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Relation of Plate Strain and Distance Between Plate and Bone

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ABSTRACT

The Limited Contact Dynamics Compression Plate (LC-DCP) is normally used in bone fractured with the locking screws. The released distance between the LC-DCP and the bone could bring about the convenience of periosteal blood transportation. However the exceeding distance may cause the plate strain reach yield point and make the LC-DCP deform into plastic zone. This research proposes a study of the effect of the distance between the LC-DCP and the bone on the strain in the LC-DCP. The strains at all points are increased when the distance increases. The maximum strains occur at the middle point of the LC-DCP near the fracture gab for all varied distances.

Keywords: LC-DCP, Limited Contact Dynamics Compression Plate, Locking Plate, Femur Fracture

1. INTRODUCTION

When the human bone fracture occurs, the internal fixation is the main method to cure it (Kim *et al*., 2012; Somasundaram *et al*., 2013). For the internal fixation, plate fixation is a interesting choice. The Dynamic Compression Plate (DCP) and The Limited Contact Dynamics Compression Plate (LC-DCP) are commonly used to fix broken bone. Only the conventional screws are used in the DCP. They fix the plate and the bone by the compressive force that is generated by the applied torque at the screw head (Kanchanomai *et al*., 2008; Field *et al*., 2004; Kabak *et al*., 2004; Gao *et al*., 2011; Wahnert *et al*., 2012; Kumar *et al*., 2013). Basically, the contact plate compresses the bone and affects the periosteal blood supply to the femur (Haasnoot *et al*., 1995; Ahmad *et al*., 2007; Kim *et al*., 2012). The LC-DCP is developed to solve this problem by using the locking screws (Borgeaud *et al*., 2000; Field *et al*., 2004; Kabak *et al*., 2004; Miller and Goswami, 2007; Kim *et al*., 2012).

For LC-DCP, the locking screws are used to generate the distance between the plate and the bone. The conventional screw can be used in the LC-DCP as the DCP.

However, the distance between the LC-DCP and the bone affect the strain (ε) in the LC-DCP. The LC-DCP will be damaged when it's strain exceeds the yield point. For the plate design, the plate strain must be in the elastic zone of the stress-strain curve.

In this research, the strain in the LC-DCP is the goal to study at various distance.

2. MATERIALS AND METHODS

The 3406 large left fourth generation femur of Pacific Research Lab is used in the present work. The Pacific research laboratories bone are usually used in biomechanics research (Greer and Wang, 1999; Stoffel *et al*., 2003; Ahmad *et al*., 2007). The 12-holes LC-DCP from synthes Inc. with the ten conventional screws are attached on the femur. The LC-DCP and the screws are made off stainless steel.

The femur model was cut in half to simulate a fracture. The 10-mm gap is generated at the middle point of the femur as shown in **Fig. 1**.

The KFG-5-120-C1-11L1M2R Kyowa strain gages are used to determine the strain along the LC-DCP surface. Its specification are presented in **Table 1**.

Three Kyowa strain gages are set along the 12-hole LC-DCP surface as shown in **Fig. 2**. At point 1, the first strain gage is set at hole 4 from the top of the LC-DCP. At point 2, the second strain gage is set at the middle point of the LC-DCP (at the fracture gap). At point 3, the third strain gage is set at hole 4 from the bottom of the LC-DCP as shown in **Fig. 2**.

Fig. 1. The experiment setup on compressive testing machine

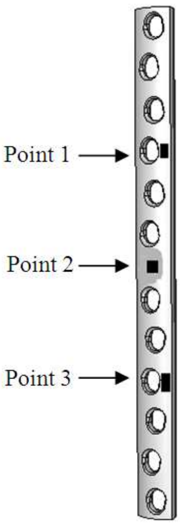

Fig. 2. The strain gauge setting

The lowest of the femur is fixed with epoxy resin while the femur head is fixed by one screw as shown in **Fig. 1**. The jig at the femur head can rotate about this screw and touch the femur head for transferring the compressive force from the compression testing machine. The compressive force from the compression testing machine and the strains signals are converted to digital signals by the Kyowa PCD-300A. The CD-300A control software is used for data recording and these data is exported to excel files.

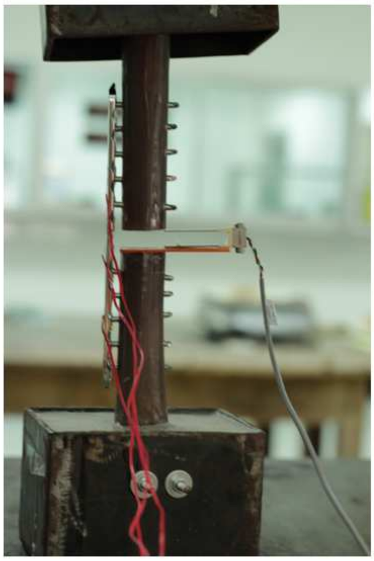

Fig. 3. The LC-DCP and the femur setting

Table 1. Strain gage specification

Gage factor (24°C, 50% RH)	2.08±1.0%
Gage length	5 mm
Gage resistance (24°C, 50% RH)	120.4±0.4Ω
Adoptable thermal expansion	11.7 PPM/°C
Temperature coefficient	+0.008%/°C
Applicable gage cement	CC-3A, EP-34B

The compressive force F on the femoral head is generated by the compression testing machine varying from 0 to 300 N.

In the three experiments, the distance between the LC-DCP and the femur are 0, 3 and 5 mm as shown in **Fig. 3**.

3. RESULTS

The graphs of the strain versus the compression force at the femur head (F) for all experiments at point 1, 2 and 3 are shown in **Fig 4-6**. Because the LC-DCP is tested in the elastic zone, the resulting graphs of the strain behave in linear function.

4. DISCUSSION

From **Fig. 4-6**, when the distance between the LC-DCP and the femur changes from 0 to 5 mm, the slope of the graphs increase. The strain in the LC-DCP at point 1 to point 3 can be increased by increasing the distance between the LC-DCP and the femur. In case of high value of the distance, the LC-DCP will be damaged more easily than the case of low value of the distance. The stability of the LC-DCP and the femur decrease by increasing of the distance.

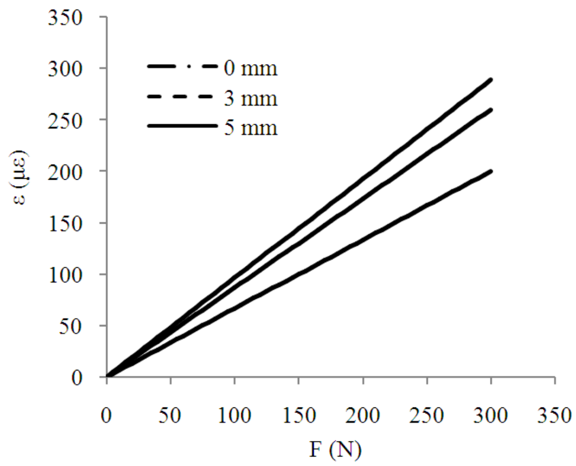

Fig. 4. The correlation between F and ε at point 1

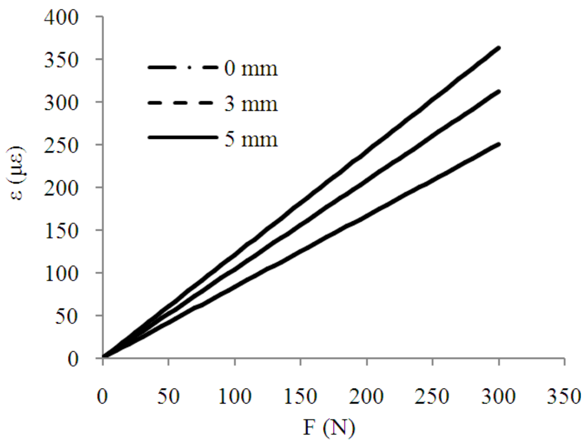

Fig. 5. The correlation between F and ε at point 2

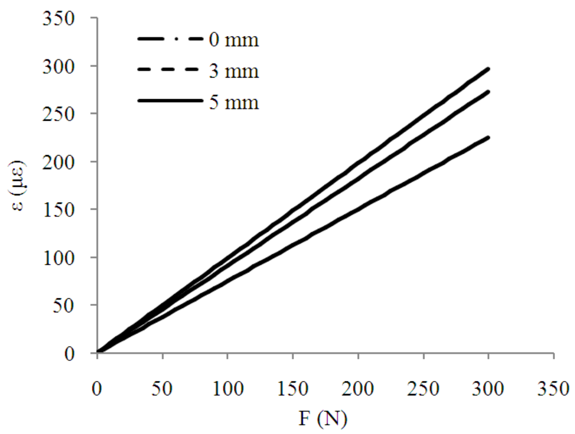

Fig. 6. The correlation between F and ε at point 3

The critical point occurs at point 2 (the middle point of the LC-DCP), because this point is near the fracture gab of the femur. The strain in the LC-DCP at this point is highest among all points for all experiments. The LC-DCP will be damaged at this point before the other points and it deforms like a column. The LC-DCP can be damaged when it's strain reach to yield strain or the compressive force at the femur head reach to the critical load of the buckling mode.

The investigation of the optimized distance is the necessary option to be done before using with patients. For each of patient, the optimization of the distance depends on, for examples, the weight of the patient, the plate size, the plate shape, the plate material, the screw size, the number of screw.

5. CONCLUSION

The strains at all points (point 1, 2 and, 3) increase by increasing the distance between the LC-DCP and the femur. The maximum strains occur at the middle point (point 2) of the LC-DCP for all cases.

6. ACKNOWLEDGEMENT

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