BME10
The Second TSME International Conference on Mechanical Engineering
19-21 October, 2011, Krabi

Biomechanical Study of Proximal Femoral Fractures with Jensen's Classification under Walking Condition

Panya Aroonjarattham[*1], Nawapol Saktaveekulkit[1], Kriskrai Sitthiseripratip[2], Banchong Mahaisavariya[3], Kitti Aroonjarattham[4] and Woottinan Morsub[1]

[1] Department of Mechanical Engineering, Faculty of Engineering, Mahidol University, Nakhonpathom, Thailand 73170
[2] National Metal and Materials Technology Center, Pathumthani, Thailand 12120
[3] Department of Orthopaedic Surgery, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand 10700
[4] Department of Orthopaedic, Faculty of Medicine, Burapha University, Chonburi, Thailand 20131
* Corresponding Author: Tel: 0 2889 2138 ext 6401-3, Fax: 0 2889 2138 ext 6429
E-mail: egpaj@mahidol.ac.th

Abstract

The implant failure is the main cause of unsuccessful bone healing process which, has been commonly found in the patients who had applied weight bearing on their fractured bone before the healing process completed. The objective of this study was to determine the stress distribution on the Trochanteric Gamma Nail (TGN), when inserted in the femoral bone fractures according to the Jensen's Classification under walking condition. The result could be divided into 2 groups; stable (Jensen type 1 and 2) and unstable (Jensen type 3, 4 and 5). It showed the maximum von Mises stress at 294 and 298 MPa in Jensen type 1 and 2 and at 1,910, 1,050 and 3,000 MPa in Jensen type 3, 4 and 5 respectively. The proximal femoral fracture in unstable group should not receive the full load for a good clinical result.
Keywords: Jensen's Classification, Biomechanical, Proximal femoral fracture.

1. Introduction

In the stable bone fracture cases, the implants have provided secure fixation and impaction with a relatively low complication rate. Over several years, there has been an interest in treating these fractures with intramedullary (IM) fixation device because of their mechanical advantages and considerably less soft tissue dissection [1]. The short gamma nail has been developed to combine the advantages of the sliding hip screw with IM nailing [2]. The gamma nail allows for controlled fracture impaction with the load sharing characteristic of an IM device [4]. The computational base on finite element analysis, has determined the stress distribution on the fixation devices [5-9].

In this study, a three-dimensional finite element model of femoral bone with proximal part fractures has created according to Jensen's classification in order to evaluate the stress distribution on Trochanteric Gamma Nail (TGN) and strain on the fracture gap regions.

2. Materials and Methods

The Jensen's classification classifies the fractures into five types in relation to the comminution of the calcar femorale or greater trochanter [10] shown in fig 1.

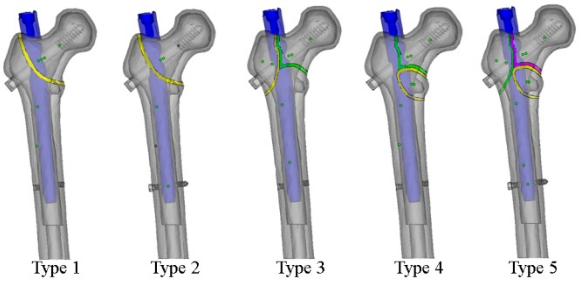

Fig. 1 The type of Jensen's classification fractures with TGN.

Linear elastic and isotropic material properties were assigned to all materials involved in the model. Five finite element models were developed under these exactly identical factors: geometry and position; bone material properties; nail geometry; nail location; fracture gap positions; loading and boundary conditions were identical while the femur was received the load under walking condition.

The Computer Aided Design (CAD) model of a three-dimensional femur [9] and all implants were created from the CT scan. After the bone and implants surface geometries were defined, all finite element models were constructed by MSC PATRAN 2005. Then, an analysis was performed by MSC MARC/MENTAT 2005 finite element software packages.

Four-node tetrahedral elements were used to build up the mesh of the bone and TGN with lag and distal locking shown in Fig 2. The femur–implant model had a total of 42,373 nodes and 164,739 elements. The implant model was shown in fig 2.

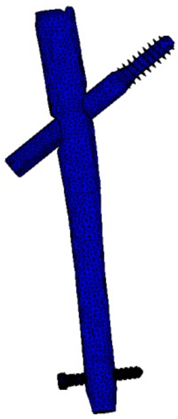

Fig. 2 Finite element model of TGN with lag and distal locking.

The elastic modulus and Poisson's ratio of the implant material (Titanium alloy), cortical bone, cancellous bone, and fracture gap were shown in table 1.

Table. 1 Material property applied for the finite element analysis model [11].

Model	Modulus (MPa)	Poisson's Ratio
Cortical Bone	14,000	0.3
Cancellous Bone	600	0.2
Connective Tissue	3	0.4
Titanium alloy	110,000	0.3

The femoral model was fully fixed (zero displacement) at the distal end. A walking load configuration was used in this study. The load condition was consisted of a joint reaction force which applied to the femoral head, while, the six muscle forces applied to the proximal part [12].

3. Results

The maximum von Mises stress on the TGN, lag screw and distal locking were shown in table 2, and 3 respectively, while, the maximum strain on the fracture gaps was shown in table 4.

Table. 2 The maximum von Mises stress on the TGN.

Type of Jensen's classification	Von Mises stress (MPa)	
	Lag screw hole	Distal screw hole
Fracture Type 1	65	294
Fracture Type 2	63	298
Fracture Type 3	1,910	412
Fracture Type 4	1,050	432
Fracture Type 5	3,000	343

Table. 3 The maximum von Mises stress on lag screw and distal locking.

Type of Jensen's classification	Von Mises stress (MPa)	
	Lag screw	Distal locking
Fracture Type 1	457	1,525
Fracture Type 2	451	1,533
Fracture Type 3	275	1,022
Fracture Type 4	325	1,172
Fracture Type 5	331	3,400

Table. 4 The maximum strain on the fracture gap.

Type of Jensen's classification	Strain (microstrain)
Fracture Type 1	400,819
Fracture Type 2	395,636
Fracture Type 3	300,487
Fracture Type 4	306,123
Fracture Type 5	294,973

Walking is a daily activity for human being. The group of unstable fractures (type 3-5) had higher maximum von Mises stress on the TGN than the group of stable fractures (type 1-2). The maximum stress occurred in Jensen type 5 because the bone had 3 fractures gap which separated the proximal part into 4. Therefore, type-5 TGN received more load than the other types.

4. Discussion

When the body weight and muscular force pressed upon the proximal bone, where the proximal-part fracture occured, the load from the femur was shared on TGN. The impact on the nail and the bone will be discussed respectively.

4.1 The trochanteric gamma nail

The stress distributed on TGN depended on the patterns and positions of fractures. The type-5 fracture had more fracture gap, which affected the stabilization of the bone. The load shared from the bone to TGN generated the highest maximum stress Von Mises on the lag screw hole. After the 4^{th} week of healing process, the maximum von Mises stress on lag screw hole decreased from 3,000 to 1,100 MPa as shown in fig 3.

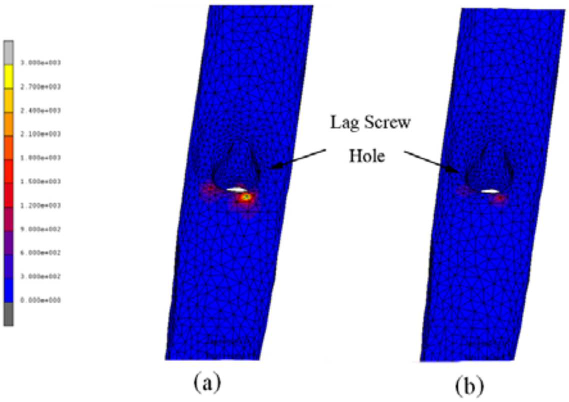

Fig. 3 The stress distribution on lag screw hole: (a) in healing process 1 week and (b) in healing process 4 week.

4.2 Femoral bone

. On the other Hand, The value of strain distributed on fracture was vice-versa. Since, the load was shared from femur to TGN type-5. After the 4th week of healing process, the maximum strain on the gap decreased from 294,973 to 102,068 microstrain.

All types of fractures according to Jensen's classification showed over 4,000 microstrain on fracture gap which, stopped the bone from remodeling [13].

5. Conclusion

For complete healing process, the patient should not put the full load on the fractured bone until the healing process ends. It is suggested that the patients should use the walker on their daily walking for a good clinical result. Other implants such as gamma 3 long nail or dynamics hip screw (DHS) must be compared with this studied implant.

6. Acknowledgement

The authors would like to acknowledge the Department of Anatomy, Faculty of Medicine Siriraj Hospital, Mahidol University for their kind support for the cadaveric femoral bone specimens; National Metal and Materials Technology Center (MTEC) for their kind support of the use of their facilities and; Young Scientist and Technologist Programme (YSTP) for their generous financial support.

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