Chemical ocular burns: use of an ex vivo model to define chemical penetration and to compare different washing solutions by OCT

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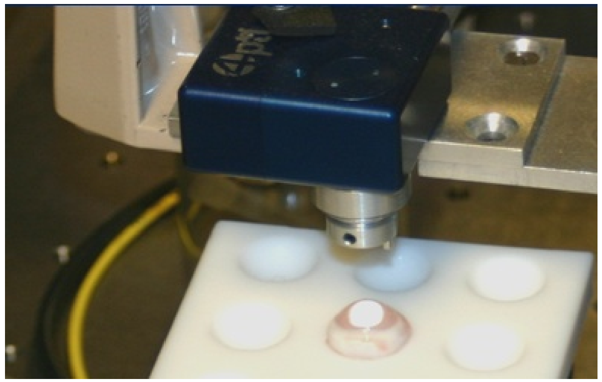
Objective

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. The objective is to study the penetration of caustic chemicals (caustic soda/NaOH, sulphuric acid/H_2SO_4 and hydrofluoric acid/HF) in an *ex vivo* model and to compare the efficacy of different washing solutions on such ocular splashes.

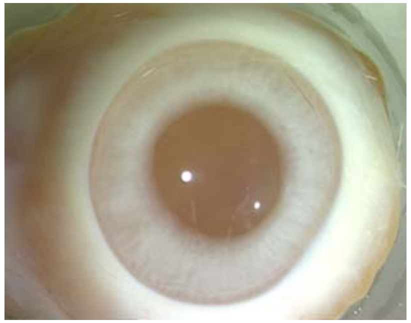
Methods

A. OCT System

For the high resolution OCT system employed in this study, a Ti:sapphire laser oscillator (GigaJet 20, GigaOptics GmbH, Konstanz, Germany) centered at 800 nm was used as a low-coherence light source. The axial and lateral resolutions were 3 and 8 µm, respectively. (1)



Methods (2)



B. Ex Vivo Eye Irritation Test (EVEIT)

In this study, enucleated white rabbit eyes were used. Rabbit heads were obtained from abattoir. The globes were stored at 4°C in a humid atmosphere. Only clear corneas without any epithelial defects were processed within 12 hours using the following protocol:(2)

Sodium hydroxide burns:

- 500µl of 1 molar sodium hydroxide solution (NaOH)
- Rinsing starts after 20 seconds of exposure:
  - One control group, without washing
  - 500 ml Diphoterine® during 3 minutes
  - Saline solution during 15 minutes

Sulphuric acid burns:

- 500µl of 25% sulphuric acid (H_2SO_4)
- Same protocol as naOH burns

Hydrofluoric acid burns:

- 25µl of 2.5% hydrofluoric acid (HF)
- Rinsing starts after 20 seconds of exposure:
  - One control group, without washing
  - 15 min of washing with tap water
  - 15 min of washing with 1% calcium gluconate solution
  - 15 min of washing with Hexafluorine®

All experiments were performed in triplicate. OCT measurements were performed at the center of the cornea. For comparison, the cornea of each eye was imaged directly before application of the chemicals. Continuous OCT observation was done during 75 min for all samples.

Results: Corrosive penetration

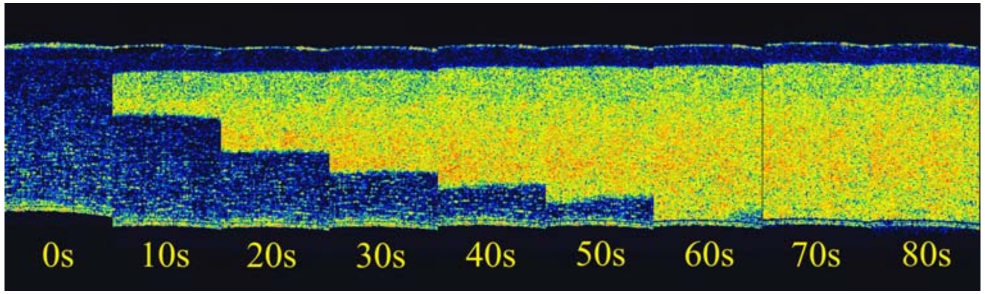


Fig. 1: High resolution OCT image of an untreated rabbit cornea *ex vivo* burned with 1 mol/l NaOH

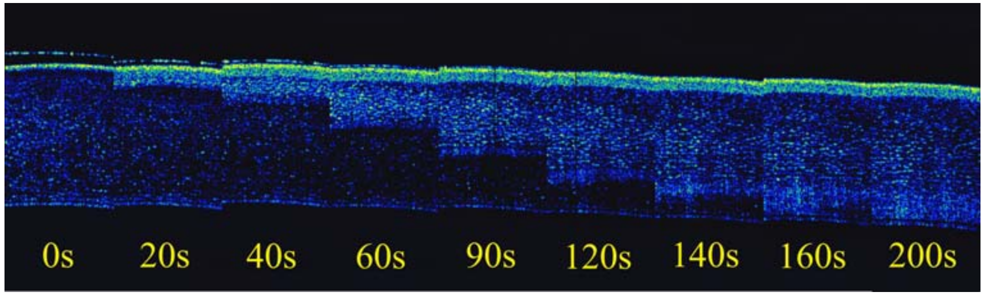
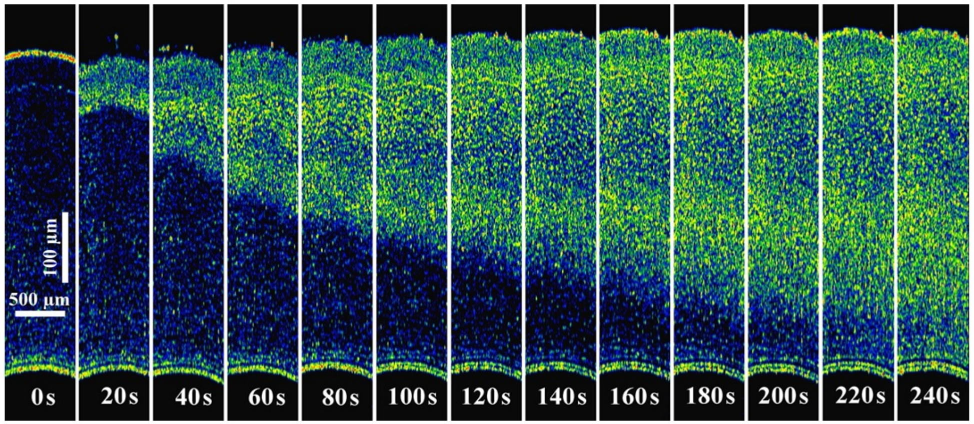


Fig. 2: High resolution OCT image of an untreated rabbit cornea *ex vivo* burned with 25% H_2SO_4



OCT pictures allow following corrosive penetration inside cornea.

Changes observed are **different depending the nature of the chemical tested**: the increase in light scattering is likewise more prominent in the alkali case. However, full penetration of the corrosive can be studied.

HF's penetration is different from H_2SO_4, because of different effects of cell alteration, due to the acid H^+ as well as the toxic F^-.

The cornea is completely penetrated in **200 s** in case of **H_2SO_4** burn (fig.2) whereas it is done fastly, in approximatively **60 s**, in the case of the **alkali** burn (fig. 1). **HF** was less concentrated but penetration is complete in **4 minutes** (fig. 3).

Fig. 3: High resolution OCT image of an untreated rabbit cornea *ex vivo* burned with 2.5% HF

Results:

Decontamination comparison in the case of the alkali exposure

In case of diphoterine® rinsing we found stop of the penetration in the middle of the cornea and no penetration into deep stroma for alkali until 60 minutes of observation whereas in water rinsing the deep stroma was affected after rinsing therapy stopped.

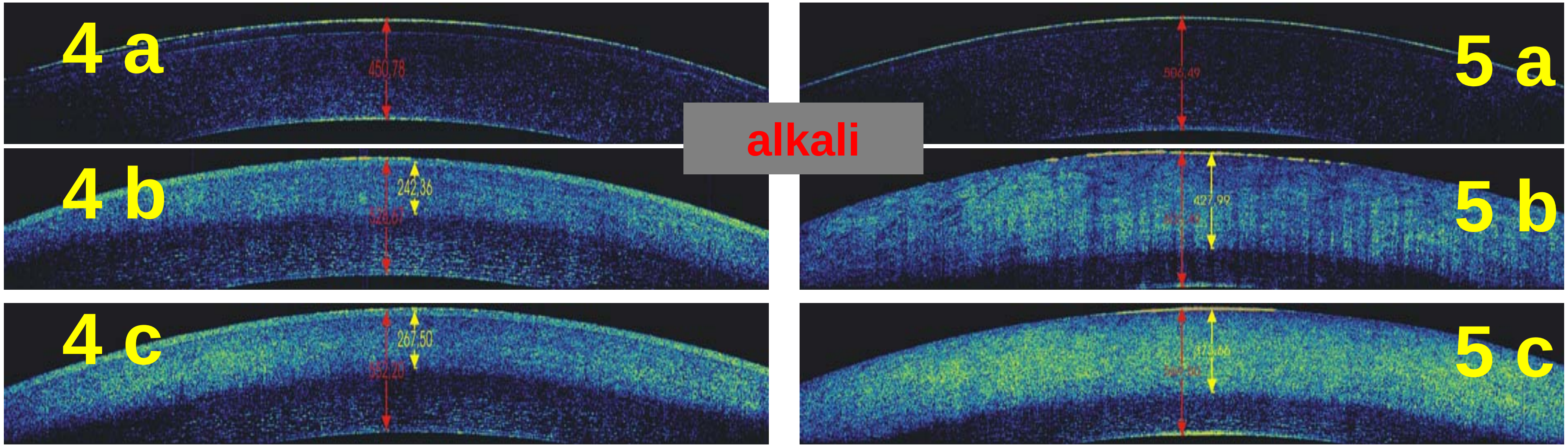


Fig. 4: OCT image of a cornea exposed to 1 mol NaOH burn for 20 sec. then rinsing with **Diphoterine®** (0.5l/3min)
4 a: control group (no washing)
4 b: 15min after rinsed burn
4 c: 60min after rinsed burn

Fig. 5: OCT image of a cornea exposed to 1 mol NaOH burn for 20 sec. then: rinsing with **saline 0.9%** 2,5 l / 15 min
5 a: control group (no washing)
5 b: 15min after rinsed burn
5 c: 60min after rinsed burn

Results:

Decontamination comparison in the case of the sulphuric acid exposure

In case of Diphoterine® rinsing we found stop of the penetration in the middle of the cornea (15 minutes after the end of the chemical exposure) and no penetration into deep stroma for acid until 60 minutes of observation whereas in water rinsing the deep stroma was affected after rinsing therapy stopped.

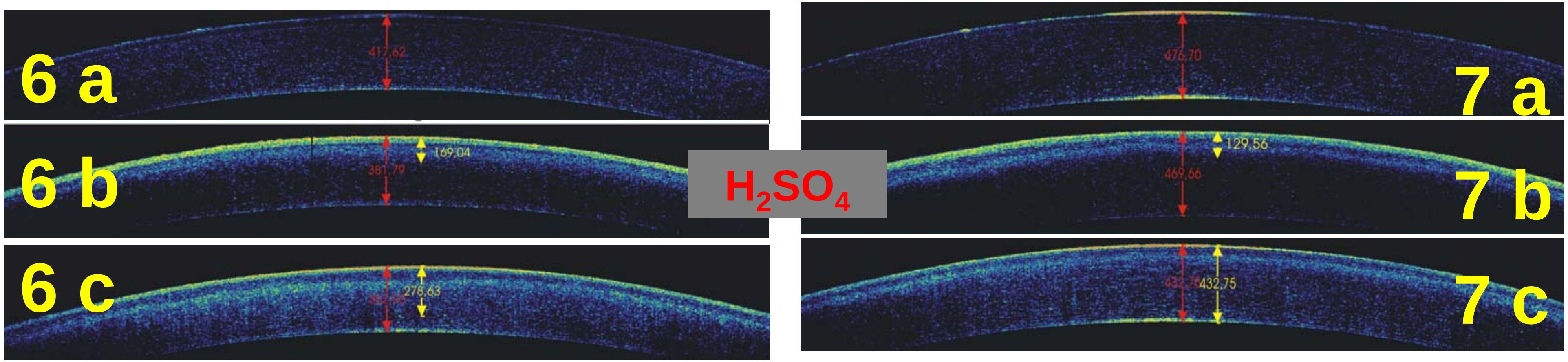
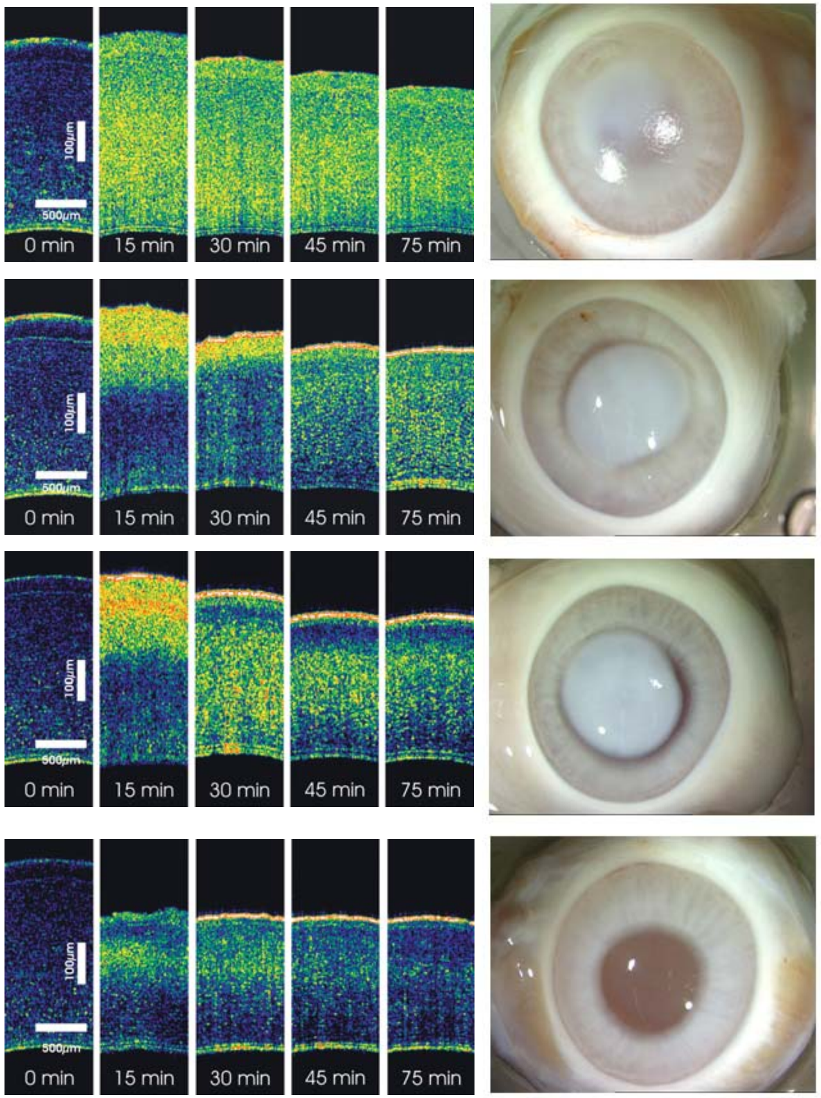


Fig. 6: OCT image of a cornea exposed to 25% H_2SO_4 burn for 20 sec. then rinsing with **Diphoterine®** (0.5l/3min)
6 a: control group (no washing)
6 b: 15min after rinsed burn
6 c: 60min after rinsed burn

Fig. 7: OCT image of a cornea exposed to 25% H_2SO_4 burn for 20 sec. then rinsing with **saline 0.9%** 2,5 l / 15 min
7 a: control group (no washing)
7 b: 15min after rinsed burn
7 c: 60min after rinsed burn

Results:
Decontamination comparison in the case of the hydrofluoric acid exposure

Fig. 8: OCT images of a cornea exposed to 2.5 % HF burn for 20 sec. then rinsing with:
8 a: control group (no washing)
8 b: tap water
8 c: 1% calcium gluconate
8 d: Hexafluorine®



8 a
8 b
8 c
8 d

- Water rinsing resulted in deep stromal changes with less severity when compared to unrinsed corneas.
- Calcium gluconate rinsing showed the initial stopping of the burn but its later progression.
- Hexafluorine® solution stopped the burn without further progression within 75 min.
- Corneal opacity was found for water, calcium gluconate and no treatment. Corneas rinsed with Hexafluorine® remained clear.

Conclusion:

- Corneal rinsing after acid and alkali burn is essential. Waiting too long will result in severe alteration of the cornea with non healing sequela (2). Therefore immediate within one minute action is required. We focused on effectiveness of currently distributed first aid rinsing solutions.
- There is no doubt that there are differences in effectiveness of those solutions. Saline solution is recommended but high volumes and times are required. There are more efficient rinsing solutions beneath the available fluids (3,4). Differences can be observed by means of depth limiting with lower volumes of rinsing in Fig. 4-7.
- We have clear indication that as lower the affected corneal stroma is touched by the chemical process of burn, and as faster this is reversed the clinical damage will be less.
- Therefore Diphoterine® and Hexafluorine® -a specific solution for HF splashes- appear to be the most efficient solutions being available in the market for first aid rinsing.

Literature:

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