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Research paper

Surface characterisation and biomechanical analysis of the sclera by atomic force microscopy

Colin A. Grant[a,*], *Neil H. Thomson*[a], *Michael D. Savage*[a], *Hong W. Woon*[b], *Denis Greig*[a]

[a] *School of Physics and Astronomy, University of Leeds, Leeds, LS2 9JT, United Kingdom*
[b] *Department of Ophthalmology, St James' University Hospital, Leeds, LS9 7TF, United Kingdom*

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ABSTRACT

The sclera is an important collagenous based connective tissue that gives the eye its shape and protects the sensitive layers within the globe. The elasticity and resilience of the sclera mainly come from the stroma, which contains a dense network of collagen fibrils comprising 90% of the thickness of the tissue. However, the outermost layer of the scleral tissue (~10 μm) is known as the episclera, which is mostly uncharacterised and seldom investigated. Here, we use AFM scanning of porcine eyes to show that the surfaces of these two distinctive layers are structurally different. Furthermore, we use AFM nanoindentation to show that the episclera has significantly different mechanical properties than the stroma. The mechanical properties of the stroma are shown to be distributed between its two component parts (proteoglycan matrix and collagen fibrils).

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1. Introduction

The sclera, or white of the eye, has an important role in encasing and protecting the sensitive cells and ocular layers within the eye. The sclera is a continuation of the cornea, both of which are collagenous tissues, although, due to the different arrangements of the collagen fibrils, the cornea is transparent whilst the sclera is opaque (Komai and Ushiki, 1991). The particular arrangement of fibrils, with diameters ranging from 25–230 nm (Komai and Ushiki, 1991), gives the sclera its strength and rigidity despite its constant movement and pull from the extraocular muscles. Unlike the cornea, which has a very ordered array of layered and parallel collagen fibrils of diameter ~25 nm (Komai and Ushiki, 1991), the sclera's ultimate design is for strength, rather than optical transparency.

The scleral thickness varies between 0.5–1 mm depending on the anatomical location; the thickest region is at the posterior pole, whereas the thinnest is at the scleral equator (Norman and Flanagan et al., 2010). The overall strength of the scleral tissue comes from the stroma layer, which accounts for approximately 90% of the thickness. These over-riding mechanical properties arise from a bundled network of parallel-aligned collagen fibrils, arranged in a lamellar structure (Watson and Young, 2004). It has recently been reported that human and porcine sclera have a similar histology and collagen structure, although the tissue thickness and permeability does vary between species

* *Corresponding address:* Advanced Materials Group, School of Engineering, Design & Technology, University of Bradford, Bradford, BD7 1DP, United Kingdom. Tel.: +44 (0)1274 235808.
E-mail address: c.grant@bradford.ac.uk (C.A. Grant).

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