BIOMECHANICAL ASPECTS OF TRANSPEDICLE SPINE FIXATION AND THEIR EFFECT ON LOAD TRANSFER AND STIFFNESS

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Introduction

Spinal fusion is primarily used to relieve pain due to abnormal vertebral motion. Next to treatment of degenerative conditions, spine fixation is also considered the preferred approach for the restoration of deformities, i.e. scoliosis and kyphosis [Rajae, 2012]. Late techniques favour immobilization and are able to restore extensive congenital and degenerative deformities, are however susceptible to prolonged diurnal loading causing loosening and eventual failure [Cho, 2010].

Even though some Finite Element (FE) studies have addressed the occurring biomechanics of transpedicle screw fixation [Faizan, 2012], the effect of several surgical related aspects on the load transfer and increase in stiffness of the treated spine segment still remains elusive.

Methods

A polyaxial pedicle screw with a double lead thread and a provisional locking system was considered as the main component of the spinal fusion device. This implant type facilitates spanning of screws over adjacent vertebral levels, at a predefined relative angle within the sagittal plane. The effect of the insertion angle was investigated on the preliminary hypothesis that altering the geometry of a pedicle based fixation will affect the load transfer within the system. Two rod materials (Ti alloy and PEEK) were simulated during the analysis to quantify the effect of fixation stiffness on the developing stress field. The implantation depth was considered as the final surgical parameter under investigation.

The pedicle screw was scanned with a μ-CT device (Werth TomoScope HV Compact) at a spatial resolution of 10μm, to reconstruct its 3D shape. Some features of the implant were considered as redundant for the analysis (i.e. internal immobilization mechanism) as their consideration would increase the complexity and computational effort, without contributing to the bio-realisticity of the model.

Each screw was embedded in a cubic geometry imitating vertebral bone. A compressive load of 50 N was applied on the superior support whereas the inferior one was restricted of any movement. A second loading scenario, corresponding to 10 Nm torsion of the vertebral column, was also adopted. The model was simulated in ANYS 14.0 considering linear elastic material properties [Gornet, 2011].

Results

The implantation of the pedicle screws at a 10° relative angle, lead to a stress decrease of approximately 10% for the Ti and 15% for the PEEK rod scenarios as illustrated in figure 1. Parallel positioning resulted however in higher stiffness of the fixation system. The range of motion increased significantly for PEEK based immobilization [Gornet, 2011] in particular during the application of torsion or shallow implantation.

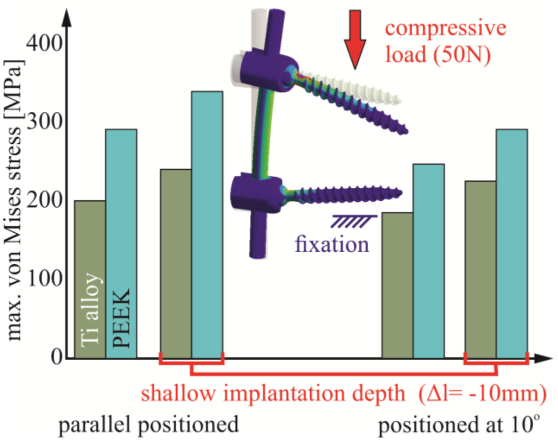

Figure 1: Parameter dependent max. von Mises stress developing on a transpedicle screw.

Discussion

The results indicate that implantation should be always performed as deep as possible. Parallel screw positioning is preferable for non-osteoporotic patients and the choice of rod material depends on desired rigidity. Osteoporotic patients should be treated with Ti rods and inclined screws positioning, in order to restrict mobility of the spine segment and avoid critical stress development within the vertebrae.

References

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