FATIGUE LIFE OF SPINAL FIXATION DEVICES: EXPERIMENTAL AND COMPUTATIONAL ANALYSIS

Luigi La Barbera[1,2], Tomaso Villa[1,2], Giancarlo Pennati[1]

[1] LaBS, Department of Chemistry, Materials and Chemical Engineering "Giulio Natta", Politecnico di Milano, Italy; [2] IRCCS Istituto Ortopedico Galeazzi, Italy

Introduction

The preclinical evaluation of any orthopaedic device is an important step before it is introduced into the market. Since the experimental evaluation requires high costs in terms of time and money, the aim of this work is to evaluate the possibility of introducing a numerical method capable of predicting the fatigue mechanical behaviour of a transpedicular screw.

Methods

In order to determine the behaviour of a commercial Ti6Al4V spinal fixation device static tests were performed according to ASTM F1798 standard (Fig. 1.a). Fatigue tests were then performed applying a sinusoidal load at different load levels (350, 325, 300, 275, 250, 225 N, load ratio 0.1, run-out 15Mcycles) and Wöhler diagram was built (n=25, Fig. 1). Starting from home-made measurements on the device and using PTC Creo, a 3D CAD model of all the components was built and a sensitivity analysis on geometrical parameters was performed. A finite element model was built up in Abaqus to describe test condition (Fig. 1.b), assuming linear elastic material behaviour. Sines criterion for high-cycle fatigue under multiaxial proportional loads was used and safety coefficients were calculated at each load level. Both static and fatigue mechanical parameters of Ti6Al4V were assumed from literature [Kallmeyer, 2002; Peters, 2002].

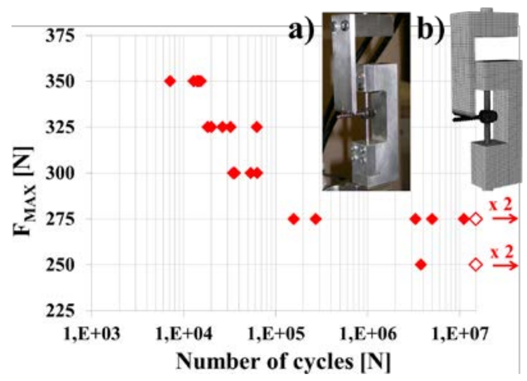

Figure 1: Wöhler diagram with experimental set-up (a) and FE model (b) according to ASTM F1798.

The influence of the different material parameters on predictions was evaluated with a further sensitivity analysis. Simulation of the static test was validated comparing the overall stiffness measured during static tests and numerical predictions. Validation of fatigue predictions was discussed by comparison with experimental results.

Results

Overall stiffness value predicted by numerical model agrees with the experimental measure within a 1%. The numerical model coupled with Sines criterion was capable of predicting the location of crack initiation in correspondence of the first complete screw thread which undergoes traction (Fig. 2).

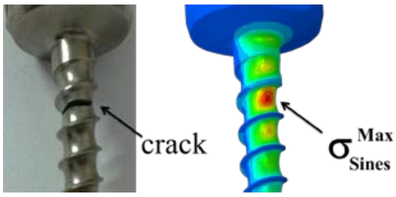

Figure 2

The numerical simulations showed stress values beyond the yielding point in the crack initiation zones: however, when these areas were limited and in correspondence of particular geometrical and material parameters, Sines criterion was able to predict failures/not failures.

Discussion

Difficulties were found when trying to predict the whole fatigue performances of the device. This was probably due to a number of factors: uncertainties on the real material parameters and geometry; influence of surface treatments on the effective strength of the device. Moreover the presence of yielded zones suggests the usage of specific criterion based on a strain approach (e.g. Manson, Coffin and Morrow criterion).

References

Kallmeyer et al, J Eng Mat and Tech, 124:229-237, 2002. Peters et al, Eng Fract Mech, 69: 1425-1446, 2002.