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The Effect of the Configuration of the Screw Fixation on the Interfragmentary Strain

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Abstract: Problem statement: The interfragmentary strain (ε_{IF}) is the important parameter for femur fracture healing. The Dynamic Compression Plate (DCP) is commonly used in femur fracture. The DCP and the fractured femur are fixed by using the conventional screws. **Approach:** This research is proposed to investigate the effect of configuration of the screw fixation on the interfragmentary stain by using Finite Element Analysis (FEA), eight configurations of the screw fixation with the body load of 400 and 500 N. **Results:** The experimental results show that the relation of ε_{IF} and screws are the polynomial equations**. Conclusion:** We can decrease the interfragmentary strain by adding the number of screw with the groups of screw configuration.

Key words: Interfragmentary strain, dynamic compression plate, femur fracture, finite element

INTRODUCTION

Fractures of human femur are one of most frequent bone fractured. The middle points of the femur is critical point because of the maximum bending moments occur at this point. Internal fixation devices are directly applied to the fractured femur. The bone-plate is commonly used in femur fracture. The Dynamics Compression Plate (DCP) and the Locking Compression Plate (LCP) are two types of favorite bone-plates.

The DCP and the fractured femur are fixed by using the conventional screws and generate compression force between the DCP and the femur. Conventional screw cannot lock with the DCP hole (Kanchanomai *et al*., 2008; Field *et al*., 2004). LCP hole is developed to solve this problem. We can use both types of screw with the LCP hole, the locking screw and the conventional screw. The distance between the fractured femur and the LCP can generate when using the locking screw and the compression force can generate when using the conventional screw (Miller and Goswami, 2007; Stoffel *et al*., 2003; Ahmad *et al*., 2007).

When the fracture occurs at the middle part of the femur, the physician will cut the fracture and form a gap of 1-10 mm.

The interfragmentary strain (ε_{IF}) is defined as the ratio of the fracture gap displacement after the body load applied and the original fracture gap as show in Fig. 1.

The Eq. 1 of IFS is:

$$\varepsilon_{IF} = \frac{\Delta L}{L} \quad (1)$$

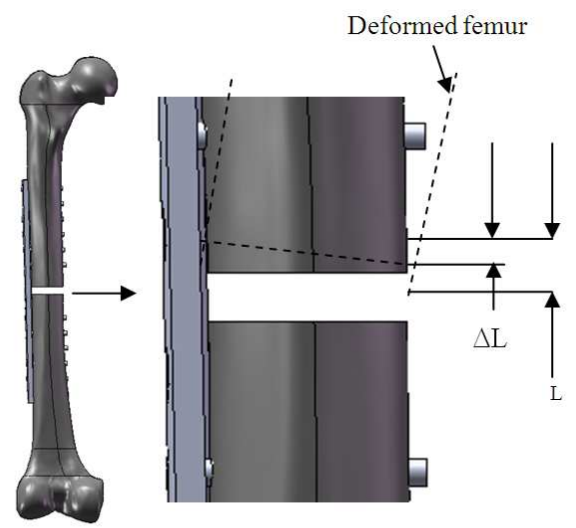

Fig. 1: The deformation of the fractured femur

Where:
ΔL = The fracture gab displacement after the body load (W) applied
L = The original fracture gap length

The best IFS ranges from 2-10% (Perren, 1979; Kim *et al*., 2010).

MATERIALS AND METHODS

Finite Element Analysis (FEA): The third generation femur of Pacific Research Lab, the 14-hole DCP and the 12 screws are assembled by using SolidWorks 2007 as show in Fig. 1 and 2.

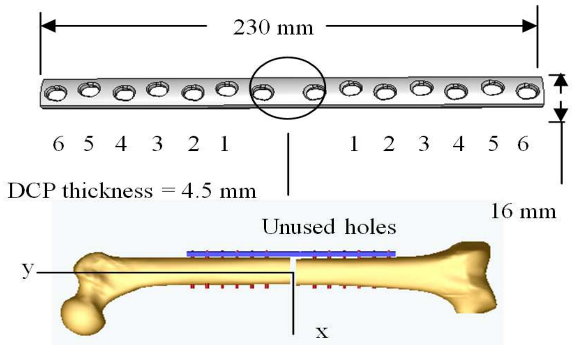

Fig. 2: The hole-number of the DCP

Fig. 3: Boundary condition of the finite element models

Table 1: The screw configurations on each side

Model	Fixed at hole-number	Number of screws
1	1 2 3 4 5 6	6
2	1 3 4 5 6	5
3	1 4 5 6	4
4	1 5 6	3
5	1 6	2
6	1 2 6	3
7	1 2 3 6	4
8	1 2 3 4 6	5

Table 2: The groups of screw configuration

Group	Model	Number of screws
1	5 4 3 2 1	2 3 4 5 6
2	5 6 7 8 1	2 3 4 5 6

Table 3: Material properties

	Young's modulus (GPa)	Poission's ratio
SS	210.0	0.3
Cortical bone	17.0	0.3
Cancelous	0.7	0.2

Table 4: Types of the contact surfaces

Surface1	Surface2	Type
DCP	Screw	Glue
DCP	Cortical femur	Touch
Screw	Cortical femur	Glue
Screw	Cancelous femur	Glue
Cortical femur	Cancelous femur	Glue

The Pacific research laboratories bone models are usually used in biomechanics research (Stoffel *et al*., 2003; Wongchai, 2011). The assembled model is imported to MSC.Patran 2008 r1 for construct the finite element model. The 4-node tetrahedral is used.

The screw configurations: The fractured femur was bridged by the 14-hole DCP as shown in Fig. 2. The 10-mm fracture gab and the 4.5-mm diameter screws are used in the model. Two screws were fixed at 1st and 6th holes on both sides. The other holes are fixed with additional screws. Two holes at the middle are left without any screws.

The eight configurations of screw fixation are shown in Table 1.

Two groups of screw configuration are conducted by using the direction of the screw fixation as shown in Table 2. The number of screws varies from 2-6.

Material properties: The DCP and screw are made of Stainless Steel (SS). Material properties of the DCP, screw, cortical bone and cancelous bone are shown in Table 3 (Stoffel *et al*., 2003; Fouad, 2010).

Boundary condition: The femur head is acted by the body load W. We obtain the fracture gab Length (L) of 10 mm. We fixed the lowest area of the femur in the finite element models as show in Fig. 3. There are many contact surfaces. Types of the contact surfaces are show in Table 4.

The finite element models from MSC.Patran 2008 r1 is solved by using MSC.Marc for nonlinear finite element problems.

RESULTS

The results of the fracture gab displacements are shown in Table 5.

From the fracture gab displacement in Table 5 we can determine ε_{IF} by using Eq. 1 as shown in Table 6.

The displacement of the femur from FEA is shown in Fig. 4.

From the groups of screw in Table 2 and the results in Table 6, we represent ε_{IF} versus the number of screws (N) in Fig. 5-8.

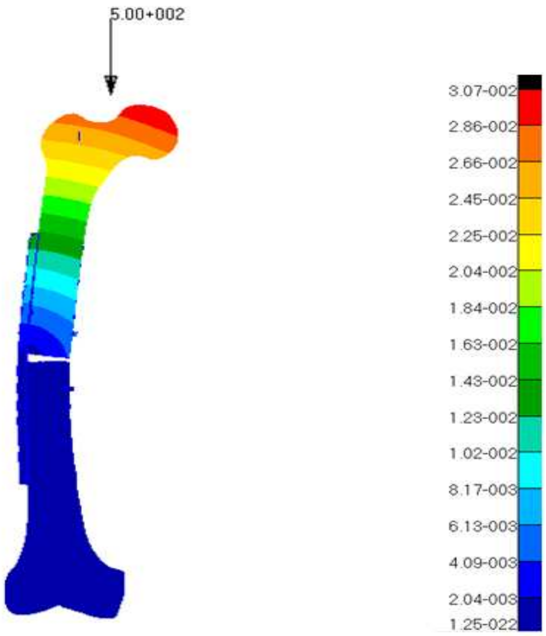

Fig. 4: The displacement of the femur

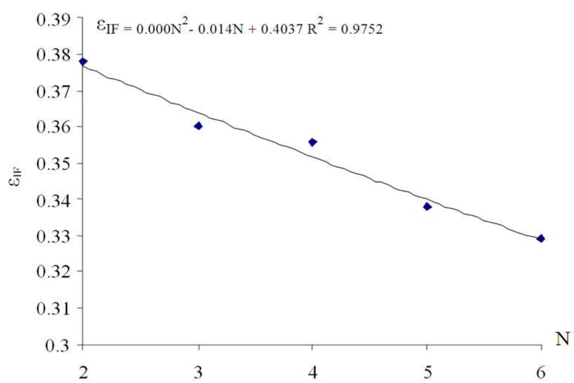

Fig. 5: ε_{IF} versus the number of screws (400 N groups 1)

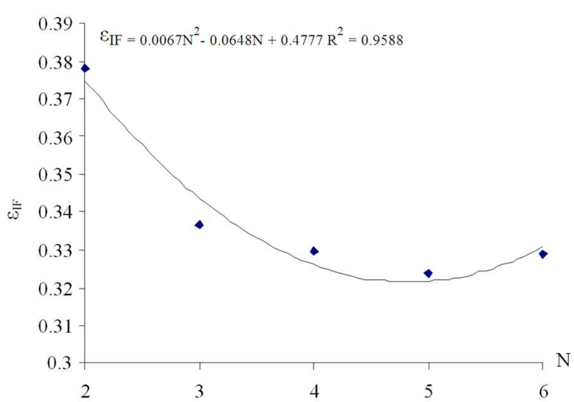

Fig. 6: ε_{IF} versus the number of screws (400 N groups 2)

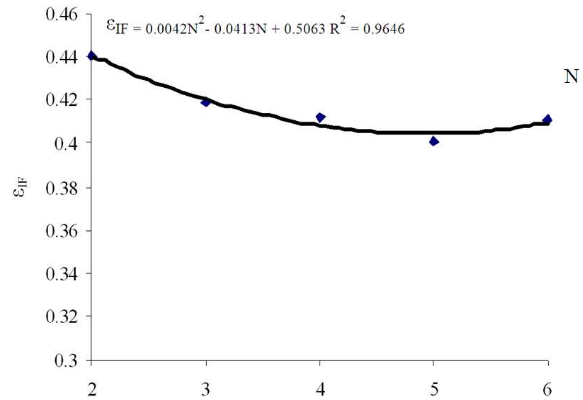

Fig. 7: ε_{IF} versus the number of screws (500 N groups 1)

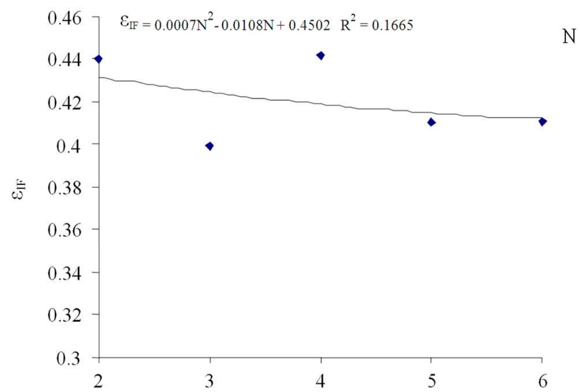

Fig. 8: ε_{IF} versus the number of screws (500 N groups 2)

Table 5: The fracture gab displacement

Model	Body load 400 N ΔL (mm)	Body load 500 N ΔL (mm)
1	3.290	4.106
2	3.380	4.007
3	3.559	4.118
4	4.179	4.189
5	3.778	4.404
6	3.366	3.993
7	3.296	4.412
8	3.237	4.098

Table 6: The inter fragmentary strain

	ε_{IF}	
Model	Body load 400 N	Body load 500 N
1	0.3290	0.4106
2	0.3380	0.4007
3	0.3559	0.4118
4	0.4179	0.4189
5	0.3778	0.4404
6	0.3366	0.3993
7	0.3296	0.4412
8	0.3237	0.4098

DISCUSSION

The graphs of ε_{IF} and number of screws are the polynomial equations with $R^2>0.95$ except in case of W = 500 N and the group of screw configuration is group 2. The results show that the values of ε_{IF} are decreased by adding the number of screws.

CONCLUSION

We could decrease the interfragmentary strain by adding the number of screw with the groups of screw configuration.

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