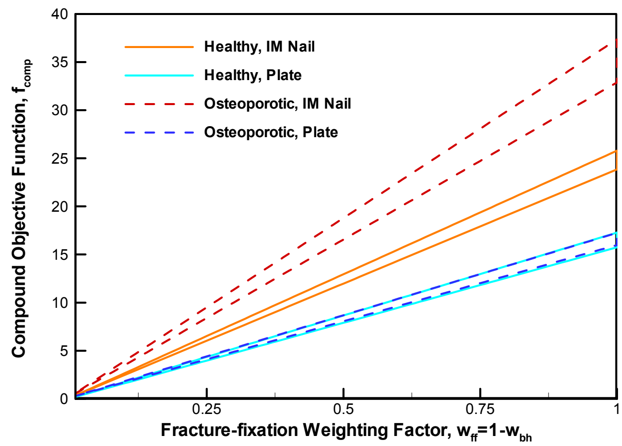

Figure 1. Efficacy of implant as a function of fracture-fixation weighing factor in (a) healthy and (b) osteoporotic bone.

Conclusions: The results from this study show that the TFN® outperformed the DHS® in both osteoporotic and normal bone. In these cases, and using assumptions described above, the finding that the performance of both implants is slightly improved when w_{ff}=0.0 compared to when w_{ff}=1.0 is consistent with the fact that more strenuous daily activities like lunging and cycling will generally increase the contact area of the fracture surface while, at the same time may lead to undesirable translational and rotational deflections. The main reason for the superior performance of the TFN® in both the healthy and the osteoporotic femur cases appears to be related to the fact that the nail itself provides an internal fracture-fixation role in the case of the pertrochanteric fracture and that there is an associated lower blade moment-arm. In our future work, an attempt will be made to include these additional factors which currently affect the surgeon's preference for a certain type of device.

References:

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