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Influence of plate lengTh on the Mechanical performance of dynamic hip screw

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Abstract. The present study aimed to investigate the possibility in the use of Dynamic Hip Screw (DHS) for intertrochanteric fracture type IA based on numerical simulation. The analysis domain under consideration included the intact femur with two millimeters fracture site stabilized by 2-hole, 4-hole, 6-hole and 8-hole stainless steel DHS. All simulations were performed under one-legged stance walking activity condition. Maximum von Mises stress and elastic strain were main criteria to evaluate the risk of implant failure and stability of fracture site, respectively. According to the results, the different length of DHS plate presented different stress levels on implants as well as stability of fracture. The 6-hole DHS and 8-hole DHS should not be used for introchanteric type IA treatment. The 2-hole and 4-hole were considered to be a better alternative. In early state bone healing, the patient should use crutch assisted walking to avoid implant failure. However, the mechanical experiment i.e. fatigue and clinical evaluation should also be further investigated.

Keywords: Dynamic Hip Screw, Stability of fracture, DHS Plate length

1. Introduction

Dynamic Hip Screw (DHS) is a device commonly used for stabilizing intertrochateric fracture [1-3]. It consists of a sliding lag screw assembled to a plate in the lateral cortex. Biomechanically, the DHS subjects to bending moment generated by hip contact force and the distance from humeral head center to the lateral femoral cortex. There are vareity avaliable DHS in commercial markets nowsaday. The current design may range from 2-hole until 8-hole and the material made of DHS are titanium and stainless steel [4],[5]. Normally, surgeon selects the length of DHS that enough to cover the fracture site. In engineering term, the longer plate allows more screw to be attached which subsequently the stability of fracture site increases. There are various reseaches presenting the results of biomechanical performance of DHS [4-6]. Nevertheless, no previous reseach has interested the influence of DHS length to performance in term of stability and safety. Therefore, this study analyzed the 2-hole and 4-hole DHS which are commonly used in hospital to with 6-hole and 8-hole DHS to compare the biomechanical performance as well as to raise the awareness of implant usage.

2. Materials And Methods

The analyses were performed using MSC Patran/Marc Mentat 2005 commercial finite element software package. The analyses were based on an intact femur with Type IA intertrochanteric fracture [7] stabilized by DHS 135°, 2-hole DHS, 4-hole DHS, 6-hole DHS and 8-hole DHS. The fracture site had two millimeters thickness located in the intertrochanteric region. Three-dimensional finite element models of femur employed in this study were based on the standard femur model developed by the International Society of Biomechanics Finite Element Mesh Repository [8] whereas the DHS implants were created from SolidWorks 2010 CAD commercial software. Ten-node tetrahedral element (Tet-10) was solely used in the simulations. In the analysis, the degrees of freedom on the distal femur were fully constrained. A body weight and muscle forces were applied at the proximal femur [9] as illustrated in Figure 1. The applied magnitude of the forces was at the maximum that occurs in gait cycle as represented in Table 1. All materials were considered to be homogenous, isotropic and linearly elastic as represented in Table 2. The analyses included two states which were the early state of bone healing (state-1) and state after bone healing (state-2) [4].

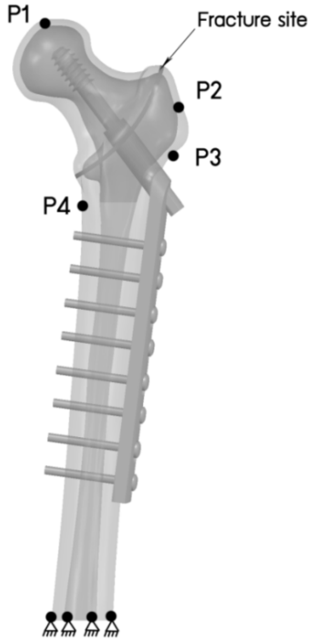

Fig.1 Domain under consideration and boundary conditions

Tab.1 loading conditions [9]

Force	Magnitudes (N)			Point
	X	*Y*	*Z*	
Hip contact	452.38	261.90	-1,833.33	P1
Abductor	-475	20	700	P2
Tensor Fascia Latae	82.40	127	-59.45	P2
Vastus Lateralis	5.63	-135	-673.13	P3
Vastus Medialis	3.80	-12.93	-70.76	P4

Tab.2 material properties [4]

Part	Elastic modulus (MPa) / Poisson's ratio	
	Cortical bone	*Trabecular bone*
Femoral head	17,000/0.3	900/0.29
Femoral neck	17,000/0.3	620/0.29
Introchanterics region	17,000/0.3	260/0.29
Fracture state-1	3/0.4	3/0.4
Fracture state-4	17000/0.3	260/0.29
Femoral shaft	17,000/0.3	
Stainless steel	200,000/0.3	

3. Results And Disscussion

Table 3 and Fig. 2 show maximum von Mises stress exhibited on the implant. It can be seen that the maximum stress occurred on lag screw. The stress exhibited in the state-1were higher than the state-2 in all models. Since the state-1 is an early state of bone healing which force mostly tranfers to implant. Different plate length influences stress on implant and stability of fracture with no significant difference. Therefore, using 6-hole DHS and 8-hole DHS may not be appropriate, because it could increase complication during operation. Therefore, the 2-hole DHS and the 4-hole DHS were considered to be a better option. Considering the 2-hole DHS and the 4-hole DHS, the maximum stress occurred in 4-hole DHS (Lag screw region), lowering than 2-hole DHS by 15 percent and stability of fracture increased by 4 percent in state-1. In state-2, it was expected that force between bone and implant should be shared in the greater magnitude than in state-1. Consequently, the 4-hole DHS model is recommended. In addition, the yield strength of stainless steel medical grade (SS 316LVM) ranges 600 to 800 MPa [10], the use of all DHS model are at risk for intertrochanteric fracture type IA under walking with full loads. As a result, the patient should use crutch for help walking to avoid implant failure. The desired partial load should induce 2 - 10 percent elastic strain to promote bone healing process [11]

Tab.3 maximum von Mises stress of implant

Model	State 1			State 2		
	Lag screw [MPa]	Plate [MPa]	Screw [MPa]	Lag screw [MPa]	Plate [MPa]	Screw [MPa]
DHS-2H	854.15	543.16	462.50	222.23	385.10	270.22
DHS-4H	722.93	586.17	518.56	159.74	91.54	321.91
DHS-6H	852.36	691.70	373.50	313.68	115.68	284.37
DHS-8H	921.35	511.99	239.84	433.00	122.71	290.87

Tab.4 elastic strain of fracture site

Model	% Elastic Strain	
	State 1	State 2
2-Hole DHS	60.216	0.148
4-Hole DHS	57.906	0.124
6-Hole DHS	60.192	0.339
8-Hole DHS	57.282	0.383

4. Conclusion

The present study shows the biomechanical analysis of DHS implant by means of finite element method. Different plate length influences stress on implant and stability of fracture with no significant difference. The 2-holes DHS and 4-hole DHS are good choice for treatment. In state-1, the patient should not full weight that a risk of implant failure. Further investigation based on other fracture type and clinical experiment should be performed.

5. Acknowledgment

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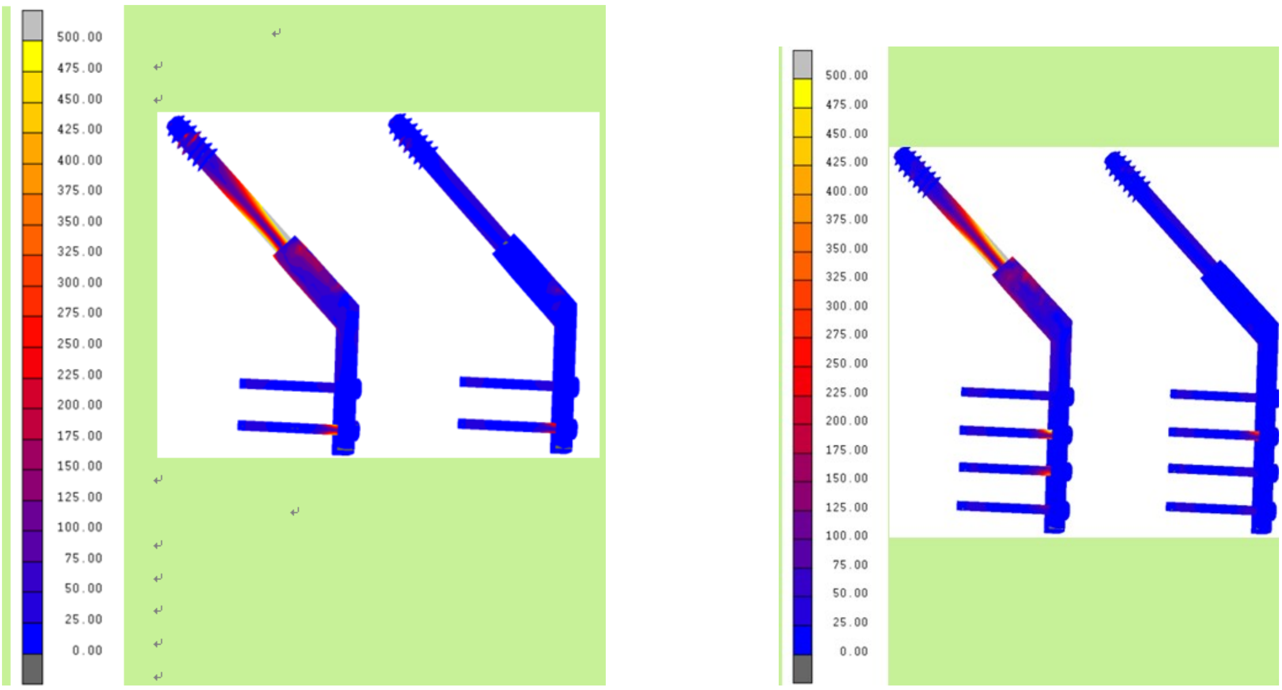
A — MPa — State-1 — State- 2

B — MPa — State-1 — State- 2



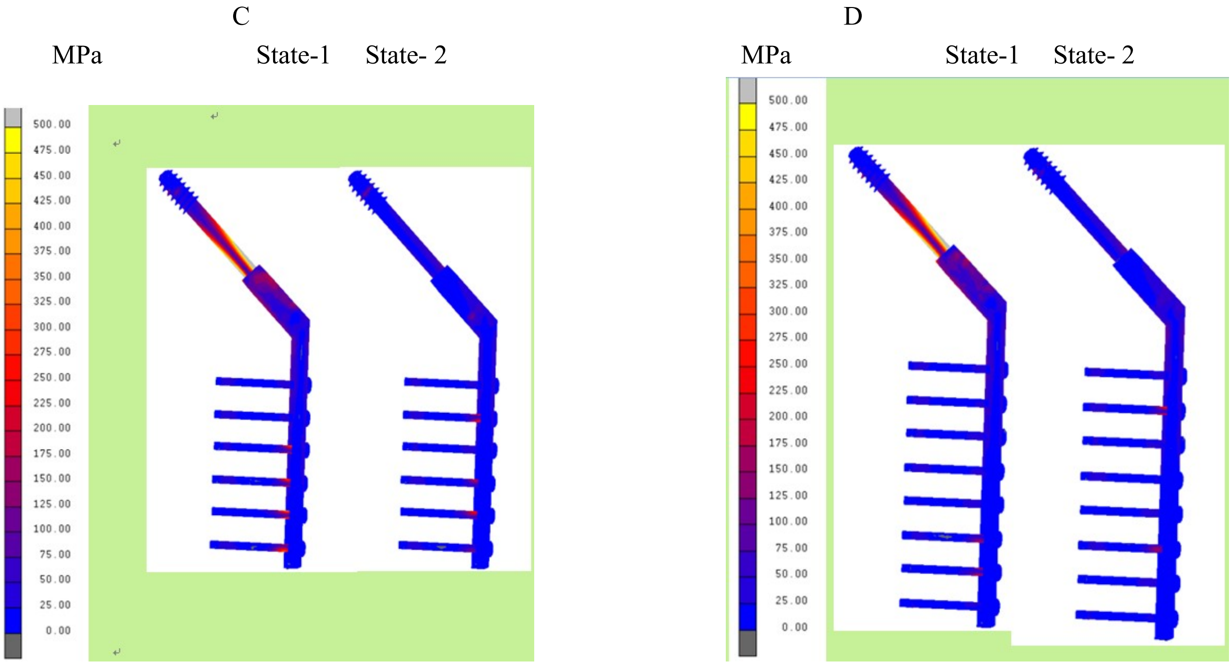


Fig.2 Maximum von Mises stress on the implants,(A) 2-hole DHS,(B) 4-hole DHS,(C) 6-hole DHS and (D) 8-hole DHS