BIOMECHANICAL SIMULATION OF A GREATER TROCHANTER FIXATION SYSTEM

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INTRODUCTION

Reattachment of the greater trochanter fragment is frequently treated with cable grip type systems. Fracture of the greater trochanter is a relatively common complication (4.3%) of hip replacement surgery (Claus et al. 2002). In addition, to improve exposure during hip revision surgeries an osteotomy of the greater trochanter is often performed. During reattachment, one concern is the effect the cables tightness has on the integrity of the system. The objective is to create a femur implant model and vary the cable tension, common muscle forces and the placement of the femoral neck cut in order to analyse trochanter fragment displacement in terms of both shear and gap.

METHODS AND PROCEDURES

A finite element model (FEM) of a femur with simulated greater trochanter osteotomy (30º) was combined with the femoral component of a hip prosthesis and a greater trochanter reattachment system with 4 cables (Cable-Ready®, Zimmer). The surface geometry for the femur was developed by Papini (2003) and was obtained from the Bel repository. Cable geometry is specific to the femur as the shape was projected onto the bone surface. The femur, implants and cables were meshed with total of 64971 tetrahedral elements (Figure 1). Femur geometry and mechanical properties represent the Sawbones third-generation composite femur model, with cancelous (137 MPa) and cortical bone (7600 MPa) (Pacific Research laboratories Inc. Vashon, WA). In total there are 6262 contact elements. For example, the cortical and cancelous bone was assembled with *fastened connections* to insure that they behave as a single body. The contact between the trochanter fragment and the femur is a *contact connection* which allows the fragment to slide and separate. No friction was assumed at the fragment interface in order to represent a worst case scenario.

Figure 1. Finite element model of a greater trochanter fixation system.

A total of 18 simulations were modeled in a full factorial design using three independent variables; cable tightening, muscle forces and femoral neck cut (Table 1). Cable tightening was 355.9 N (80 lbf) based on the manufacturer's recommendation; in addition 177.9 N (40 lbf) and 533.8 N (120 lbf) were tested. Muscle forces were held at zero or applied to simulate walking and stair climbing as described by Heller et al. 2005. Finally, the placement of the femoral neck cut was simulated in two positions: 10 mm and 15 mm above the lesser trochanter. The relative gap and shear displacement magnitudes were determined at three points around the perimeter of the fracture surface: two at the top corners and one at the bottom.

A local coordinate system was defined with the x,y plane (shear) on the fracture surface of the femur and z perpendicular (gap). Interfragmentary displacements were resolved at each point into gap and shear components and the maximum was determined. During statistical analyses, differences were considered significant if they were greater then 0.1mm and $p \leq 0.05$.

Cable tension (N)	Muscle forces	Femoral neck cut (mm)
177.9	0	10
355.9	Walking	
533.8	Stair Climbing	15

Table 1. Independent variables

RESULTS

The placement of the femoral neck cut closer to the lesser trochanter (10mm) reduced the osteotomy contact surface area by over 20% and significantly increased the fragment displacement. Maximum gap (0.38 mm) and maximum total displacement (0.41 mm) was observed during stair climbing, while the cables were tightened to 177.9 N and with the femoral neck cut at 10 mm. Excessive cable tightening provided no reduction in fragment displacement. In fact, maximum shear (0.20 mm) occurred while the cables were tightened 533.8 N and the 10 mm femoral neck cut. The gap displacement at the upper points was zero. Actually, these points were subject to shear but primarily served as a pivot and the maximum gap (0.38 mm) was present at the bottom of the fracture (Figure 2).

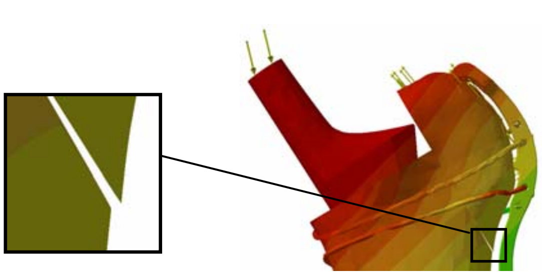

Figure 2. Location of the maximum gap

DISCUSSION

The results obtained with the proposed FEM are generally in accordance with the literature. In particular, Plausanis et al. 2003 observed trochanter displacement generally less then 0.5 mm. One limitation was that friction was not simulated in our model but was neglected providing a worst case scenario. Because pivoting was observed at the proximal line of the osteotomy surface, friction is potentially inconsequential. Complete validation of this FEM against an experimental model is currently underway. However, it allows us to highlight key findings regarding the relative importance of cable tightening, muscles forces and contact area.

SUMMARY

Lowering the femoral neck cut reduced contact surface area and significantly increased fragment displacement. Preservation of the contact surface area is recommended. Excessive cable tightening provided no reduction in fragment movement. Caution must be used to not over tighten the cables. This model can be used to test and compare the performance of new implant designs.

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