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Determination and mapping of corneal stiffness in keratoconic corneas

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Purpose

This research addresses an unmet clinical need by making it possible to estimate corneal biomechanical stiffness in vivo and how it varies across corneal surface in keratoconic corneas.

Conclusion

With this technology, clinicians can achieve a number of important goals: (1) estimate magnitude and distribution of stiffness in a KC cornea and use them to optimise the CXL treatment, (2) accurately quantify the disease progression and decide when intervention was needed, and (3) estimate magnitude and distribution of stiffness post-CXL to determine the effectiveness of the treatment.

Materials and Methods

While it is well known that keratoconus (KC) leads to tissue softening, the degree by which this softening takes place cannot still be determined clinically and hence cannot be used in the optimisation of collagen cross-linking (CXL) treatment. An added difficulty is the expectation that KC would not have a uniform effect on the cornea, but rather the softening would be concentrated at and around the KC cone. This research addresses these two challenges and presents technology that can estimate the magnitude and distribution of mechanical stiffness across corneal tissue. The technology is based on representative numerical modelling, leading to an algorithm for estimating the full stress-strain relationship for corneal tissue, which can then provide values of the tangent modulus at any stress or intraocular pressure level. The next step relies on the proven link between the distribution of collagen fibrils in corneal tissue and the distribution of mechanical stiffness. It uses microstructure maps of both healthy and KC corneas to translate the stiffness value obtained from the algorithm into a map of stiffness across corneal surface.

Results

In preliminary results, a clear difference is observed between normal and keratoconic eyes. A relative reduction of up to 70% of the total collagen fibrils is present inside the cone area. The cone position and dimensions can be evaluated with this method.