COMPARATIVE KINEMATIC ANALYSIS OF INTERVERBAL CONNECTION

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1. Introduction

The degeneration of the intervertebral disc is more and more frequented problem of aging population [1]. Approaches to its treatment are various [2]. The choice of the treatment method depends on a range type of the disc degeneration. Damaged spinal disc can be replaced by an artificial one. This approach suffers from: problems with a design of mainly used artificial discs - behaviour of those implants badly follows behaviour of the real intervertebral disc and whole joint. Problems with a type of an artificial disc which will be implanted are that the chosen implant type depends only on subjective decisions of attending surgeon. Problems are also with accuracy of positioning the artificial disc during surgical intervention. The aim of our whole work is to help to spinal surgery to solve these problems and objectify surgeon’s determination from the biomedical engineering point of view. There is an idea to build up a sophisticated numerical model of the part of spine which will be able to simulate an effect of applicable surgical techniques on the unique treated spine. More advanced understanding healthy intervertebral joints behaviour in the comparison with implanted artificial disc behaviour is necessary for this purpose. So the intervertebral kinematics is in the centre of our interest and this paper is focused on a validation of the approach and methodology. It is necessary to describe and compare the change of the intervertebral kinematics after the implantation of an artificial disc.

The bony vertebrae was simplified and modelled as a rigid body and the more complicated intervertebral discs were modelled as the assembly of an outer hyper elastic

2. Experiment

An experimental study of kinematics is required for a successful FEM modelling as well as for a verification of the final intervertebral kinematics model. The helical axes were used for the description of the intervertebral joint movement [4]. Several porcine three-vertebras chains were used for these experiments. Each vertebra of the prepared specimens was marked by three markers which allow us to examine its 3D motion. The Qualisys – 3D motion capture system with six cameras was used for this examining. The load of the specimens was realized by an original loading mechanism. Kinematical loading was applied into L3 vertebra whereas the L5 vertebra was fixed and the kinematics of the spine segment during flexion and extension was examined. Each specimen was examined before and after implantation of an artificial disc. The artificial disc was always implanted between L4-L5 intervertebral joints. Three anatomically significant points were marked at each specimen for the definition of the local coordinate system which helps us with comparison experimental and numerical model data.

3. Numerical model

Geometry of the tested specimens was obtained by using commercial Mimics software via computer tomography images and exported to commercial software ABAQUS which was used for the numerical analysis. material (annulus fibrosus) and an inner incompressible fluid (nucleus pulposus). The simulation of the spine motion with an artificial disc was repeated for four different positions of the artificial disc. The boundary conditions were the same as in the experiments.
4. Results

Centres of rotation positions were examined for experimentally measured healthy specimen in comparison with the experimentally measured specimen with the artificial disc. Results of this comparison are shown at Fig. 1 where circles represent the healthy spine centres of rotation and dots represent centres of rotation of the spine with implanted artificial disc.

![Fig. 1: Comparison of centres of rotation positions obtained by experimental analyses](image1)

The same comparison (healthy specimen versus the specimen with the artificial disc) was made for results of numerical analysis by FEM. Fig. 2 shows results of these analyses, squares represent the healthy spine centres of rotation and other symbols represent the centres of rotation of the spine with in different positions implanted artificial disc.

![Fig. 2: Comparison of centres of rotation positions obtained by numerical analyses](image2)

Finally, results of FEM models and experimental data were compared. This comparison (experiment versus FEM) is necessary for fitting data to the model as well as for the model validation.

5. Conclusion

The position importance of an artificial disc was demonstrated on the intervertebral kinematics. There are evident differences between experimentally obtained centres of rotation and centres of rotation obtained by FEM analysis. The problem is based on difficulty to obtain the relevant mechanical properties of the model because there are many differences in published mechanical properties.

We are going to put more precisely the methodology of the experiment and debug the numerical model in the next step of our work.

It is assumed that the model of the human spine created by the same procedure will be valid as well as the model of the porcine spine.

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7. References


