Characterization of Fracture Properties of Very Soft Tissue

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ABSTRACT

Single notched tensile tests were used to investigate the fracture properties of pig kidney cortex material under tensile load. Fracture toughness of pig kidney cortex estimated from the fracture work divided by the new crack surface area under single load cycle was presented with the assumption of no viscoelastic and plastic responses. The fracture energy estimated by experiments is approximately 1.187E-04 N-m/mm².

INTRODUCTION

Soft tissues such as brain, liver and kidney are very vulnerable to trauma during car crash and other impact consequences. Furthermore, the failure properties of soft tissues are important in disease and tissue engineering. The knowledge of fracture mechanics properties of these very soft tissues is valuable for simulation, designing methods of injury prevention, tissue engineering and medical procedure. For example, Extracorporeal Shock Wave Lithotripsy (ESWL) is the medical procedure by which large amplitude acoustic shock waves, generated extracorporeally, are focused onto a kidney stone in the kidney or ureter causing the stone to fragment and by far is the method of preference to treat kidney stone. However, there is evidence that the shock wave leads to permanent damage to healthy tissue in the kidney and the significance of the injury is also debated. In order to investigate the issues of kidney tissue damage under ESWL procedure, the understanding of fracture properties of kidney soft tissue is required. The most common method to measure failure properties of soft tissues is the uniaxial tensile test. This test is appropriate for load-bearing tissues like ligaments and tendons, but is less suitable for other tissues which do not fail by direct tension. A crack propagation or tear test is more suitable for these tissues [1-3]. Single notched tensile tests were frequently used to investigate the fracture properties of this type of soft tissue. For example, cyclic tension tests were performed in displacement control for notched specimens to acquire fracture properties of soft tissues with the consideration of viscoelastic work dissipation by Koop et al. [4] and Oyen-Tiesma et al. [5]. In this paper, fracture toughness of pig kidney cortex estimated from the fracture work divided by the new crack surface area under single load cycle was presented with the assumption of no viscoelastic and plastic responses.
EXPERIMENTAL METHOD

Fresh porcine kidneys obtained from an abattoir were stored in refrigerator for experiments. Sections of pig kidney were cut with approximately 1.5 mm in thickness prior to experiments. The specimen was cut from the location of kidney section as shown in Figure 1. The approximate specimen dimension is 12 mm wide by 40 mm long. Experiments were performed by using a step motor driven linear stage. Specimen was first glued to glass slides on both sides and held by a set of custom-made clamps. One clamp was fixed on an optical bench and another clamp was mounted on a step motor driven linear stage. (Figure 2). The gage length of the gripped notched specimens was approximately 10 mm. After the specimen was properly mounted on the clamps, a notch abot 1 mm was cut in the specimen with a sharp razor blade. The loading and unloading displacement rate used for current study was 2 mm/sec. Force and clamp displacement data were recorded for each test at a sampling rate of 4 Hz, and a high resolution digital camera was used to monitor the notch propagation and recorded the image at a rate of 1 frame per second.

Figure 1. Pig kidney cortex specimen for tensile tests.

Figure 2. Experimental setup for soft tissue fracture tests.

RESULTS

Figure 3 and 4 shows typical fractural process and load-displacement results of notched pig kidney cortex specimens subjected to tensile load and unload procedure (single cycle).
Figure 3. Fractural process under loading and unloading cycle.

Figure 4. Load-displacement result of fracture test.

Tabulated results of experiments are shown in Table 1.

<table>
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<th>No.</th>
<th>Notch length (mm)</th>
<th>Final crack length (mm)</th>
<th>Fracture length (mm)</th>
<th>Specimen thickness (mm)</th>
<th>Fracture surface area (mm²)</th>
<th>work (N-m)</th>
<th>Fracture energy (N-m/mm²)</th>
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Table 1. Tabulated results of experiments.
The average fracture energy computed from above experimental results is $1.187 \times 10^{-4}$ N-mm$^2$.

**DISCUSSION**

In current study, the viscoelastic work dissipation was not taken into consideration. However, in order to compute the fracture toughness of soft tissue more accurately, the amount of viscoelastic work done during the test must be considered. Furthermore, if compared with maximum load during the experiment, the force due to the self weight of specimen cannot be ignored. Performing experiments with specimens submersed in a saline bath should be able to minimize the self weight effects.

**ACKNOWLEDGEMENTS**

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**REFERENCE**