A Preliminary Study on Effects of Cyclic Loading and *In Vitro* Degradation on Mesh Porosity

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INTRODUCTION

Porosity and pore size are important properties of mesh-based implants as a porous structure allows tissue ingrowth and provides mechanical support to tissues for such procedures as tension-free hernia repair [1-2]. Furthermore, foreign body response to implanted mesh has direct correlation to its surface area in contact with tissue, which is highly dependent on its porous property [3]. Implanted mesh into dynamic anatomic structures may be strained, which may lead to its deformation and possible change in porosity and pore size [4]. For a partially degradable mesh, material loss may lead to changes in the porosity. Studies in the related areas are rare. As a result, this study was conducted to investigate effects of cyclic loading and *in vitro* degradation of degradable components on porosity and pore size of two types of meshes.

MATERIALS AND METHODS

Experimental polypropylene (PP) mesh strips (25x90mm) were subjected to fatigue testing on an Instron 5544 tester with a 100-lb load cell and 25-mm gauge length. Mesh samples of both machine and cross directions were subjected to displacement-control fatigue testing with extension 0-4.3mm (elastic region) or 0-13mm (elastic-plastic region) at 1 Hz for 10000 or 2000 cycles. Then porosity, the percentage of open area in the total mesh area, was measured using a Nikon SMZ 1500 optical microscope with NIS-Elements BR-2.30 Imaging software by threshold analysis. For the degradation effects on porosity, partially degradable mesh samples (25x25mm) made of PP and poliglecaprone (slightly different from pure PP mesh) were subjected to *in vitro* degradation in a phosphate buffer solution of pH 7.3 and 55°C. Two samples were removed at various time intervals and porosity was measured.

RESULTS AND DISCUSSION

Examples of the mesh and threshold images used for pore analysis are shown in Fig 1. Major information that could be obtained from image analysis includes porosity, pore size and their distribution. Fig 2 illustrates an example of pore analysis result, showing maximum calculated pore size of 4.4mm for PP mesh control. It is known that to permit ingrowth of soft tissue, pore size should be >0.1-0.6 mm [4] of which the results showed that a good percentage of pores had this size range for this mesh. Table 1 is an example of data compilation for PP mesh from imaging analysis leading to porosity results. Fig 3 (left) exhibits the porosity results for PP meshes, indicating that effects of the fatigue testing were small on porosity. The results showed that the porosities for PP meshes before and after fatigue were between 60 to 70%. Fig 3 (right) shows the experimental results of porosity for the partially absorbable mesh samples subjected to *in vitro* degradation for up to ten days. This figure demonstrates a negligible effect on porosity before the degradable components were gone, which could be easily understood based on the fact that the degradable fibers were braided into the PP fibers. For pore size, similar results were obtained.

SUMMARY

A study was conducted to examine effects of fatigue testing and *in vitro* degradation on two mesh materials. This study indicated that image analysis is an effective method to determine the mesh porosity in two dimensions. The results showed that the fatigue cycling conditions in this study did not significantly change the porous structure of the PP meshes. For the partially degradable mesh, *in vitro* degradation had little effect on its porous properties due to its constructure.

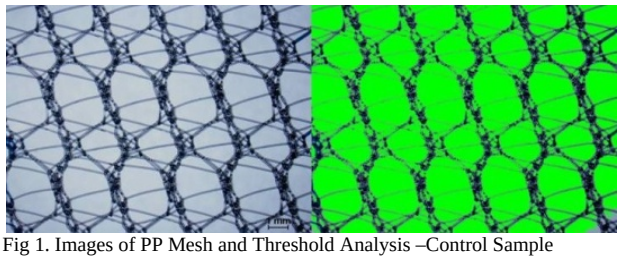

Fig 1. Images of PP Mesh and Threshold Analysis –Control Sample

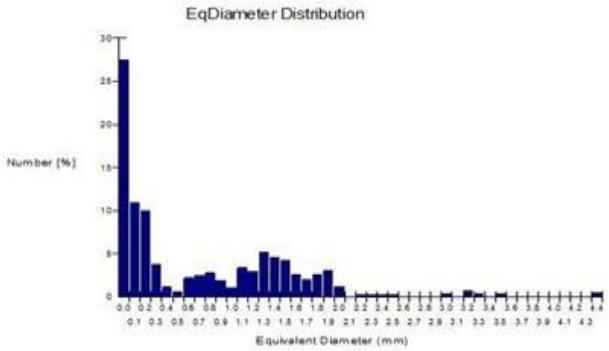

Fig 2. Pore Equivalent Diameter Distribution of PP Mesh (Control)

Table 1. PP Mesh Analysis Results

Sample	Control	Fatigue displacement (mm)	
		0-4.3	0-13
Number of Fields	4	2	3
Number of Objects	6743	3105	3217
Measured area (mm^2)	751.58	375.79	332.62
Objects per Area (mm^2)	9.0	8.3	9.7
Area Fraction (%)	67.32	72.41	64.72

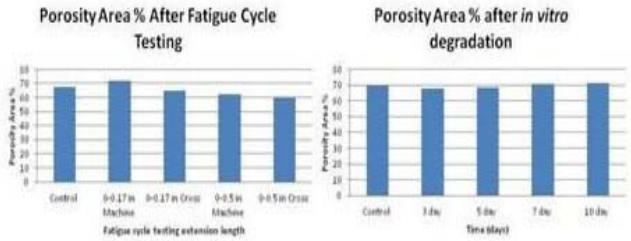

Fig 4. Effects of Fatigue and Degradation on Mesh Porosity

REFERENCES
1. F.H. Greca et al. Hernia 12(2008); 2. L. Boulanger. et al. Euro J Ob & Gy & Repro Biol 125 (2006); 3. B. Klosterhalfen et al. Expert Rev. Med. Devi 2 (2005); 4. T. Mühl T. et al. JBMR Appl Biomat (2007)

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