IN SILICO OPTIMIZATION OF A NOVEL PEDICLE SCREW DESIGN AND VALIDATION BY EXPERIMENTAL RESULTS

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Introduction

Posterior dorsal instrumentation with pedicle screw rod systems is still the gold standard for spinal fusion procedures. The pedicle screw itself plays a major role for this stabilization construct regarding bone anchorage and load bearing of the adjacent vertebrae.
However pedicle screw failure is reported in the range of 3-7% [1]. The aim of this study was to increase the mechanical strength of a pedicle screw by stress optimization of the thread screw design with respect to improve the endurance properties.

Methods

A closed loop numerical and experimental procedure was used to investigate the stress concentration of two types of pedicle screws: A (S^4 standard pedicle screw design, Aesculap, Germany) and B (novel Ennovate Pentacore pedicle screw design, Aesculap, Germany).
The experimental part was to evaluate the fatigue strength of the screws in a single component test setup according to ASTM F2193. The load was applied in compression and tension with a load ratio ($R=F_{max}/F_{min}$) of R=-1 with a lever arm of 7 mm to the polyaxial screw head. The numerical analysis was a FEA investigation (ANSYS, V16.2) simulating the same load case as used in the experimental setup for evaluation and localization of the maximum principal stress (Fig.1).

Figure 1: FEA model used for stress optimization

This was done for all screw lengths and diameters to determine the influence of screw thread design, length and diameter regarding occurring principal stress.

Results

From the experimental test setup it could be shown that the fatigue strength of the optimized pedicle screw design, B, was improved by 28% in comparison to the pedicle screw design A. The location of the maximum stress concentration evaluated in the numerical model is in perfect agreement with the failure mode seen in the experiments for both screw types (Fig. 2).

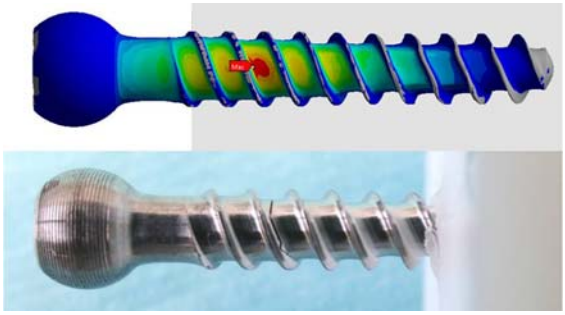

Figure 2: Location of the maximum stress concentration - FEA simulation (top), failure mode in the experimental setup (bottom) for design B

The numerical simulation predicted 38% of stress reduction for the optimized screw design B (Fig.3).
Only for the Ø 4.5 mm screws a decrease of stress with screw length could be determined. With larger screw diameters the stress decreased as well and stayed constant with increasing screw length.

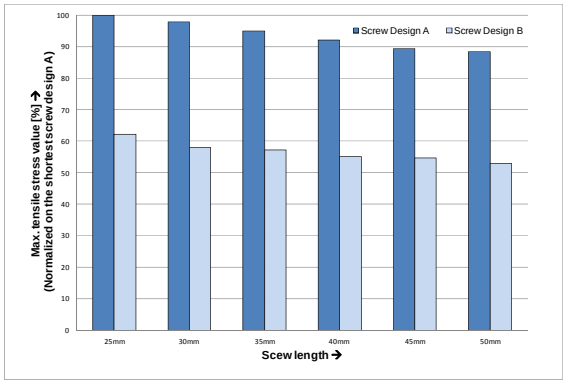

Figure 3: Observed max. tensile stresses for the Ø 4.5 mm screws of design A and B

Discussion

Based on design optimization of the pedicle screw thread design with FEA regarding location and amount of occurring principal stress under representative pedicle screw loading scenarios a substantial improvement could be achieved. This improvement could be confirmed by the experimental test series for the optimized screw design. Hence, for the optimized screw design a reduction of clinical screw failures could be expected.

References

1. Yuan et al, Spine, 19:20S, 1994.