Creep, Stress Relaxation and Fatigue Properties of Polypropylene Mesh

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INTRODUCTION

Polypropylene (PP) meshes have wide applications in surgical procedures such as hernia repair, gynecological and urological repair, and cardio-thoracic repair. Past studies on PP meshes have mainly concentrated on morphology, porosity, fabric count, and static mechanical properties,[1-3] paying little or no attention to the viscoelastic behaviors these materials may exhibit. To understand their time-dependent properties, we have conducted a series of investigations on PP meshes. Reported here are the results of creep, stress relaxation and fatigue tests.

MATERIALS AND METHODS

The PP meshes used in this study were experimental materials (ETHICON, Somerville, New Jersey). The tensile breaking strength of the mesh is about 80 N. For the purpose of this study, the mesh was cut into specimens with lengths of 200 mm and width of 10 mm. Five specimens were used for each of four tests: stress relaxation, creep, displacement-controlled fatigue and load-controlled fatigue. All tests were conducted at room temperature on an Instron 5544 tester with a 50-N load cell using Merlin software. A gauge length of 127 mm was used. The stress relaxation tests were realized by applying a 25-mm constant elongation to the specimen for 60 min and recording changes in load with time. The creep experiments were conducted by applying a 4.45-N constant load to the specimen for 60 min and recording changes in elongation with time. For the displacement-controlled fatigue test (extension range of 0-25.4 mm) and load-controlled fatigue test (load range of 0.44 to 4.4 N), the crosshead speed was 12.7 mm/sec and changes in load or elongation with fatigue cycling were recorded for a total of 2000 cycles.

RESULTS AND DISCUSSION

All four experiments showed good repeatability on 5 replicates. Following the testing, PP meshes retained their structural integrity. The permanent elongation due to creep and stress relaxation was less than 8% after recovery. Fig 1 displays a typical stress relaxation experimental result for a PP mesh. The figure clearly shows stress relaxation behavior of the sample, i.e., the force needed to maintain the elongation decreased with time, and the relaxation rate decreased with time. The typical creep behavior of a PP mesh is illustrated in Fig 2. This graph shows that the PP mesh samples exhibited a limited creep during test, with an initial elastic response followed by slow elongation over time under constant load. The fatigue results are presented in Figs 3 and 4. In displacement-controlled fatigue, the peak load showed some drop at the beginning of the test, then rose above initial load and kept almost unchanged for the most of fatigue cycles. Fig 4 is the result of load-controlled fatigue. The graph indicates that the changes in peak elongation were small during fatigue cycling, from ~19 to 20 mm. Overall results suggest that the fatigue cycling conditions in this study had minimal effects on PP meshes, and the meshes responded to the cycling load mainly elastically.

SUMMARY

Creep, stress relaxation and fatigue studies were conducted on PP meshes. The meshes exhibited time-dependent properties under the experimental conditions used in this study. Since a PP mesh is a permanent implant, these types of behavior are important to understand in order to understand their effects on the material's long-term performance in biological environment.

REFERENCES

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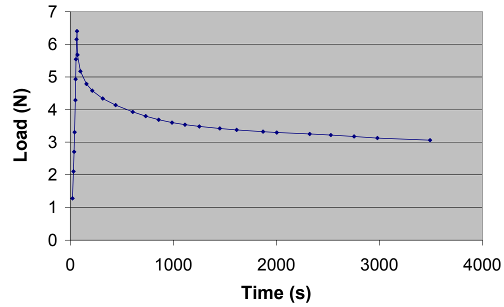

Fig 1. Change of load with time in a stress relaxation test

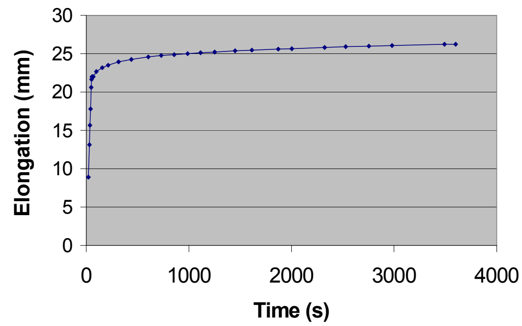

Fig 2. Change of elongation with time in a creep test

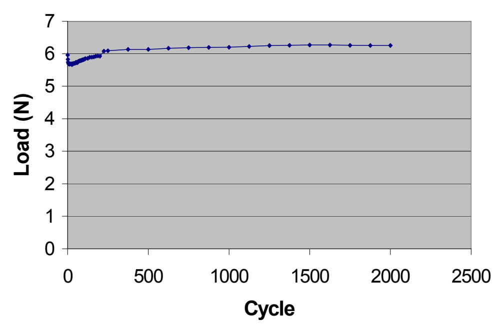

Fig 3. Change of peak load with cycle in a displacement-controlled fatigue test

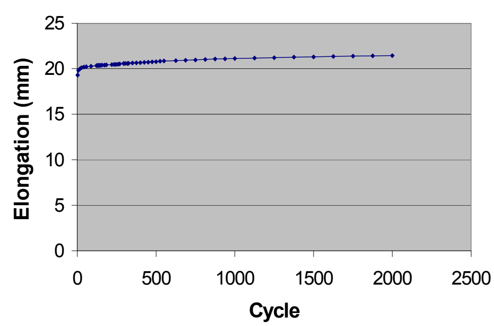

Fig 4. Change of peak elongation with time in a load-controlled fatigue test