TENSILE BEHAVIOR OF ANTERIOR AND POSTERIOR CORNEAL FLAPS SUBJECTED TO CXL TREATMENT PROCEDURE

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INTRODUCTION

Keratoconus is an eye disease that causes the cornea to become conical in shape. One of the treatment option to prevent the progression of this disease is corneal collagen cross-linking (CXL). In CXL, the photosensitizer riboflavin solution and ultraviolet A light (UVA) are used to create additional crosslinks in the corneal stroma [1]. These crosslinks have been shown to result in significant improvement of corneal mechanical properties.

The mechanical properties of the cornea are mainly from its extracellular matrix. The corneal extracellular matrix is composed of collagen fibers embedded in a proteoglycan matrix. The collagen fibers form sheet like structures, which are called lamellae. The composition of the collagen lamellae through the thickness of the cornea shows significant variation. In particular, anterior layers are composed of interwoven collagen lamellae while the posterior part of the cornea is composed of parallel collagen lamellae [2].

The CXL treatment has an effective crosslinking depth of a little more than about half of the thickness of the cornea. This depth has been recommended to avoid the toxic effects of UV light on the endothelium layer and other internal components of the ocular globe. There has been previous efforts in the literature in order to increase the depth of crosslinking with the hope of enhancing the stiffening effect of CXL procedure in patients. The primary objective of the present study is to determine the effects of the inhomogeneous microstructure of the cornea on the outcome of the crosslinking procedure. In other words, the present work assesses whether crosslinking the posterior part of the cornea has the same efficacy as crosslinking its anterior portion.

METHODS

Porcine eyes were obtained from a local abattoir. The corneal disks of about 800 um were divided into anterior and posterior flaps of almost equal thickness using a DSEAK system, Figure 1. From the flaps, corneal strips were prepared and soaked in the riboflavin solution for 30 minutes. The samples were then crosslinked following the Dresden protocol, i.e. they were subjected to a UVA irradiance of 3 mW/cm^2 for 30 minutes with continuous application of riboflavin solution to the strips during the crosslinking time [1]. Crosslinked specimens were tested in tension using a DMA machine (TA instruments, Maryland) at displacement rate of 2 mm/min. The same experiments were done on similar samples (control group), which were not crosslinked. The specimens in control group were subjected to similar treatment procedure with the difference that the UV light was turned off during the CXL treatment. The stress-strain curves for the samples in the control and treatment groups were compared together in order to determine the relation of CXL and microstructure of collagen fibers on improving the corneal biomechanical behavior.

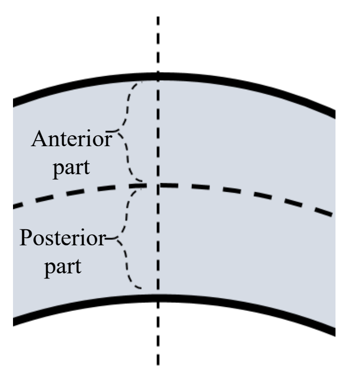

Figure 1: From corneal samples, an anterior and posterior flaps were dissected using a DSEAK system.

RESULTS

Figures 2-4 show the tensile stress-strain behavior of anterior and posterior samples from the control and treated groups. It is observed that the flaps from the anterior part of the cornea had a much stronger tensile properties compared to those of the samples from the posterior part, Figure 2. Furthermore, it is seen that the CXL treatment significantly improved the mechanical response of anterior flaps, Figure 3. However, it had an insignificant effect on the tensile response of the posterior samples, Figure 4.

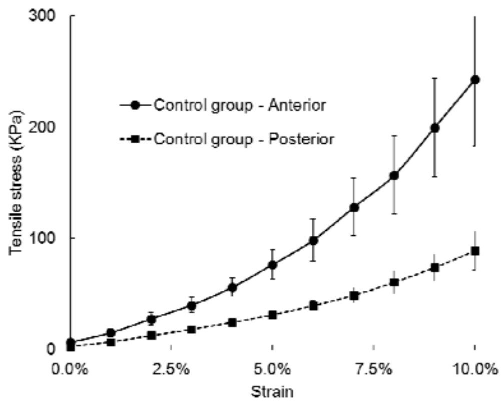

Figure 2: The tensile stress-strain response of the posterior and anterior flaps excised from the porcine cornea.

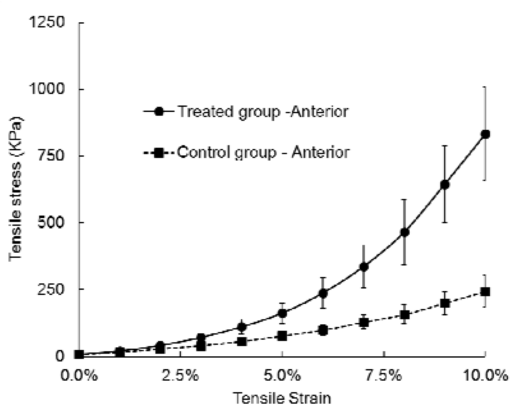

Figure 3: The effect of corneal crosslinking procedure on the tensile stress-strain response of the anterior flaps excised from the porcine cornea.

DISCUSSION

The present study compared the effects of CXL treatment on improving the tensile behavior of corneal flaps obtained from the posterior and anterior part of the cornea. The anterior flaps from the control group showed a stronger tensile properties compared to the posterior flaps, Figure 2. This finding is in agreement with previous studies [3] and is because the collagen lamellae in anterior part of the cornea are interweaved while they lie in parallel arrays in the posterior part. The interweaving of the collagen lamellae in anterior flaps induces stronger resistance to tensile force. The CXL procedure enhanced significantly the tensile behavior of anterior flaps, Figure 3. This result is also in line with general consensus in the field, i.e. the CXL treatment causes enhancement of the mechanical properties of the cornea [1,4-6]. The unexpected result is that the CXL procedure did not significantly affect the mechanical response of the posterior flaps, Figure 4. This confirms that the architecture of collagen lamellae plays an important role in the efficacy of the corneal crosslinking treatment [6]. It is noted that the depth of crosslinking in normal corneas is often limited to the top portion of the corneal thickness in order to limit the toxic effects of UV radiations on the endothelial cells. Nevertheless, the normal architecture of the corneal lamellae are expected to be disturbed because of the keratoconus disease. Thus, it is important that clinicians pay extra attention to the important role of the collagen architecture whenever they decide to use the CXL procedure for arresting the progression of this disease.

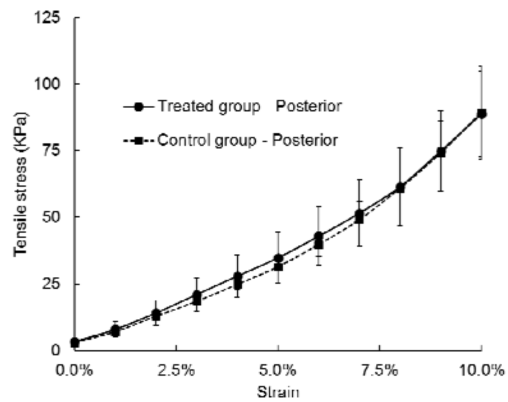

Figure 4: The effect of corneal crosslinking procedure on the tensile stress-strain response of the posterior flaps excised from the porcine cornea.

ACKNOWLEDGEMENTS

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