Biomechanical analysis on design variables in relation to the strength of compression hip screws

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INTRODUCTION

Compression Hip Screw (CHS) is one of the most widely-used prostheses for the treatment of intertrochanteric fractures because of its strong fixation capability[1]. Fractures at the neck and screw holes are frequently noted as some of its clinical drawbacks, which warrant more in-depth biomechanical analysis on its design variables. In this study, we investigated the effects of the changes in design variables to the strength of the CHS. Particularly, changes in the plate thickness and number of screw holes at the side plate were studied in relation to the strength of the implant.

METHODS

Specimen Preparation

Twenty compression hip screws (Solco Biomedical Co. Ltd., South Korea) with an inclination angle of 135° between the barrel and the long axis of the side plate were used in this study. All side plates were made of Grade 2 titanium and the lag screws of Ti6Al4V. Specimens were classified into four groups (n=5 each):Group I was the control group with the neck thickness of 6-mm and 5 screw holes on the side plate, Group II 6-mm thick and 8 holes, Group III 7.5-mm thick and 5 holes, and Group IV 7.5-mm thick and 8 holes.

Mechanical Test

Each of the specimen(n=3 for each group) and the jig were mounted on the mechanical testing machine (MTS 858, MTS system Corp., MN, USA)[2]. Compressive load was applied at a rate of 0.17mm/sec with the maximum displacement set at 60mm for failure tests. The failure loads were determined by 0.2% offset method which is 0.2% of the lever arm length. Fatigue tests were done (n=2 for each group) to determine the fatigue life. Fatigue loads were applied at 5Hz with data acquisition rate of 20/sec. The 50% and 75% of the failure loads that was obtained earlier from the failure tests were used for each group. Maximum number of loading cycle was set at 1 million cycles according to ASTM[3].

Finite Element Analysis

Finite element models simulating each group were constructed to analyze the change in stress distribution due to changes in thickness and hole numbers.

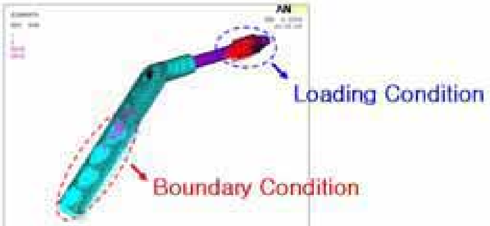


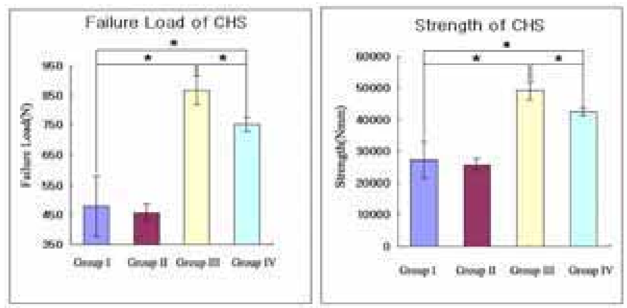
Figure 1: Loading and boundary conditions of finite element models

To reflect the same loading and boundary conditions as in the mechanical test, a compression load of 300N and contact areas between side plate and the jig were restricted in all directions [4](Figure 1).

RESULTS AND DISCUSSION

Experimental Results

Group III was found to be the strongest type with the failure strength of 867N and the bending strength of 49KN-mm, followed by Groups IV. Adding 1-mm of the plate thickness reinforce the CHS by 80% (480N in Group I vs. 867N in Group III) and it was statistically significant ($p<0.05$) (Figure 2). No fatigue failures were found in all specimen groups after 1 million cycles regardless the magnitude of fatigue loads 50% and 75% of the failure loads.



(a) **(b)**

Figure 2: The results of the failure tests of the CHSs: (a) Failure loads, (b) Strengths (*: $p<0.05$)

Finite Element Analysis Results

Peak von-Mises stresses at the neck region are analized. Group Ⅰ(175MPa) showed the highest stress but Group Ⅲ (111MPa) had the lowest. Stresses were appeared to be more concentrated around the perimeters of the lag screw holes than at the junction between the barrel and the side plate.The highest peak von-Mises stresses were found at the most superior screw hole location.

CONCLUSIONS

In this study, both biomechanical tests and finite element analyses showed that the thickness was a far more effective and sensitive design variable for the reinforcement of the CHSs than the screw hole numbers. It was also indicated that more screw holes on the side plate rather decreased the overall strength of CHSs.

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