Injury, Int. J. Care Injured (2006) 37, 778—785

INJURY
INTERNATIONAL JOURNAL OF THE CARE OF THE INJURED

www.elsevier.com/locate/injury

# Finite element study of the proximal femur with retained trochanteric gamma nail and after removal of nail

B. Mahaisavariya[a,*], K. Sitthiseripratip[b], J. Suwanprateeb[b]

[a] *Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand*
[b] *National Metal and Materials Technology Centre, Pathumthani, Thailand*

Accepted 12 January 2006

**KEYWORDS**
Fracture;
Trochanteric fracture;
Intramedullary nail;
Gamma nail;
Finite element study

**Summary** This study aims to evaluate the stress and strain distributions in the healed proximal femur after fixation with a trochanteric gamma nail (TGN) and after TGN removal, using the finite element method. The stress distributions in the proximal femur with retained TGN and after TGN removal were very similar. The strain and the strain energy density in the femoral neck region with retained TGN were much higher than in the lag screw hole at the subtrochanter and the distal locking screw hole at the proximal femur, and even higher after TGN removal. Stair climbing resulted in higher strain and higher strain energy density at the femoral neck than normal walking. The conclusion can be drawn that removal of the TGN may result in high risk of femoral neck fracture.


## Introduction

Proximal femoral nailing using the trochanteric gamma nail (TGN) (Stryker—Howmedica—Osteonics) is now widely accepted as one of the treatment methods for unstable trochanteric fractures.[17] The method has been found effective and less invasive than using the compression hip screw or angle-blade plate osteosynthesis.[13] Our previous study, using the finite element method of trochanteric fracture stabilisation with a TGN and the one-legged stance, showed that even when the fracture had healed high stress levels still occurred at the implant structure. This may lead to the fatigue failure if the implant is retained for a long period.[16] However, there have been two recent reports of femoral neck fracture after removal of the gamma nail.[7] The authors considered that the fracture resulted from bone weakening where there was a relatively large bony defect at the femoral neck after implant removal. Although removal of the TGN is not routine, it may be necessary when there are clinical symptoms of mechanical irritation by the TGN. In such cases, after implant removal, the stress—strain distribution may be altered and may result in high susceptibility to

* Corresponding author. Tel.: +662 4197968; fax: +662 4128172.
*E-mail address:* sibmh@mahidol.ac.th (B. Mahaisavariya).

0020-1383/$ — see front matter 
doi:10.1016/j.injury.2006.01.019

fracture in the area of bony defect resulting from implant removal. To our knowledge, there are no studies of alteration of stress distribution, and we therefore conducted this study using a finite element method to evaluate the stress and strain distributions in the healed proximal femur with retained TGN and after TGN removal.

## Materials and methods

All finite element models presented here were constructed using the digital CAD technique based on CT data, and all analyses were performed using MSC Patran/Mentat/Marc finite element software packages.

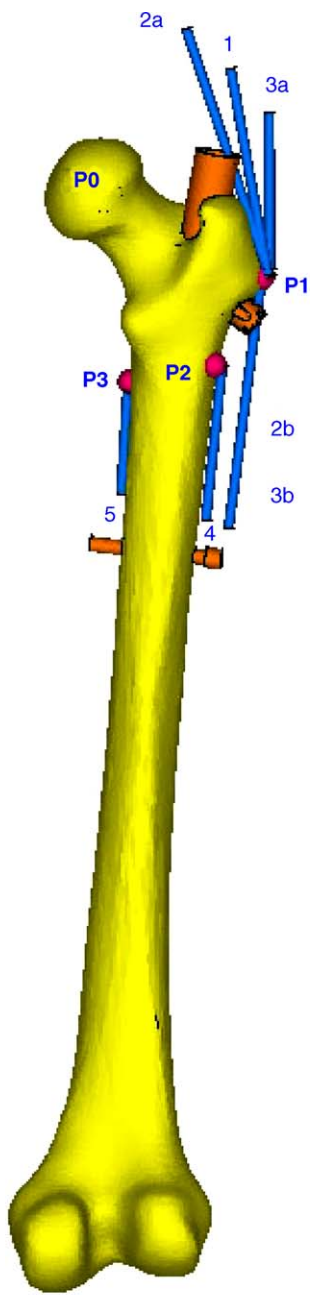


**Figure 1** Loading condition for the pre-clinical testing.[4]

### The finite element model

A three-dimensional CAD model of the intact femur was created from the average geometry derived from CT of 108 Thai cadaveric femora[11] using a Philips spiral CT scanner (Tomoscan AV). In the proximal and distal regions of the femur, CT scan acquisition was performed with 3-mm slice thickness, and reconstruction with 1-mm interpolated slice thickness. For the femoral shaft, CT scan acquisition was performed with 10-mm slice thickness, and reconstruction with 5-mm interpolated slice thickness.[11] The TGN employed in the model had a proximal diameter of 17 mm, distal diameter of 11 mm, length of 180 mm, 130° neck shaft angle and 4° valgus angle, with only one transverse distal locking screw. The TGN was virtually inserted into the intramedullary canal of the intact femur. The lag screw was inserted through the femoral head centre and away from the outer boundary of femoral head by 10 mm, according to the surgical technique for TGN fixation.

Four-noded tetrahedral elements based on STL automatic mesh generation technique (Magic RP, Materialise N.V., Belgium) were used to build up the mesh of the intact femur and the TGN. Different regions were introduced into the model (Fig. 1), enabling the definition of different material properties (Table 1) and contact conditions in the fracture plane. The femur model had a total of 17,059 nodes and 102,052 elements, whereas the TGN model had a total of 15,441 nodes and 104,668 elements.

### Material properties

Linear elastic isotropic material properties were assigned to all materials involved in the model.

**Table 1** Properties applied for the FE model[20]

| Region modeled | Young's modulus (MPa) | Poisson's ratio |
|---|---|---|
| Cortical bone | | |
| Femoral cortex | 17000 | 0.28 |
| Femoral neck cortex | 2000 | 0.3 |
| Cancellous bone | | |
| Femoral head | 600 | 0.3 |
| Femoral neck | 1000 | 0.3 |
| Femur | 600 | 0.3 |
| Implant | | |
| Trochanteric gamma nail | 200000 | 0.3 |

MPa: equivalent von Mises stress.