DEVELOPMENT OF FATIGUE TESTING PROTOCOL AND IMAGE BASED ANALYSIS OF SMALL FRAGMENT CORTICAL BONE SCREWS

Suneel Battula MS [1], Emily M.Njus [2], John Konicek [1] and Glen O. Njus PhD [1]

[1] Department of Biomedical Engineering, The University of Akron, Akron, OH, USA
[2] Department Biology, The University of Akron, Akron, OH, USA
E-mail: bsuneel@uakron.edu

INTRODUCTION

Self-tapping cortical bone screws (STS) have been used as effective tools for osteosynthesis but there have only been a few studies comparing the biomechanical and fatigue properties of these screws. Fatigue characteristics of small fragment screws haven't been extensively studied as they involve time and resource intensive testing. But fatigue is an important characteristic as the implants are subjected to cyclic loading. Fatigue is the result of cumulative process consisting of crack initiation, propagation and finally fracture of the component/construct. During cyclic loading localized plastic deformation may occur at the highest stress site. This plastic deformation induces permanent damage to the component and a crack may develop. As the component experiences an increased number of loading cycles, the length of the crack increases and after a certain number of cycles, the crack will cause the component/construct to fail. Hence arises a need for failure analysis of the whole construct and the each component by itself.

The purpose of this study is to design an efficient testing protocol and use image analysis as a tool for fatigue analysis of small fragment screws. The main objectives of this study are to determine the effect of the screw design parameters and geometry on the fatigue characteristics and to analyze the effect of the screw material on fatigue properties for screws with similar design.

METHODS

The fatigue life analysis of 4 different types of screws was conducted using a fatigue-tester designed according to the American Society of Testing and Material (ASTM) standards. The tested screws were all 3.5mm cortical screws (specifications given in Table 1) and included both stainless steel and titanium screws.

Table 1. Significant measurements of the screws from the four vendors.

	OD *(mm)*	ID *(mm)*	Pitch *(mm)*	Head Dia *(mm)*	OD/ID
V1	3.51	2.64	0.78	6.32	1.33
V2	3.53	2.21	1.30	4.60	1.59
V3	3.48	2.39	1.28	5.92	1.46
V4	3.48	2.39	1.28	5.92	1.46

Thirty-two screws were categorized into two test groups (sixteen per group), one group was used to determine the fatigue characteristics based on screw design and the other group was tested to analyze the effect of material on the fatigue life. The screws were tested in cantilever bending mode using the fatigue tester on an Instron 8511 (Canton, MA), material testing system. The testing was performed under load-control mode with an R-ratio of 0.1 with appropriate safety limits for load and displacement. The tested specimens were then analyzed using microscopic images.

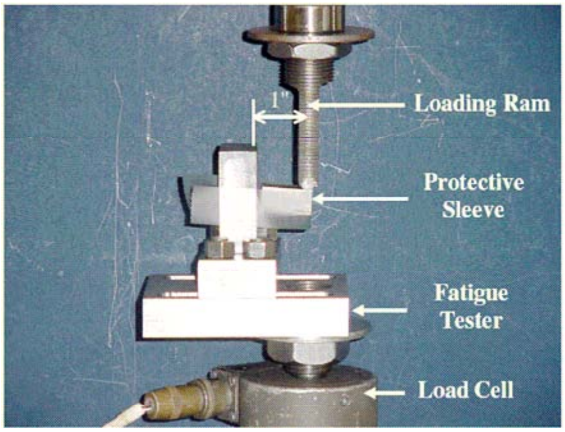

Figure 1: Experimental Set-up

RESULTS AND DISCUSSION

All the tests ended in failure with a broken screw specimen. The fatigue lives of the screws from vendors V1 and V4 (SS) were longer than the screws from vendors V2 and V3 respectively. The screws with lower OD/ID ratio had longer lives than those with higher OD/ID ratio demonstrating that the core (minor) diameter is a principal factor determining the fatigue life.

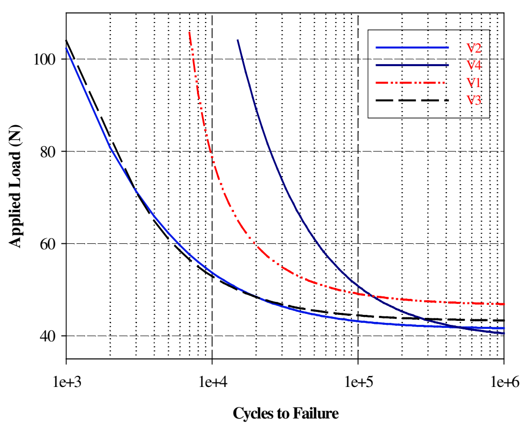

Figure 2: S-N Curves illustrating the fatigue life in number of cycles for applied loads.

The results also show that the screws with finer threads (lower pitch) have longer fatigue life. Stainless steel screws had a longer fatigue life than the titanium screws with similar screw geometry demonstrating the effect of the material properties on the fatigue life.

The image analysis yielded a stable propagation area of 49% for V1 as compared to 44% of V2 and 42% for V4 as compared to 37% of V3. The correlation values between the applied load and stable propagation area weren't very high. Testing of more samples might yield a higher correlation that might aid in the analysis of the failed samples retrieved from the patients.

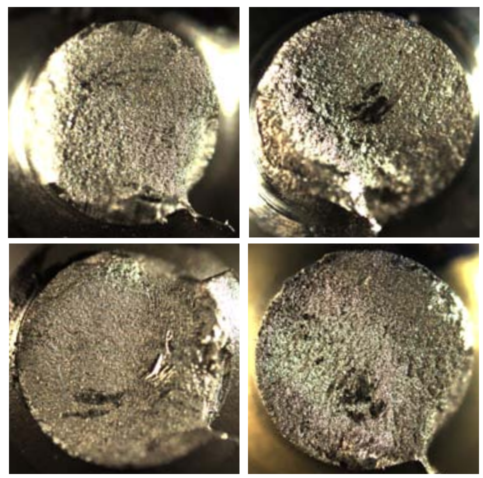

Figure 3: Fracture surfaces of the screws after their failure. (a) V2 (b) V4 (c) V1 & (d) V3.

SUMMARY/CONCLUSIONS

The analysis supports OD-to-ID ratio as the principal factor determining fatigue life as results paralleled implant geometry. But a design modification to improve bending and fatigue strength based on a decreased OD/ID ratio (and decreased pitch) might affect the pullout strength. It was also observed that stainless steel screws had better fatigue characteristics (more cycles to failure) than pure titanium screws in spite of similar geometric designs

REFERENCES

Merk. B, Stern. S, et al. (2001). *Journal of Orthopaedic Trauma,* 494-99.