

# Detecting deformation asymmetries on multiple meridians in an *ex vivo* keratoconic eye model

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**Purpose :** Ocular biomechanical simulations show that air-puff induced corneal deformation imaging (APCDI) can reveal pathological asymmetric responses, as in eccentric keratoconus. Such asymmetries often go undetected when monitoring deformation on only one meridian (Birkenfeld *et al.*, IOVS, 2019), as is the case with commercial instruments. We present a novel custom optical coherence tomography (OCT) system coupled with an air-puff module capable of detecting deformation asymmetries on multiple meridians in a keratoconic-mimicking *ex vivo* porcine eye model.

**Methods :** Corneal deformation was induced by a piston-based air-puff module colinearly coupled to a custom OCT system. The puff module provided an air-puff FWHM duration of ~11 ms, reaching a maximum pressure on the corneal apex of ~13 kPa. Our OCT system used a 200 kHz 1300 nm VCSEL swept source, with an axial range of 26 mm. A freshly enucleated porcine eye globe was treated with a cross-linking (CXL) protocol with Rose Bengal (RB) photosensitizer and Green light irradiation (0.25 W/cm<sup>2</sup>, 2x200 s) of only the lower half of the cornea. We performed OCT APCDI measurements under controlled intraocular pressure (IOP, 15-30 mmHg) after application of RB (=baseline, BSL) and after partial CXL. We quantified the displaced area (DA) between the undeformed and deformed anterior cornea positions and asymmetry in displaced area (ADA), *i.e.* the difference between the nasal/temporal (or superior/inferior) DA referenced to the undeformed corneal apex.

**Results :** We implemented a cross-meridian scan pattern over a lateral range of 15 mm sampled with 64 points at a repetition frequency of 1 kHz. For the BSL case, we validated the system by verifying the reduction of DA, from a maximum of ~4.3 to 1.8 mm<sup>2</sup>, with increasing IOP, from 15 to 30 mmHg. ADA was limited to below 0.2 mm<sup>2</sup> in all cases for both meridians. For the partial CXL case and an IOP of 15 mm Hg, the ADA peaked at 0.5 mm<sup>2</sup> for the vertical meridian, while it was below 0.2 mm<sup>2</sup> at all times for the horizontal meridian.

**Conclusions :** We acquired corneal deformation images with a cross-meridian scan pattern over a field of view of 15 mm at unprecedented scan rates. In keratoconus-mimicking cases, we detected deformation asymmetries up to 0.5 mm<sup>2</sup>, otherwise missed on a single meridian, that will substantially aid in corneal biomechanics diagnostics and pathology screening.