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Dynamic analysis of hydrofluoric acid penetration and decontamination on the eye by means of optical coherence tomography

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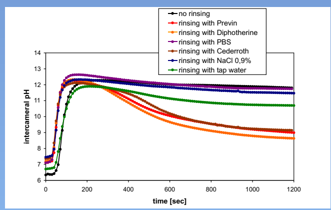
IHT RWTH Institute of Semiconductor Electronics

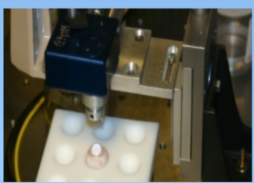
ACTO Aachen Centre of Technology Transfer in Ophthalmology

Motivation

Chemical eye burns cause approximately one forth of all traumatic ocular injuries. To improve the efficiency in the emergency treatment of such injuries the penetration and the effects of decontamination within tissue have to be qualified and quantified. Conventional methods like intraocular pH measurements only give limited insight into the mechanism of chemical trauma and fail completely by trying to examine the extremely hazardous eye burns caused by hydrofluoric acid. With its ability to non-destructively generate cross sectional images of tissue morphology at high speed with micrometer scale resolution, the optical coherence tomography (OCT) offers large potentials to close this analytical gap.

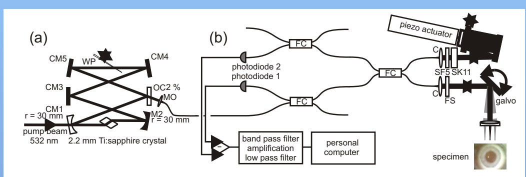


acute Ex Vivo Eye Irritation Test (aEVEIT)



Experiments were performed using the acute EVEIT. This model has been proven to react very similarly to living eye tissue concerning the behavior during chemical eye burns. In this study, enucleated white rabbit eyes were used. Rabbit heads were obtained from an abattoir and kept cool until enucleation of the eyes. The globes were stored at 4°C in a humid atmosphere to ensure preservation of the corneal epithelium. Only clear corneas without any epithelial defects were processed. All measurements were performed within 12 hours after animal death.

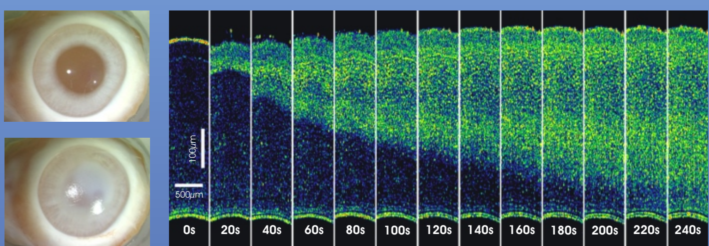
Experimental setup



(a) highly compact Ti:sapphire laser (GigaJet 20, GigaOptics GmbH) modified to support higher spectral bandwidth

(b) OCT system (Sirius 713, 4optics AG) modified to support the high axial resolution given by the spectral bandwidth of the light source

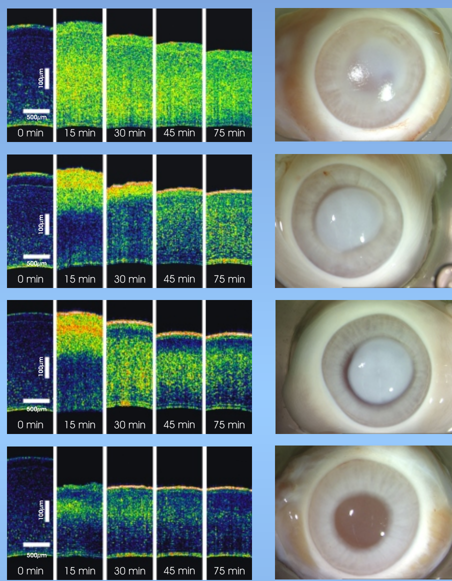
Dynamic analysis of hydrofluoric acid penetration



OCT time series after topical application of 25 μl 2.5% HF
the change in the scattering cross section induced by the chemical is imaged
the penetration velocity is decreasing with time due to dilution
full corneal penetration is observed 240 s after topical application

Analysis of decontamination after hydrofluoric acid (HF) burn

HF penetrates while burning due to both active dissociated corrosive and toxic ions and partly undissociated HF molecule
decontamination is usually recommended with water and/or Ca-gluconate
Hexafluorine® is available as a chelating and hyperosmolar specific solution for HF
the outcome without rinsing is compared to results after using the three different rinsing fluids for therapy
rinsing (15 min) starts 20 s after topical application of 25 μl of 2.5% HF
OCT image sequences and top view photographic images are given



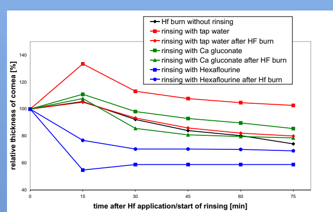
HF burn without rinsing

HF burn rinsed with tap water

HF burn rinsed with 1% Calcium-gluconate

HF burn rinsed with Hexafluorine®

Analysis of corneal thickness changes



- change of thickness was observed in non burned and burned corneas after different treatments
- HF burn causes strong corneal dehydration with and without rinsing therapy
- without prior HF burn on healhy eyes significant swelling was observed following water rinsing and was abated within the following 60 minutes
- the effect of calcium gluconate on corneal thickness was negligible
- Hexafluorine® showed shrinkage of about 40% of the corneal thickness.

Conclusion

In summary, the use of OCT as an additional diagnostic tool within the EVEIT system is capable to essentially enhance the information available by this ex vivo animal model. The direct access to the diffusion process by means of OCT measurements during exposure is a favorable instrument to give exact definitions of the possible damage at different intervention time points. It allows the comparison different rinsing solutions like water, calcium gluconate and Hexafluorine® with a reduced number of tests in order to improve therapeutic strategies.
The hyperosmolarity of Hexafluorine® is effective in the physical inversion of water flow characteristics highlighted by observed cornea shrinkage.
The chemical neutralisation of H^+ and F^- ions, another property of this rinsing solution is visible by the fact that the cornea remains clear for 75 min post - burn.

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