Modelling Aberrations from Surface Measurements of ex-vivo isolated Human Crystalline Lenses

6124

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INTRODUCTION

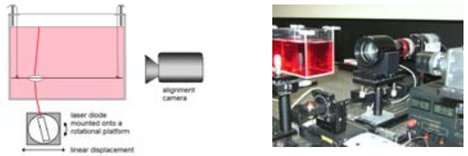
The aberrations of the crystalline lens result from both, the shape of their surface and the refractive index distribution. We measured the anterior and posterior surfaces of isolated (fully accommodated) ex-vivo human crystalline lenses. From this geometrical data, the lens aberrations were predicted when assuming a constant refractive index or a gradient refractive index (GRIN). Computed aberrations were compared with experimental measurements in some of the lenses.

METHODS

Shadow Photography

While the crystalline lens was back-illuminated, a CCD camera recorded shadow-images of meridians 10° apart.

Laser Ray-Tracing



As the translation stage moves the laser beam through the meridional plane of the lens the camera records images of the trajectories.

HUMAN DONOR CRYSTALLINE LENSES

All the measurements were performed within one day after death, right after extraction of the lens from the ocular globe. The crystalline lenses were kept in cell culture medium all the time.

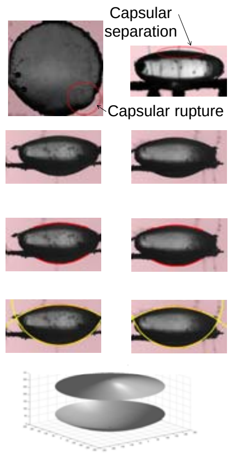
- 4-64 years ⇒ Surface measurement
- 38-57 years ⇒ + Ray-Tracing and aberraction prediction
- 38-50 years ⇒ + Aberration measurement

See companion poster 6123 (Bueno et al.)

DATA ANALYSIS

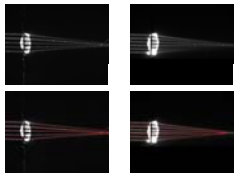
Surface geometry

1. Inspect all crystallines on possible damage
2. Record shadow images 10° apart
3. Obtain surface profiles for a central 6-mm region
4. Fit functions to anterior/posterior surface
5. Reconstruct 3D-model of the lens



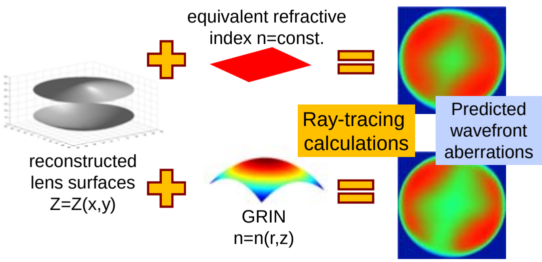
Measuring back-focal lens distances

1. Perform ray-tracing measurements
2. Detect rays and compute back-focal distance



LENS ABERRATIONS PREDICTIONS

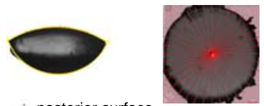
The optical power and aberrations of the lenses were calculated by ray-tracing from the measured geometrical data (3D-fitted).

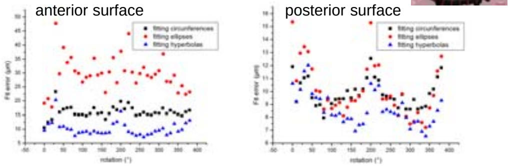


RESULTS

Which function fits best for every meridian?

Circumferences?
Ellipses?
Hyperbolas?





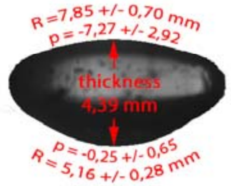
Fit errors for the three functions and meridian angle

Hyperbolas!

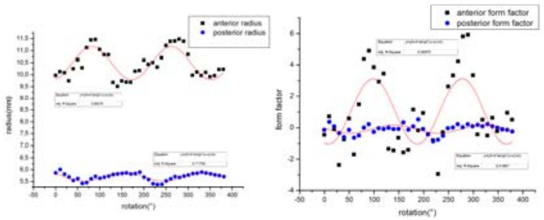
Fit function: $y = y_0 - \frac{(x-x_0)^2}{R + \sqrt{R^2 - p(x-x_0)^2}}$

with radius of curvature R and form factor p

Average geometrical data from all lenses



How asymmetric are the lenses?

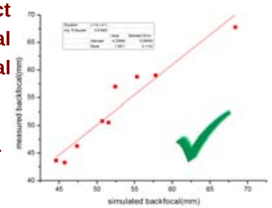


Both radius and form factor vary over the projection angle, especially for the anterior surface. This would have an impact on astigmatism and other asymmetric aberrations.

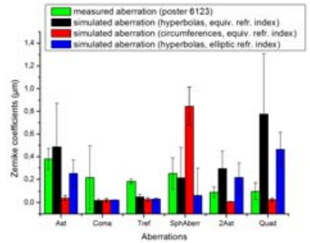
RESULTS

Can we accurately predict the measured back-focal distance from geometrical data?

$n_{equivalent}$=1,42 ⇒ ✓



Measured versus predicted aberrations: impact of surface fitting and refractive index



CONCLUSIONS

-The shape of ex-vivo human crystalline lenses was measured using a custom built shadow photography technique.

-Hyperbolas produce the best fitting to the lens surfaces.

-The changes of the lens radius with the meridian angle are larger in the anterior surface.

-Lens back-focal distance and aberrations were predicted by ray-tracing from the 3D reconstructed lenses using three fitting functions and two refractive index models.

-Predicted aberrations were compared with measured aberrations in three of the lenses.

-Although we found some average agreement in astigmatism and spherical aberration, this procedure is not adequate for an accurate prediction of the aberrations. This is due to limitations involved in the surface measurements, the fitting procedure, the refractive index assumptions and the experimental measurement noise.

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