Biomechanical Study of Kümmell's Disease by Finite Element Analysis

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INTRODUCTION

Delayed posttraumatic vertebral collapse (Kümmell's disease) is a rarely reported, poorly documented, and poorly understood phenomenon. Schmorl and Junghanns [1] and Resnick and Niwayama [2] supported and defined the delayed vertebral collapse as a form of vertebral osteonecrosis. Based on the Symptoms, radiographies, and MRI findings from 129 patients, classification of the Kümmell's disease has been studied by Li et al in 2004 [3]. Three stages of the disease were found. The object of this study is to understand the stress distribution of vertebral body with various levels of vertebral collapse. The comparison of stress distributed on the vertebral body can be a good reference to the development of three-stage classification system.

METHODS

A three-dimensional finite element model of the intact vertebra was developed. There were 5334 nodes and 25720 elements in this intact model. Four zones of materials, including cortex, cancellous bone, posterior elements and cleft element, were assigned. Various percentages of cancellous bone in other models were excavated to simulate different levels of vertebral collapse (Fig.1). Totally, twenty-two models with various sizes of intravertebral clefts, including 0% (intact), 1%, 2.5%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90% and 95% clefts in vertebral height. Nodes under the inferior end plate of vertebral body were fixed as the boundary condition under loadings. A 1000 N compression was evenly loaded on the superior end plate. In addition to compression, flexion and extension condition were also simulated by loading a 5 N-m torque. The von Mises stress distribution on vertebra was compared among vertebral models with various collapses.

RESULTS AND DISCUSSION

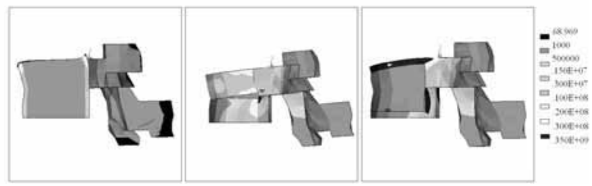
In compression, the maximal von Mises stress in vertebra was much higher than intact and distributed at the bilateral corners of the intravertebral cleft inside the superior endplate (Fig. 2). Comparison among models with various sizes of clefts showed that there were three zones on the curve of maximal von Mises stress along increasing sizes of clefts (Fig. 3). Vertebral collapses with 10 % and 80 % clefts were two transitional points on this curve. In flexion and extension, curves with a similar trend were also found. On the other hand, high stress also concentrated at the posterior cortex behind the cleft.

Three-stage classification has been established by Li et al. The stage I was defined as when the plain x-rays or MRI revealed osteonecrosis signs in vertebral body. The stage II was that body collapsed with intact posterior cortex of body. The stage III was that posterior body cortex collapsed with cord compression. Treatment for each stage was different.

This finite element simulation has shown that the level of stress distributing on vertebral body depended on the size of the intravertebral cleft. Especially, there were three stages in the relation curve between the maximal stress and cleft's size. This becomes a biomechanical evidence to support the clinical finding of three-stage classification for the Kümmell's disease.

Intact (0%) 20% 40% 60% 80%

Figure 1: Models with various sizes of intravertebral clefts.



Intact (0%) 10% 80%

Figure 2: The von Mises stress distribution under flexion

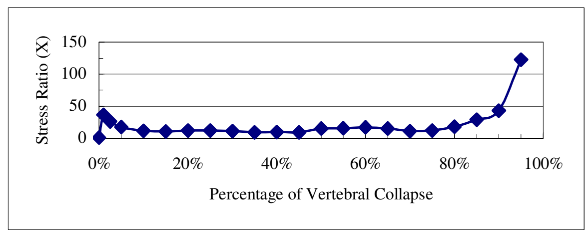


Figure 3: The ratio of maximal von Mises stress in vertebral body with various collapses to the intact under compression. The 0 % of vertebral collapse represents the intact.

CONCLUSIONS

From view points of pathological and biomechanical progress, three-stage classification system is probably appropriate to the diagnosis of Kümmell's disease.

REFERENCES

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