Biomechanical and structural comparison of lenticule addition procedures (LIKE, sLIKE and delamination) for the treatment of keratoconus and refractive errors

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BACKGROUND AND PURPOSE

- Keratoconus leads to progressive biomechanical weakening of the cornea.
- Lenticule addition using allogenic/xenogenic tissue is an emerging therapy for keratoconus and for refractive error corrections
- Surgical approaches may differentially affect stromal collagen structure and biomechanics.
- Three surgical approaches to lenticule insertion were evaluated using Second Harmonic Generation microscopy:
- Flap-based (LIKE), pocket-based (sLIKE), and manual lamellar dissection (delamination)

METHODOLOGY

Tissue model

Porcine corneas

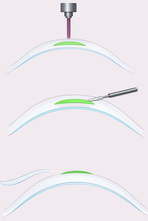
Baseline (non-operated):
n = 4
Lenticule addition groups:
LIKE (flap) n = 2
sLIKE (pocket) n = 2
Delamination n = 2

Surgical techniques

sLIKE (Pocket-based)

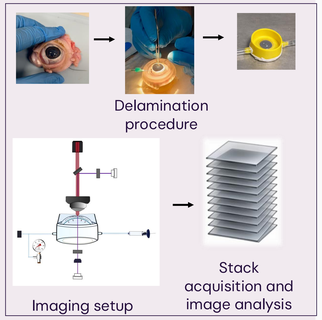
Delamination (manual)

LIKE (Flap-based)



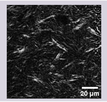
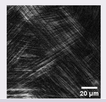
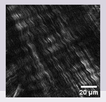
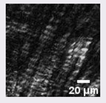
Setup and imaging

- Operated and unoperated corneas were mounted in sealed, pressurised chambers with a transparent base
- SHG imaging was performed using a Zeiss LSM980 microscope with an 820 nm femtosecond laser, linear x-axis polarisation, and a 20× water immersion objective (NA 1.0). Forward SHG signals were detected using an SP485/IR+ filter and NA 0.8 condenser.

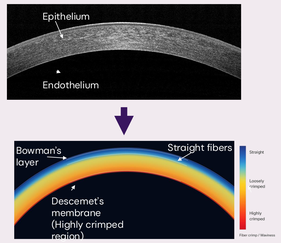


RESULTS 1

Corneal structure across the depth

Layer	Representative SHG image	% of total thickness
Bowman's layer (Highly interwoven short fibres)		~2%
Transitional region (Straight long fibres)		~5–10%
Loosely crimped (crimp varying between 35 µm and 10 µm)		~80–86%
Highly crimped region (crimp varying between 14 µm and 6 µm)		~2%

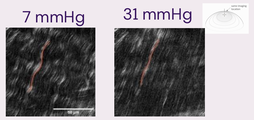
Color-coded maps of corneal crimp

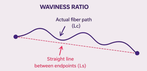


The degree of collagen waviness ("crimp") was quantified across the corneal depth to generate colour-coded structural maps of both unoperated and operated corneas, showing how this feature changes with depth.

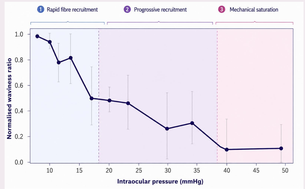
Response to intraocular pressure

Example of fibre straightening across different pressures



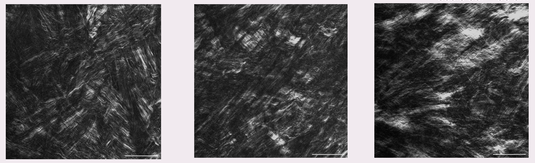


R = Lc / Ls



RESULTS 2

Lenticule characterisation

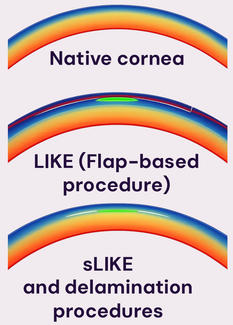


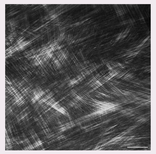
Unprocessed (Native) | Decellularised | Decellularised and cross-linked

- Native lenticules showed collagen features similar to the native cornea, including stromal collagen crimp – an important biomechanical feature.
- Decellularisation and high-energy crosslinking disrupted collagen organisation.
- Processed lenticules showed less distinct collagen bundles and reduced crimp appearance.

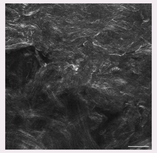
Comparison of different surgical insertion techniques

- sLIKE and delamination procedures induced minimal structural disruption at the lenticule–host interface.
- Flap creation produced significant structural alterations extending beyond the interface. LIKE caused complete collagen straightening in a zone extending ~240 µm beneath the flap.
- There was reduced collagen tension within the flap which led to increased collagen crimp.
- Preservation of crimp extension in response to increasing IOP was observed only in sLIKE and delamination procedures.





Beneath the lenticule in flap-based procedures



Lenticule interface in delamination procedures

CONCLUSION

In structurally compromised corneas such as keratoconus, preserving corneal structural integrity is paramount for long-term success, highlighting the importance of careful insertion method selection. Further work is required to optimise these procedures and improve lenticule biomechanics relative to the native cornea to reduce post-surgery complications.