

## THE EFFECT OF CANNULATED HIP SCREW SIZE IN THE TREATMENT OF FEMORAL NECK FRACTURE

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### Graphical abstract



### Abstract

This study aimed to investigate the mechanical performance of different cannulated hip screw size in the treatment of femoral neck fracture via finite element method. The 3D model of a proximal femur was constructed CT data of human lower limb. The femoral neck fracture was stimulated with a 40° cut from the anatomical femoral axis. This model was treated with multiple cannulated hip screws with three different sizes – 6.5, 7.0 and 7.3mm. The chosen arrangement for this particular study was a triangle configuration. All analyses were performed using stair climbing loads. The results showed for different sizes different stress distribution. The 7.3 mm cannulated hip screw option for treatment of femoral neck fracture.

Keywords: Femoral neck fracture; cannulated hip screw; finite element method

### Abstrak

Kajian ini bertujuan untuk menyiasat prestasi mekanikal saiz skru cannulated berbeza dalam rawatan patah leher pinggul melalui kaedah unsur terhingga. Model 3D tulang paha proksimal dibina daripada bahagian bawah anggota badan manusia data CT. Patah leher pinggul dirangsang dengan potongan dari paksi pinggul anatomi 40°. Model ini telah dirawat dengan beberapa skru cannulated dengan tiga saiz yang berbeza - 6.5, 7.0 dan 7.3mm. Susunan yang dipilih untuk kajian ini khususnya adalah konfigurasi segitiga. Semua analisis dilakukan menggunakan beban mendaki tangga. Hasil kajian menunjukkan untuk pelbagai saiz yang berbeza agihan tegasan. 7.3 mm skru cannulated adalah pilihan untuk rawatan patah leher pinggul.

Kata kunci: Patah leher pinggul, skru cannulated pinggul, kaedah unsur terhingga

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## 1.0 INTRODUCTION

Femoral neck fracture is a common clinical type and difficult problem of bone injuries<sup>1,2</sup>. A common device used for treat femoral neck fracture is a multiple cannulated hip screws<sup>3</sup>. It is because multiple cannulated hip screws are capable to stabilizing the fracture. In addition, multiple cannulated hip screws

are better than other internal fixation device. Currently, there are three sizes of cannulated hip screw that commonly used for treat femoral neck fracture. The sizes of screw are 6.5, 7.0 and 7.3 millimeter (mm)<sup>4</sup>. Besides, the multiple cannulated hip screws were fixed with several configurations for treat femoral neck fracture<sup>5,6</sup>. Therefore, there are a lot of researches and studies were done to find the suitable configuration for treat femoral neck fracture. As the result, there are

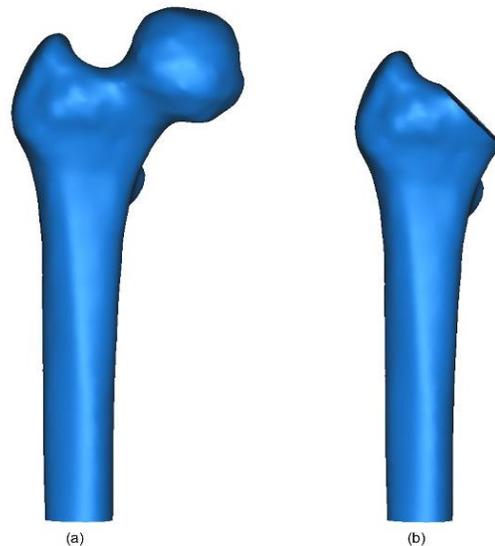
several authors reported that triangle configuration is the most suitable configuration for treat femoral neck fracture<sup>7, 8</sup>. It is because triangular configuration has higher ultimate load, higher load to fail and less displacement than other configuration<sup>7, 8</sup>.

Most of studies were usually investigate the mechanical properties of multiple cannulated hip screws for treat femoral neck fracture with different number of screw and configuration through the in vitro. Therefore, this study aimed to evaluate mechanical properties of multiple cannulated hip screws with different size of screw in a triangle configuration through the finite element method. A three-dimensional (3D) finite element model of proximal femur with femoral neck fracture was fixed by multiple cannulated hip screws with triangle configuration was developed to investigate von Mises stress distribution exhibits on the cannulated screw during stair climbing activity.

## 2.0 EXPERIMENTAL

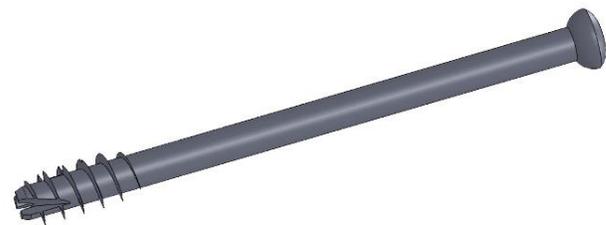
### 2.1 Finite Element Models

The 3D model of proximal femur was created using medical image processing software, MIMICS. In order to created 3D model of proximal femur, the two-dimension (2D) lower limb computer tomography (CT) data images of healthy female was imported to MIMICS software. Then, threshold was done to define cancellous and cortical bones through the ranges of Hounsfield scale value. In this study, the Hounsfield scale value of cancellous bone was set from 200 HU to 750 HU while cortical bone was set from 700 HU to 3071 HU. Afterwards, semi- automatic segmentation method was done to create 3D model of proximal femur. Fig. 1a shows the 3D model of proximal femur. Besides, the MIMICS software also used to create the femoral neck fracture on proximal femur model. The neck fracture was created at angle of 40° from the anatomical femoral axial. The femoral neck fracture creates on proximal femur model show in Fig. 1b.



**Figure 1** (a) 3D model of proximal femur, (b) 3D model of proximal femur with femoral neck fracture

The 3D models of 6.5, 7.0 and 7.3 mm cannulated hip screws were created using computer aided design (CAD) software, SolidWorks. The dimensions of each cannulated screw were collected from cannulated screw manufacturer surgical guide brochures. In this study, the dimensions of cannulated hip screw that collected from surgical guide brochures were shaft diameter, thread diameter, thread length, and screw length. Fig. 2 shows the cannulated hip screw model which creates in SolidWorks. Table 1 show the dimension value of each cannulated hip screw that used in this study.



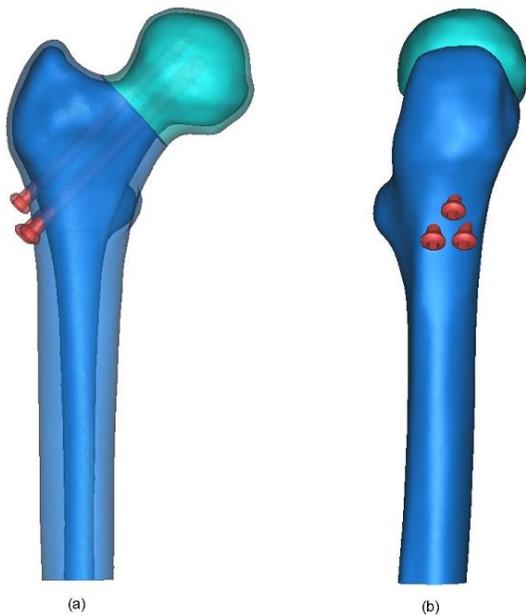
**Figure 2** Cannulated hip screw model in SolidWorks

**Table 1** Dimensions of each cannulated hip screw

Screw Size (mm)	6.5	7.0	7.3
Shaft Diameter (mm)	4.8	4.5	4.8
Thread Diameter (mm)	6.5	7.0	7.3
Screw Length (mm)	75.0		
Thread Length (mm)	16.0		
Head Screw Diameter (mm)	8.0		

**2.2 Assembly**

Three cannulated hip screws were inserted to the proximal femur model which sustains femoral neck fracture with triangle configuration. There are several surgical guide lines from manufacturer surgical guide brochure need to follow during insert the cannulated hip screw. The guide lines are the cannulated hip screw was inserted aligned to neck of femur model and it also perpendicular to the fracture line as presented in Fig. 3a. Besides, the fixation of cannulated hip screw into proximal femur model is following the three-point fixation method. In addition, all sizes of cannulated hip screw in triangle configuration were fixed at exactly same location on the proximal femur model to ensure the accuracy of the results. The 3D models of femoral neck fracture fixed with three cannulated hip screws in triangle configuration are shown in Fig. 3b. The volumetric mesh of proximal femur model and three cannulated hip screws in triangular configuration were generated using finite element software package, MSC MARC. The proximal femur model with three cannulated hip screws had a total number of 84651 nodes and 313086 elements.



**Figure 3** 3D model of proximal femur sustain femoral neck fracture fix with cannulated hip screw

**2.3 Materials Properties Assignment**

The material properties for cannulated hip screw, cancellous and cortical bones were assigned to be homogeneous, linear elastic and isotropic. The material of cannulated hip screw was assigned as stainless steel with the Young's modulus is 193 GPa. Meanwhile, the Young's modulus of cancellous and cortical bones was assigned as 0.104 GPa and 12.4 GPa respectively. In addition, the Poisson's ratio for each material was assumed 0.3.

**2.4 Boundary Condition**

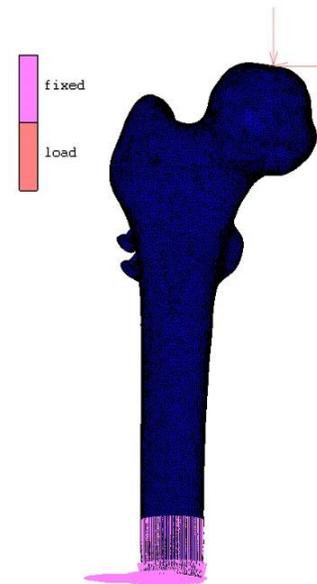
The hip joint force during stair climbing activity was applied to the proximal femur model. The hip joint force were stimulate on head of proximal femur model while the distal end of proximal femur model was fully fixed. The point load was choosing as hip joint force and fixed displacement were assigned at end distal of proximal femur model are shown in Fig. 3. The loading condition of hip joint force was shown in Table 2.

**2.5 Contact Assignments**

In this study, the friction coefficients for all material were assigned to 0.3 for simplify the analysis. The deformable-to-deformable contact elements were used for contact simulation.

**Table 2** Loading condition under stair climbing activity

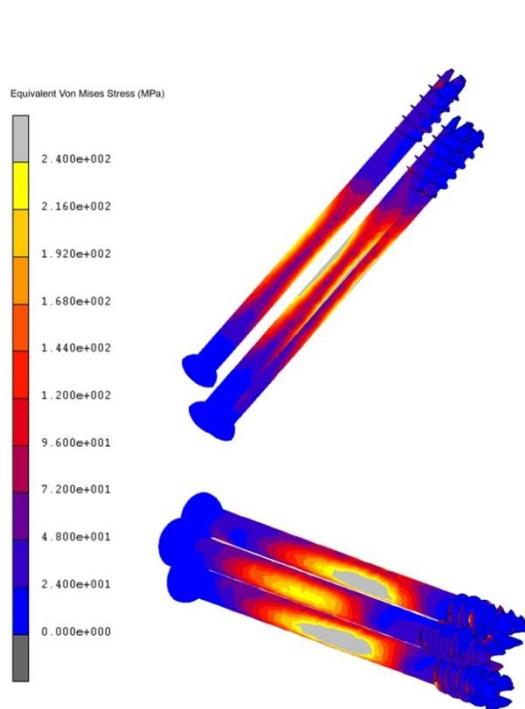
Hip Joint Force	
Axis	Magnitude
X	-476.4 N
Y	-486.8 N
Z	1898.3 N



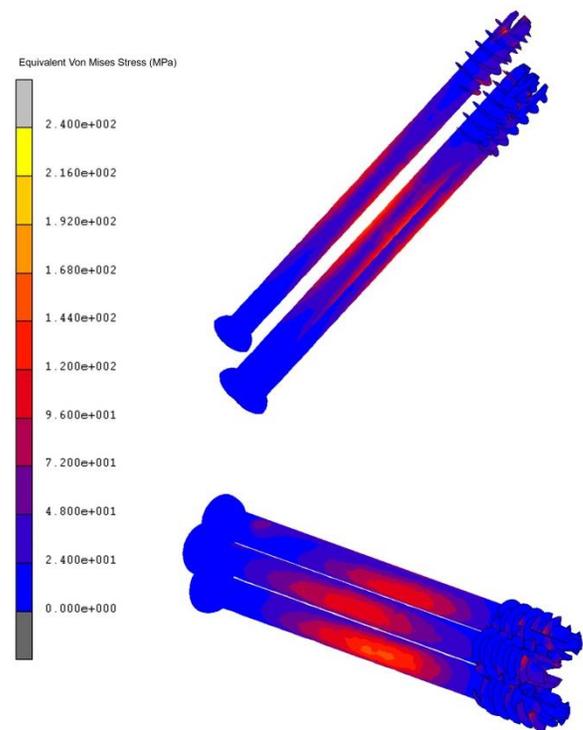
**Figure 4** The load condition

**3.0 RESULTS AND DISCUSSION**

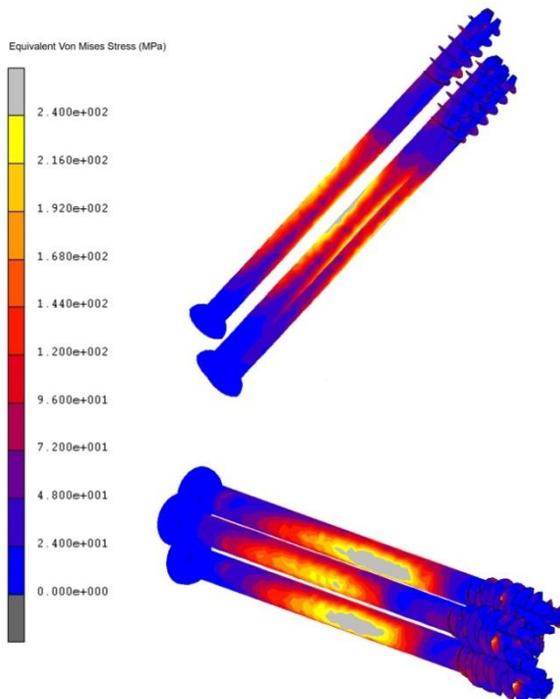
The von Mises stress distributions on different size of cannulated hip screws in triangle configuration are shown in Fig. 4, 5 and 6. As can be seen, the stress distributions were concentrated on the middle part of all cannulated hip screws. High stress concentration on the superior and center part of the cannulated hip screw will lead to screw tension. On the other hand, high stress concentration on the inferior and center part will lead to screw compression. Both conditions will therefore result in the occurrence of bending screw.



**Figure 5** The von Mises stress distribution on 6.5 mm cannulated hip screw



**Figure 7** The von Mises stress distribution on 7.3 mm cannulated hip screws



**Figure 6** The von Mises stress distribution on 7.0 mm cannulated hip screw

In comparing the results of different screw size, it can be observed that 7.3 mm cannulated hip screw in triangular configuration exhibited the lowest von Mises stress distributions. Therefore, the 7.3 mm screw will be able to resist bending more than the other screws. This result is identical to the previous literature by Giotakis and Narayan which explained that larger diameter of screw or pin has higher resistance to bending<sup>9</sup>. Earlier study by Zhang et al also proved that large diameter of screw inside the femur head has increased the contact surface and contributed to greater shear stress, thus preventing the screw from loosening and extraction<sup>10</sup>. Meanwhile, the results between 6.5 and 7.0 mm cannulated hip screws showed approximately similar von Mises stress distributions. Hence, both cannulated hip screws will sustain almost similar bending rate.

In this study, the cannulated hip screws were fixed in triangle configuration according to previous literatures<sup>7, 8, 11</sup>. It is due to the stability that could be achieved by comparing to other configurations such as inverted triangle, diamond and linear configurations<sup>7, 8, 10</sup>. In this study, the thread length of the cannulated hip screw was designed at 16 mm. It has been shown by the previous study that there was no significant difference between 16 and 32 mm length of thread<sup>12, 13</sup>. Moreover, in-vitro biomechanical analyses by Yang et al. and Selvan et al. have used 16 mm length of thread screw in their experiments<sup>6, 7</sup>.

There are two limitations have been set for this study. In physiological condition, there are several forces act on femur – hip joint, abductor, iliopsoas and vastus lateralis forces. In this study, the applied load on the proximal femur model was only set to hip joint force which is identical to other biomechanical analyses<sup>5</sup>.

<sup>14</sup>. The other limitation was set on the material properties of the cortical bone. The cortical bone in this research was assigned as homogeneous and isotropic to simplify the analyses and to reduce the simulation error. However, this simplification has been widely used in the finite element method studies that related to orthopedics<sup>15, 16</sup>

## 4.0 CONCLUSION

In this study, the 7.3 mm cannulated hip screw in triangle configuration exhibit the lowest von Mises stress distribution than other size with same configuration. Therefore, this size is recommended to be used to treat femoral neck fracture.

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