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Evaluation of the protective layer formation of Ophthalmic Viscosurgical Devices in ex vivo porcine eyes using intraoperative Optical Coherence Tomography

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Purpose

- During cataract surgery the lens gets destroyed with ultrasound.
  - Fragments can potentially become projectiles that cause irreversible damage to the corneal endothelium.
- To coat the endothelium with a protection layer, Ophthalmic Viscosurgical Devices (OVDs) are injected into the anterior chamber.
- The protective properties and thickness of OVDs have previously been the subject of investigation, using fluorescein and a Scheimpflug camera [1, 2].
- Protective properties are however still poorly understood.
- We present a method to quantitatively evaluate the distribution of OVDs, using Optical Coherence Tomography (OCT) and a Convolutional Neural Network (CNN) in an ex vivo porcine eye model.

Methods

- We simulated cataract surgery (irrigation & aspiration (I/A) and phacoemulsification (phaco)) and used BSS-milk-solution (100:1) to generate contrast.
- We imaged 10 different OVDs each 10 times
  - Twice: each after I/A and after phaco.
  - Scan size 2.9 (Z) x 6 (X) x 6 (Y) mm^3, sampled @ 1024 x 512 x 128 pixels.
  - with ZEISS LUMERA® 700 with ZEISS RESCAN® 700.
- Segmentation pipeline consists of
  - Manual segmentation path: we manually segmented ~3000 B-scans for training of the network. We segmented entire volumes to include all cases, inclusing artifacts like reflexes and air bubbles.
  - Segmentation path (based on Unet [3]): automatically segmented >25k B-scans.
- Our CNN is capable of segmenting 3 semantic categories: the cornea (Fig. 1: white), Background (fig. 1: black) and BSS-milk-solution (Fig. 1: grey).

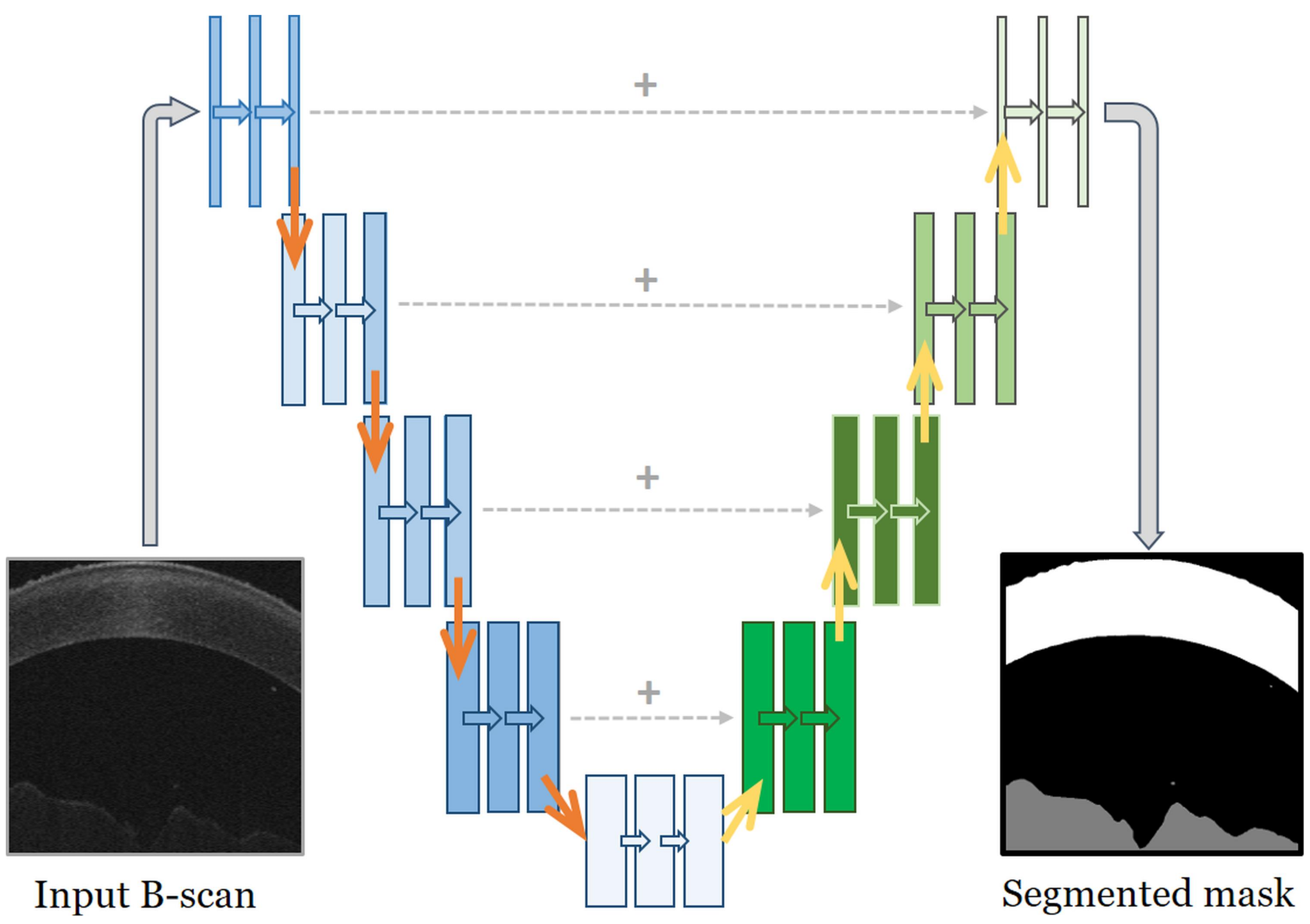

Figure 1: *Architecture of the CNN for B-scan segmentation (modified U-Net).*

Results

- We quantitatively determined thickness maps and applied segmentation to volumes (Fig. 2(1) A-F).
- Maps revealed huge fluctuations of the individual measurements (Fig. 2(2) A-F).

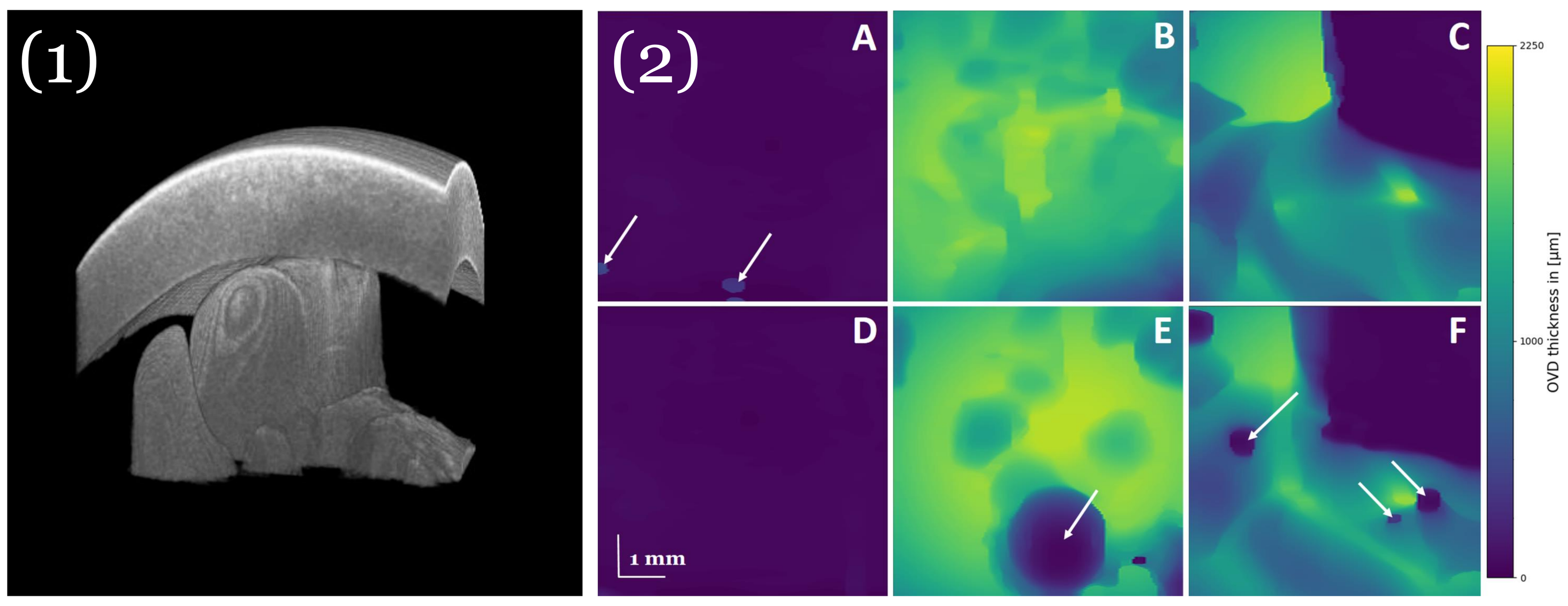

Figure 2: *(1) 3D-rendering of segmented and noise reduced OCT scan for better spatial understanding. (2) Example thickness maps after segmentartion. White arrows indicate air bubbles in the OVD layer.*

- Median thickness values ranged from 39 ± 599 µm (PROVISC®) up to 1437 ± 489 µm (Healon EndoCoat).
- Cohesive OVDs have the thinnest layer values, followed by combi-systems. Dispersive OVDs had the highest group median thickness value (Fig. 3).

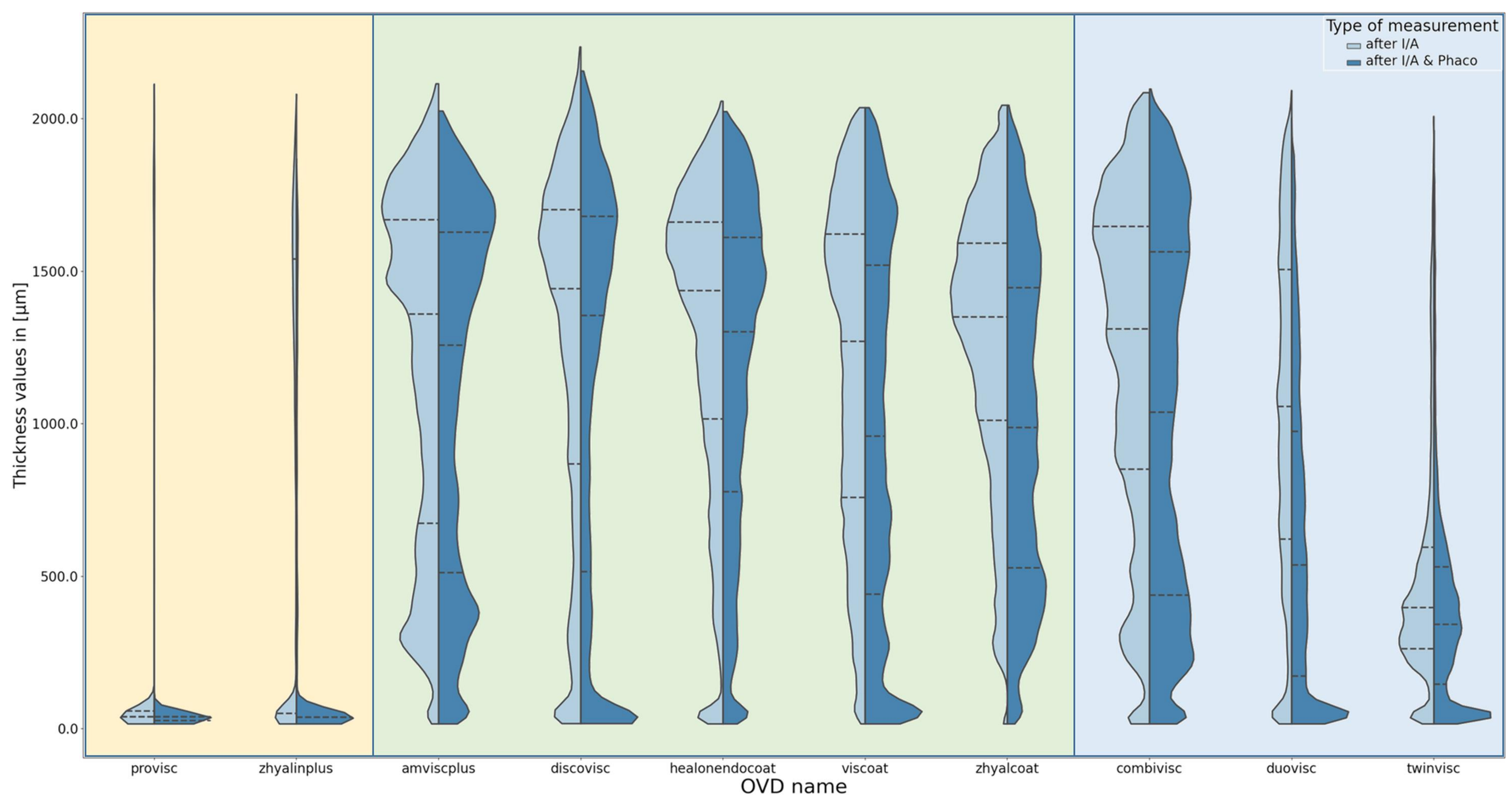

Figure 3: *Thickness value distribution of all OVDs as violin plots. Colored boxes highlight different groups (from [4] – modified).*

Conclusion

- We measured for the first time the thickness of the OVD over a large FOV of 6 x 6 mm^2.
- We evaluated thickness layers of 10 different OVDs and acquired a data base of 200 OCT volumes from 100 porcine eyes.
- Understanding layer formation and persistence over a large FOV are essential steps for the comprehension of the protective properties of OVDs and potentially for
  - Confirmation for surgeons that protection was during surgery.
  - OVD manufacturers to improve the properties of their products .
- Our pipeline can be expanded for 3D-sementation which would increase the spatial accuracy of the segmentation.

References

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