A Simulation of Throwing Fracture Using Three-Dimensional FEM Model of the Humerus

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INTRODUCTION:

Spontaneous fracture of the humeral shaft in throwers is a rare but well-known phenomenon. It is said that the external rotation torque acting on the humerus during the throwing motion causes humeral shaft fracture. Most of the fracture line is spiral shape and located in the distal side of the humerus. However, it is still not clear how fractures occur in the pitching motion.

In this study, to elucidate the mechanism, we simulated the throwing fracture by using a three-dimensional FEM model of the humerus.

METHODS:

Humeral CT images of 3 healthy college students were obtained after the informed consent. The images were taken at an interval of 1.25 mm, vertical to the humerus. From the DICOM data of the images, the shape of the cortical bone form was extracted using the software (AMIRA, MERCURY).

The cortical bone form was used to build the three-dimensional mesh model. The mesh model consisted of approximately 18000 tetrahedron elements. The material properties of the cortical bone were decided from the literatures (Young's modulus: 17GPa, Poisson's ratio: 0.3). In this study, Pre/Post processor MARC/MENTAT was used for analysis.

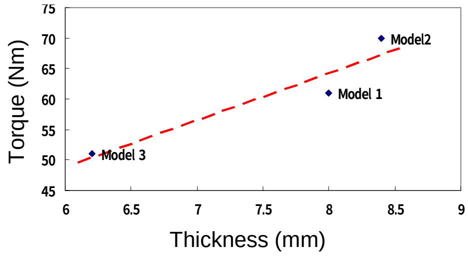
In order to reproduce the load condition during throwing movements, the head of the humerus was fixed, and the external rotation torque was applied to the distal end of the humerus. Then the torque was gradually increased from 10Nm. The torque was applied to 5 points on the humeral capitulum and 5 points on the medial epicondyle where the medial collateral ligament is attached to the humerus.

In this study, we removed the elements when the stress of the elements become greater than a yield stress in shear (68 MPa [2]) after the analytical calculation. The calculation and the element removal process were repeated until the humerus was completely separated.

RESULTS

An example of the stress distribution under the 61Nm axial torque is shown in Figure 2. The fracture lines created in three models are shown in Figure 3. In all cases, the fracture lines became spiral. The thickness of the cortical bone (measured at deltoid muscle adheres) and the lowest external rotation torque that cause fracture in the three models were shown in Table 1.

Table.1 The relationship between the thickness of the cortical bone and the lowest torque to make fracture in each model.



Discussion

The fracture lines created in this study are close to the typical fracture line seen in clinical cases (Figure1). This fact supports the validity of our model and simulation.

Our results proved that the axial torque more than 51Nm could cause the humeral fracture. In addition, we consider that the thinner the cortical bone is, the humerus is easier to be fractured. So we suggest that the thickness of the humerus should be one factor to cause the throwing fracture.

Figure.1
Typical fracture line of the throwing fracture [1].

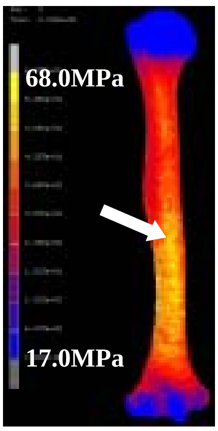


Figure.2
An example of the stress distribution .

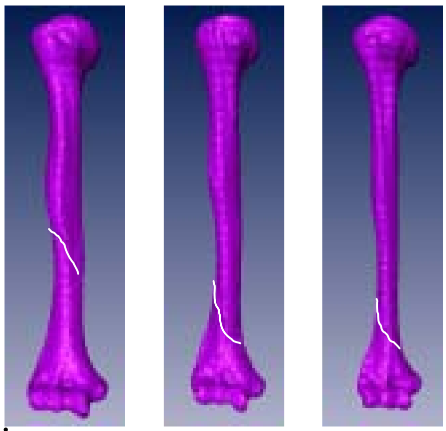


Figure.3
The fracture line in three models.

REFERENCES:

[1] Ogawa K et al. Am J Sports Med Vol.26 (2) p.242, 1998
[2] Reilly DT et al. J Biomech 8 (6) p.393, 1975