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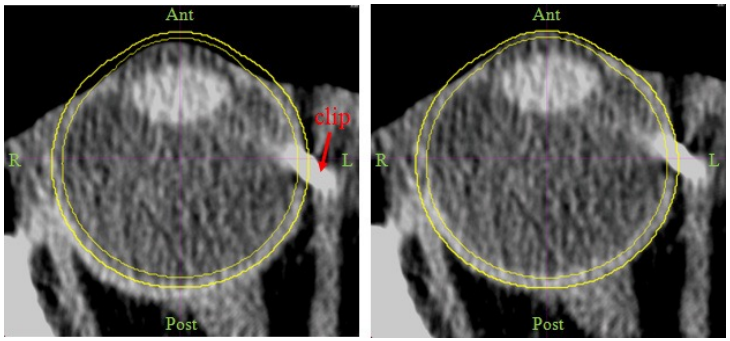
Fringe pattern profilometry for anterior eye segment reconstruction in ocular proton therapy

Second International PTCOG Ocular Proton Therapy Symposium,March 26, 2024

Eye modelling in OPT

Conventional eye modelling during treatment planning consist in a Spherical/elliptical eye globe fitted to measurement of :

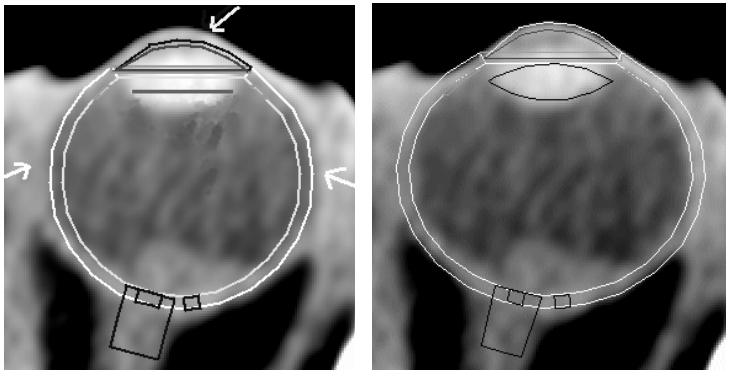
- Clips position using X-ray
- Ultrasound measurement of eye length



[Slopsema et al 2019 Phys. Med. Biol.]

Discrepancies with volumetric imaging exist and have been investigated

- Anterior eye segment is particularly affected by uncertainties in case of posterior tumours

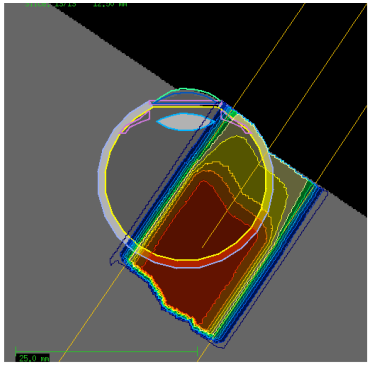


[Barbara Dobler and Rolf Bendl 2002 Phys. Med. Biol.]

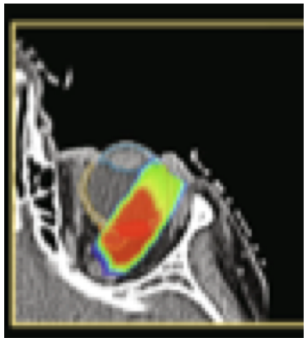
3D Treatment planning in OPT improves the accuracy of eye models

Anterior eye segment

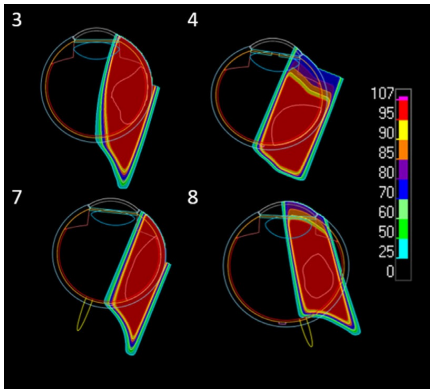
Skin plane



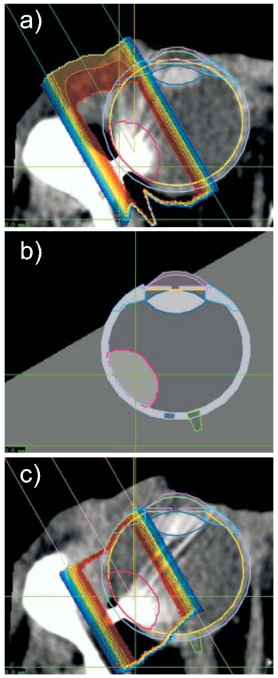
[Pfeiffer et al, 2001, Phys. Med. Biol.]



[Fleury et al, 2022, Green Journal]

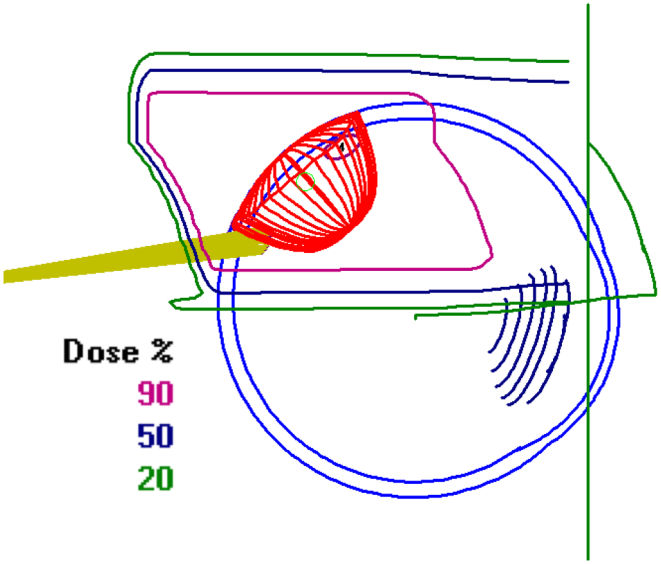


[Wulff et al, 2021, Med. Phys]



[Rethfeldt et al, 2006, Med. Phys]

Eyelid



Aim of the study

Can high resolution 3D topography of the patient surface using Fringe Pattern Profilometry improve anterior eye segment definition?

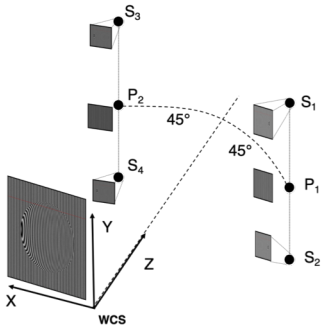
Dataset

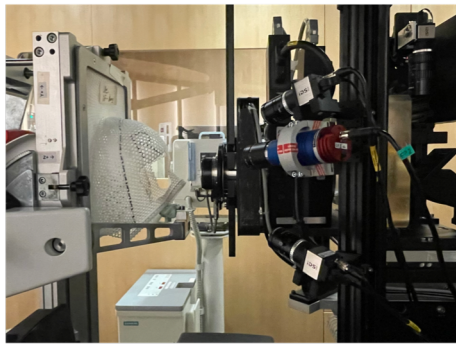
- 17 patients (3 lid Down)
- 93 concurrent measurement of
  - 3D position of clips using X-rays
  - 3D topography of eye anterior segment/eyelid

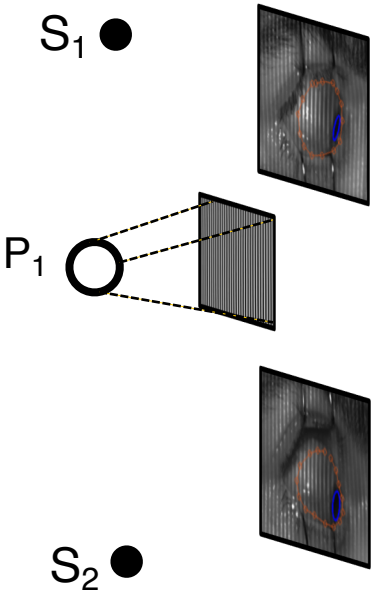
- MRI based eye model
- EyePlan treatment plan

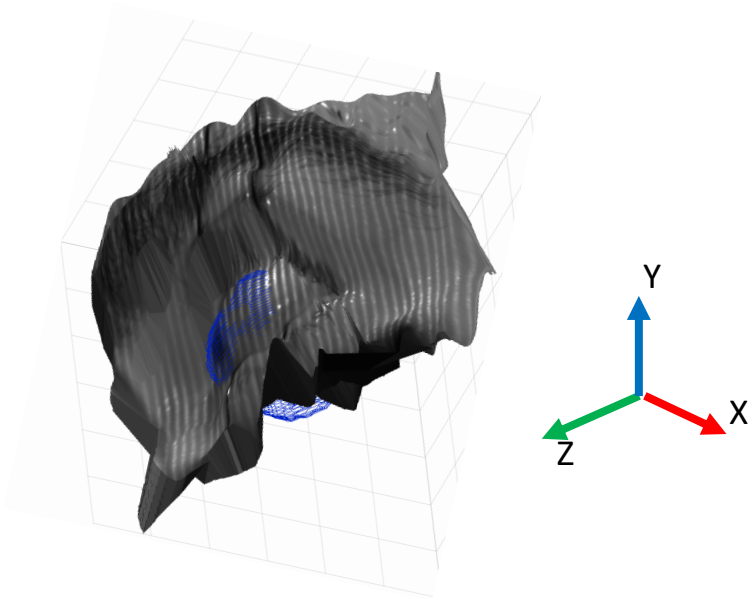
3D Eye anterior segment reconstruction

- Four calibrated optical cameras
- Two fringe pattern projectors









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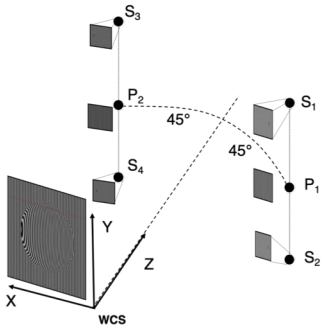
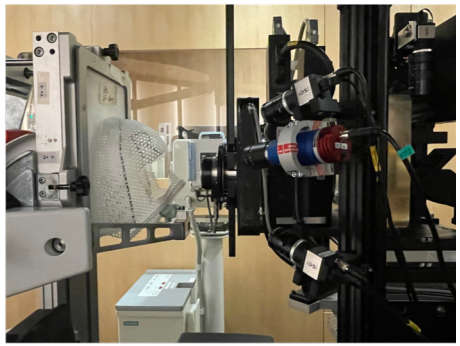
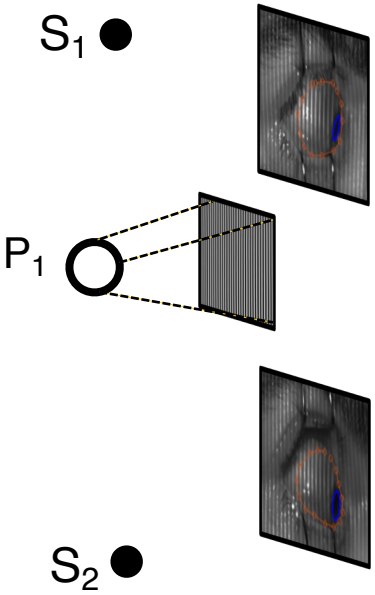
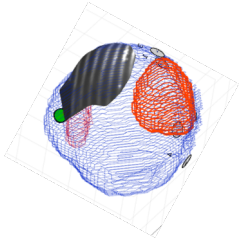
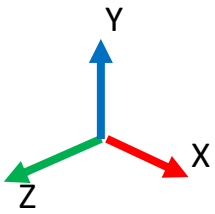






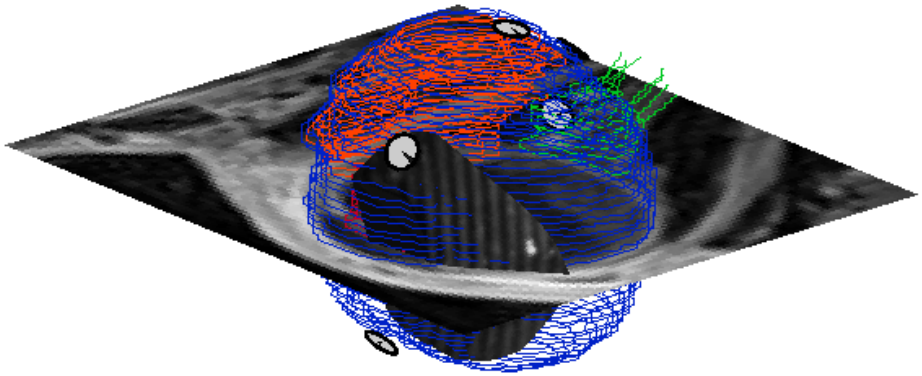


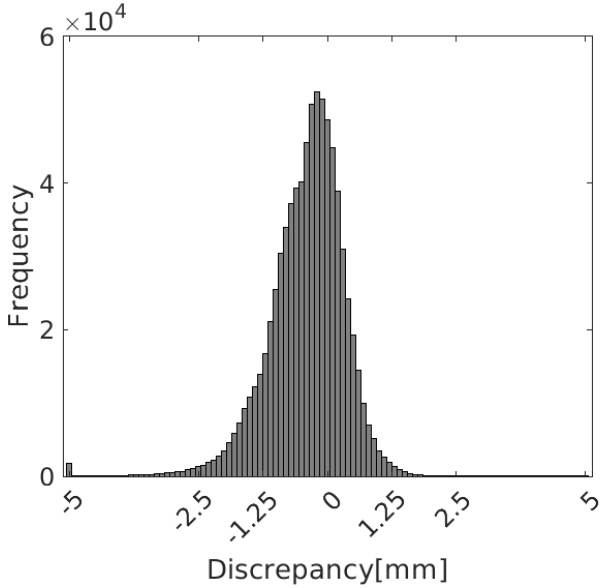


Cornea-sclera topography

- Discrepancy between 3D scans and the anterior eye segment retrieved by aligning the MRI-based eye model to the measured clips configuration

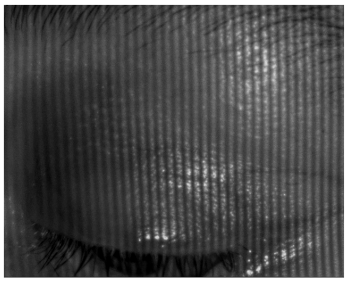
abs	3D
$median_{[mm]}$	0.46
$IQR_{[mm]}$	0.65

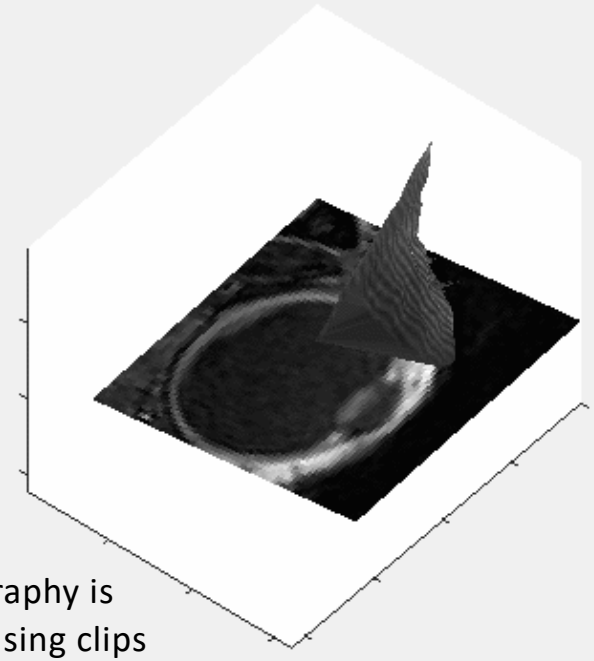




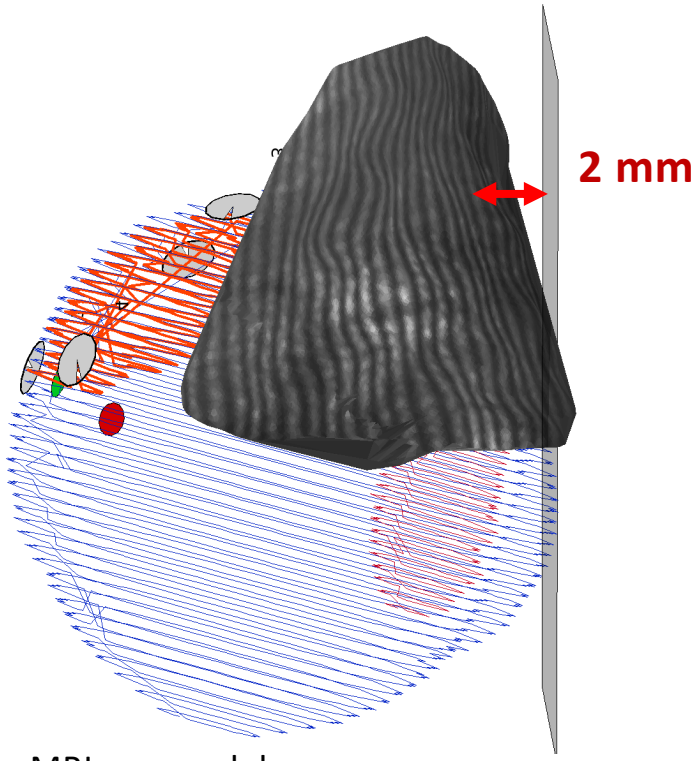
Eyelid – an exemplary case

Fringe pattern on eyelid





Eyelid 3D topography is aligned to MRI using clips as geometrical reference



MRI eye model

'Skin Plane'

Conclusion

- Volumetric imaging in treatment planning improves the anatomical description of the eye anterior segment
- The use of the ‘skin-plane’ remains a crude approximation

- Fringe pattern profilometry can be used to measure the patient surface with submillimetric accuracy
  - Further validation is necessary

- 3D topographies of the patient surface measured in the treatment room can
  - Improve accuracy of dose prediction
  - Introduce anatomically accurate definition of the eyelid in treatment planning

Thank you for your attention