Numerical study of intervertebral prosthesis

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ABSTRACT

Lumbar interbody fusion is a lumbar surgical procedure that consists of replacing the intervertebral disk with a stiff prosthetic device (the fusion cage), promote bone growth in between the two vertebrae, and finally get them fused into one single rigid unit. In order to that the fusion cage is usually hollow in order to be able to accommodate new bone in its interior. Often this kind of surgery has been considered the only option when disk diseases are severe.

The numerical studies described in this paper are oriented to clarify the mechanical behavior of the new vertebral configuration after the fusion cage has been installed. The geometrical model includes vertebrae L5 and S1 and has been directly generated from radiological images, with individual representation of the stiffer cortical bone on the surface and the softer trabecular bone in the interior, as well as the prosthesis device in between the two vertebrae. Two load cases are considered which correspond to the body in static rest and to the person lifting a weight with his arms.

The FE analysis was first performed using a tetrahedral mesh and looking at the results in terms of conventional continuum stresses. A second study took advantage of the fact that cortical bone seems to work as a bending shell. Based on that, a new mesh was developed with the cortical bone made of 'extruded' prismatic elements of triangular base, in such way that all integration points through the thickness were aligned and it became possible to calculate the shell forces (moment, shear and axial) associated to the cross-sectional behavior of the cortical shell.

In this paper both types of results are presented, in terms of continuum stresses and of shell cross-sectional forces. In the biomechanical literature it seems traditional to represent the stresses state by means of the equivalent von Mises stress [1]. However, some studies [2] show that the behavior of cortical bone is dependent on the hydrostatic pressure (I_1 invariant) and also exhibits additional frictional mechanisms. In this article the continuum stress results are discussed using a hyperbolic model of Mohr-Coulomb type (Hyperbolic Mohr-Coulomb Model) in comparison to traditional von Mises. On the other hand, the results in terms of shell cross-sectional forces make it possible to identify the most critical areas of the two vertebrae in the configurations analyzed.

REFERENCES

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