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Correlating Collagen Orientation and Density with Age and Region in Human Eyes

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Retinal detachment, separation of the light sensitive layers of the eye, occurs in one out of 10,000 people in the United States and can lead to permanent blindness. While detachment may occur due to trauma, it can also be caused by age-related vitreous degradation or other age-related ocular disorders exacerbated by adhesion between the vitreous and retina. Collagen fibers are believed to be the primary contributor to vitreoretinal adhesion, but little empirical data exist to show how collagen varies with age and region in the eye. In this study, we characterize collagen at the vitreoretinal interface, and identify changes with age and region. Data from this research will be useful in understanding mechanisms of adhesion, and assist in creating mechanically accurate computational models for the human eye.

Transmission electron microscopy images (TEM) were taken at the vitreoretinal interface from the equator and posterior pole of human donor eyes (n=13, Fig. 1). TEM images were filtered with a non-local means denoising filter with smoothing parameter of 10. A technique called ridge detection was used to detect and segment collagen fibers, then a MATLAB code was used to combine segmented fibers based on slope, intercept and least-squares regression fit. Output parameters were collagen density, collagen fiber angle, and inner limiting membrane (ILM) thickness. ANOVA statistical analyses were used to compare results by region (equator vs. posterior) and age (greater than 60 years of age vs. less than 60 years of age).

Fiber angles in the equator from donor eyes less than 60 years of age (19.8°±1.1°) were significantly lower than posterior fiber angles ($p<0.03$, 26.0°±8.6°). After 60 years of age fiber angles in the equator increased to 36.1°±6.8° but this increase was not statistically significant (Fig. 2). There were no region or age effects in collagen density. ILM thickness was significantly thicker in the posterior pole (1811.4µm ±104.5µm) compared to the equator ($p<0.03$, 322.3µm ±73.9µm), regardless of age (Fig. 3).

The data in this study show age and region dependent trends in collagen structure and ILM thickness at the vitreoretinal interface. Further statistical significance could be achieved by gathering more data at the posterior pole, but findings to date suggest that the vitreous contracts with age and increases traction forces applied to the retina. This may provide insight into why diseases are exacerbated by lingering adhesions. The next step in this study would be correlating our parameters to vitreoretinal adhesion forces, and using the data to develop computational models capable of predicting retinal detachment or posterior vitreous detachment in the elderly.

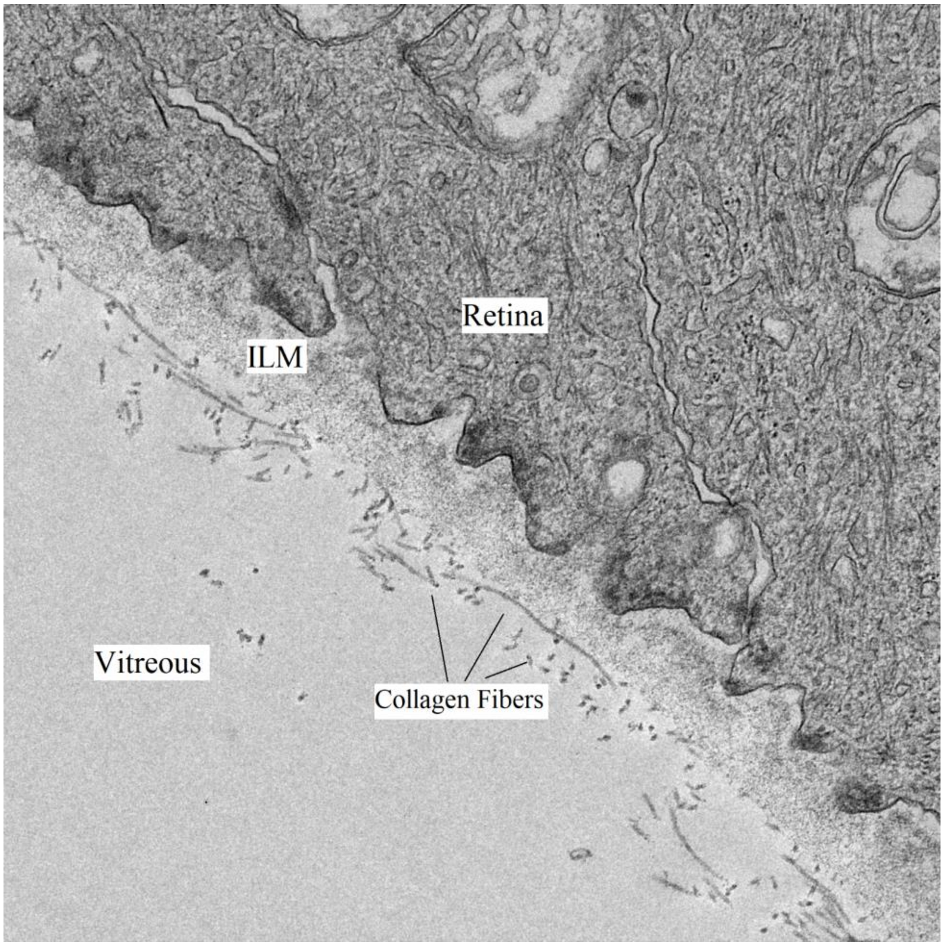

Figure 1. Transmission electron microscopy image of the vitreoretinal interface in the equator of 63-year-old human eye.

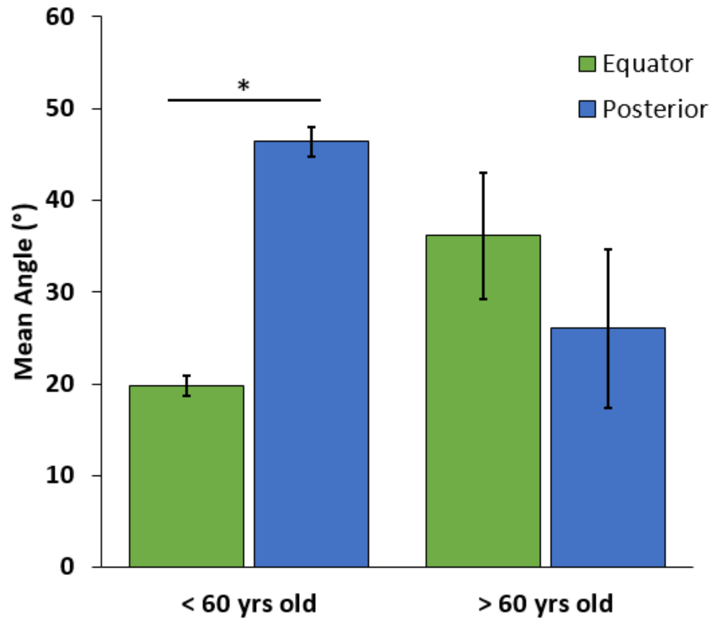

Figure 2. Average collagen fiber angle in human eye by age and region. Error bars are pooled error variances. *p<0.03

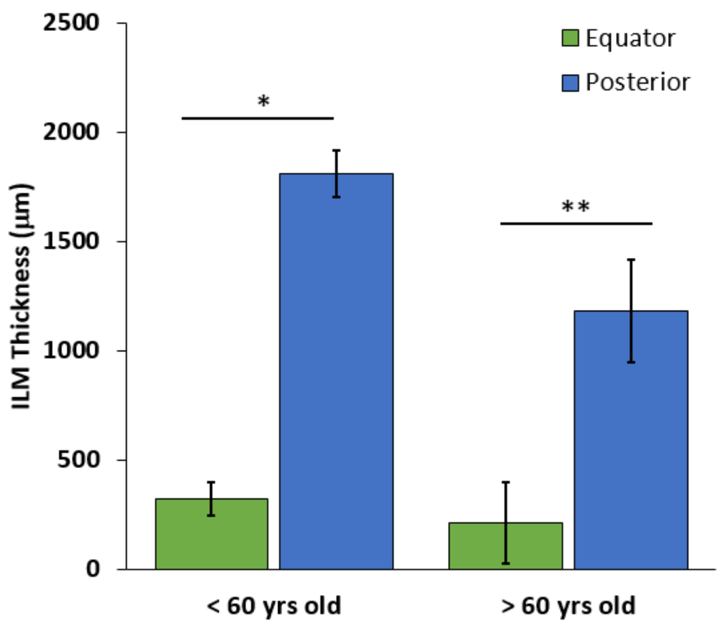

Figure 3. Average ILM thickness in human eye by age and region. Error bars are pooled error variances. *p<0.03; **p<0.005