INTRODUCTION

Orbital fat (OF) and its encapsulating connective tissue (CT) (abbr. OFCT) have recently been found to play a significant role in orbital biomechanics. Some studies have reported that OFCT prevent anterior globe displacement in trauma, which provide an important mechanism of eye stability, and the injury mechanism of trauma was caused principally by the dynamics of OFCT relating to both the rotation and the increased intraocular pressure of the globe [1,2]. Other studies have suggested that OFCT play an important role in supporting eye movements. It was found that OFCT displace and deform proportionally in the same direction at significant level as the extraocular muscles and optic nerve during the eye movements, and this action helps in stabilizing the muscle paths [3,4,5].

The aim of the present study is to characterize the mechanical properties of OFCT.

METHODS

A total of 20 pig eyes and 20 human eyes will be obtained to complete this study. We have performed experiments on 8 pig eyes so far. The pig eyes were obtained from a local slaughterhouse within 4 hours of death of the animals, and the human eyes will be obtained from an eye bank within 48 hours of death of the donors.

One OFCT sample was obtained from each eye. The sample was dissected in either superior-inferior or nasal-temporal direction in the posterior region adjacent to the optic nerve head. Samples were consistently 1.5 mm in width by using a 1.5-mm-wide customized twin-blade cutting tool in the dissection. Dissected sample was placed in a custom clamp instrument that predefined the sample length to be 1.0 mm. Thickness of each sample was measured under a microscope. Though it would be ideal to measure the individual properties of the OF and CT. Separating them without damaging the integrity is impossible.

The clamp instrument with the secured sample was transported to our mechanical testing system (Bose® ElectroForce® 3100, Eden Prairie, Minnesota) and was submerged in a 37 ± 1 °C saline chamber. Displacement was applied to pull the sample linearly at 1 mm/sec by the machine. The reaction force was recorded during the testing.

Engineering stress was calculated from dividing the
reaction force by the initial area. Strain was obtained from dividing the applied displacement by the initial length. The stress-strain relationship was approximated linear before deformation reached plasticity (Figure 1), and this region was defined to be the elastic region of the samples. The elastic stress-strain relationship was best-fitted into a linear curve.

Statistical analysis using the two-sided rank sum test was performed to evaluate the difference of the yield stress, yield strain, and Young’s modulus between the samples in superior-inferior and nasal-temporal direction. The significance level was set to be 5 %. All data processing was done in MATLAB®.

RESULTS AND DISCUSSION

The yield stress, yield strain, and Young’s modulus of the samples are reported in Table 1. Although the nasal-temporal samples in average had an 86 % and 83 % higher yield stress and Young’s modulus than the superior-inferior samples had, our statistical analysis found that there was no significant difference between the samples in these directions.

The samples in average had a 1.5 % yield strain (Table 1), which is relatively small in soft tissues in general. When the samples were stretched beyond the elastic region, they did not fail completely. After the elastic region, the stress-strain relationship showed a long plateau region, which indicates that OFCT had a long plastic deformation characteristic (Figure 1). Future simulation study is required to understand how such mechanical characteristic may play a role in orbital biomechanics.

This is the first time the yield stress, yield strain, and Young’s modulus of OFCT are reported in the literature. We are continuing this study on both pig and human eyes, and we believe that these data are valuable to help us to understand the mechanical properties of OFCT and also to build a realistic computer model of the eye in the future.

REFERENCES


ACKNOWLEDGEMENTS

The authors would like to thank the financial support from the Department of Energy’s Office of Science (grant no. DE-FC02-04ER63735), W.M. Keck Foundation, and Clarence and Estelle Albaugh Trust.

### Table 1: Mean and standard deviation of the yield stress, yield strain, and Young’s modulus of the pig orbital fat and its encapsulating connective tissue samples in superior-inferior and nasal-temporal direction (n = 4).

<table>
<thead>
<tr>
<th></th>
<th>Superior-Inferior</th>
<th>Nasal-Temporal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield stress (kPa)</td>
<td>2.9 ± 2.5</td>
<td>5.4 ± 2.5</td>
</tr>
<tr>
<td>Yield strain (mm/mm)</td>
<td>0.015 ± 0.001</td>
<td>0.015 ± 0.001</td>
</tr>
<tr>
<td>Young's modulus (kPa)</td>
<td>302.4 ± 258.5</td>
<td>552.3 ± 266.7</td>
</tr>
</tbody>
</table>