FINITE ELEMENT ANALYSIS OF DIFFERENT DESIGN TYPES OF ARTIFICIAL CERVICAL DISC

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INTRODUCTION

Non-fusion type artificial disc prostheses have been developed in hoping to keep the mobility of the instrumented level [1]. Several types of artificial discs are on the market. The objective of this study was to use a computational finite element method to generate the cervical spine model from digitized CT scans, and to evaluate the effects of different motion design types of artificial cervical disc on the biomechanical behavior of the cervical spine.

METHODS

Finite element model (FEM) of intact cervical spine (C3-C7)

The geometry of the cervical spine was generated from the digitized CT scans using an image-processing software (Amira, Mercury Computer Systems, Inc., Massachusetts, U.S.A.). The surface models of the vertebral bodies and discs were transferred to a finite element pre-processing program-Mentat (MSC Software Corp., Los Angeles, U.S.A.) and the finite element mesh of the intact cervical spinal model (C3-C7) was generated with 76,400 10-node tetrahedral elements as shown in Fig. 1a.

FEM with artificial disc

The simple models for three different types of artificial cervical discs as shown in Fig. 2. The FEMs of the C3-C7 motion segments implanted with three different design types of artificial disc are shown in Figs. 1b-d. The loading conditions were applied on the superior surface of the C3 with a 73.6 N compressive preload, together with four different kinds of 1.0N-m moments to simulate the following motions: (1)flexion, (2)extension, (3)lateral bending, (4)torsion, respectively [2]. All analysis results for the models with artificial disc prostheses were compared with those of the corresponding intact ones.

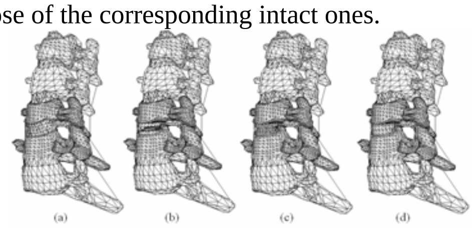

Fig. 1: Finite element model of the C3-C7 spinal unit, and the same unit implanted with the prosthesis (a)Intact (b) Type Ⅰ (c) Type Ⅱ (d) Type Ⅲ

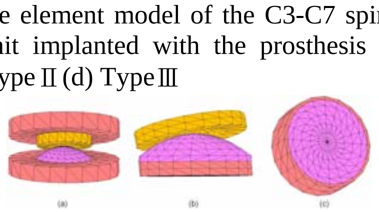

Fig. 2: The finite element models of the artificial cervical discs (a) Type Ⅰ (b) Type Ⅱ (c) Type Ⅲ

RESULTS

Operative level range of motion (ROM) analysis

Under flexion, the ROM after the Type I artificial disc insertion was smaller (14%) than the intact model. However, there was no significant difference in ROM under the other loading conditions. By implanting Type III artificial disc, ROM showed no significant difference (overall below 10%) in all loading conditions.

The distribution of center of rotation (COR)

At the implanted level, the COR relative loci for three different designs of artificial cervical discs range in front of cervical spine during flexion. In addition, the COR relative loci showed slightly backward than those of the intact group during extension (Fig. 3).

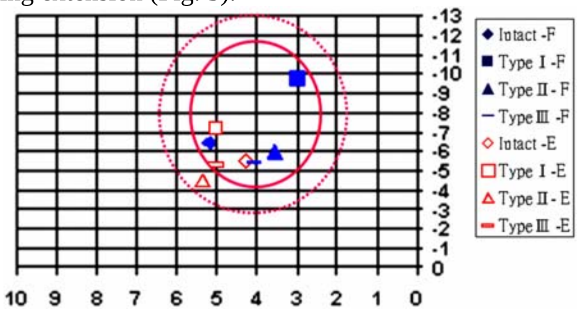

Fig. 3: The FE analysis results compared with past experimental studies, the COR of cervical spine under flexion-extension moment.

DISCUSSION

Compared with past experimental studies, our analysis results were somehow different. It was possibly caused by the simplified condition associated with the height of simple models in artificial cervical discs. The oversize on models could possibly result in numerical variance. The Type Ⅲ movable joint was designed with a flexible structure and this design concept is more similar to the real structure of cervical disc. In addition, Type Ⅰ and Type Ⅱ movable joints were designed with a ball-and-socket joint, as well as the design of sliding joint. Thus, after the implantation, there would be height variances on the COR loci.

CONCLUSIONS

The current study compared the influence on cervical spine motion of the intact group with and without the implantations of artificial cervical discs with various movable joint designs. The loci of COR in Type Ⅲ were closer to that of the intact group. The design for movable joints with implanted objects could affect the locus heights or the forward and backward shifts for the COR when receiving loading moments.

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