LA ROSES

Laser Assisted RObotic Surgery of the anterior Eye Segment

Project full title:	Laser Assisted Robotic Surgery of the anterior Eye Segment
Project Acronym:	LA-ROSES
Grant Agreement number:	601116
Deliverable no.:	D7.2
Title:	Test report on eye model
Contractual Date of Delivery	Month 16
Actual Date of Delivery	September 21, 2016
Organization Short Name of Milestone Leading Partner	IFAC
Organization Short Name of Other Participants	EKY, Fastenica
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Version	1.0
Tasks contributing to this deliverable	Task 7
Dissemination Level [1]	RE
Total number of pages (including cover page)	

[1] Dissemination Level:
PU Public
PP Restricted to other programme participants (including the Commission Services)
RE Restricted to a group specified by the consortium (including the Commission Services)
CO Confidential, only for members of the consortium (including the Commission Services)

Version Management

Version	Date	Status	Author	Modification
1	10/01/2015	Setup	EKY	Creation of document
2	15/06/2016	Draft	IFAC	Structure and initial content
3	10/10/2016	Draft	All partners	Revision/Comments
4	11/10/2016	Final	IFAC	Final Revision

Summary

1 Executive Summary

This document reports the tests that were performed in an eye model (porcine eyes) to test the feasibility of the welding technique performed with the new laser and the LA ROSES system.

2 Introduction on cornea morphology

The cornea is the transparent part of the eye that covers the iris and pupil; whit the lens and the anterior chamber, it refracts the light. It's composed by five layers: the corneal epithelium, the Bowman's membrane, the stroma, the Descemet's membrane and the endothelium.

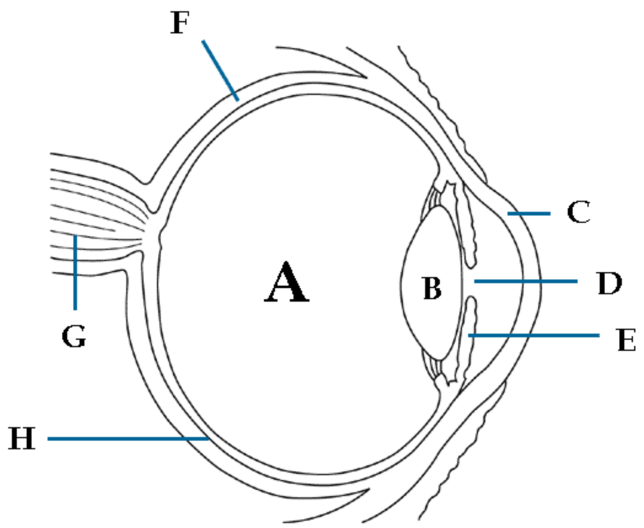


Figure 1: Sketch of an eyeball: A) vitreous humor, B) lens, C) cornea, D) pupil, E) iris, F) sclera, G) optic nerve, H) retina

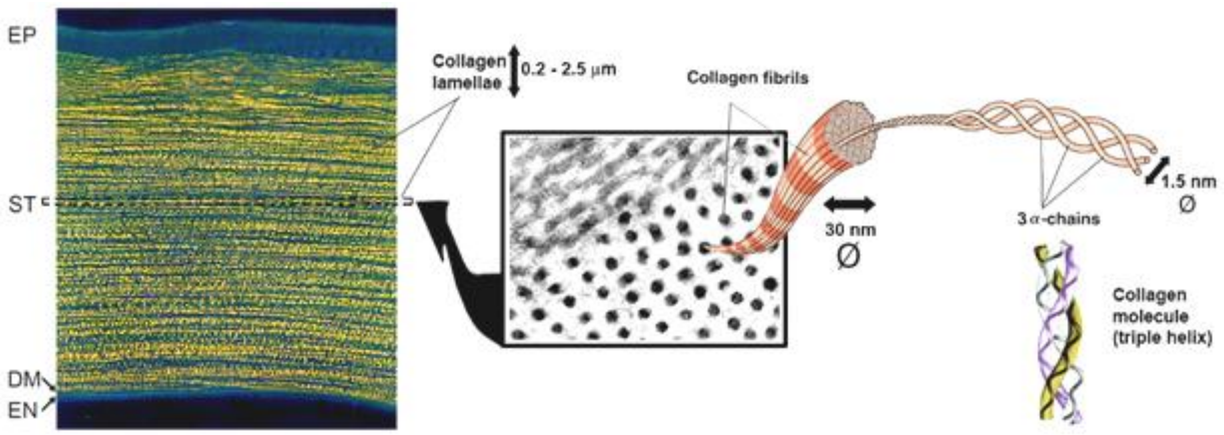


Figure 2: Corneal layers and collagen structure

The cornea is highly innervated and it is avascularized. This properties, together with the peculiar type I collagen distribution within the stroma, are essential to maintain the transparency and the refractive power. The refractive power of the cornea is about 43 dioptres and depends also on the cornea curvature. For this reason, it's of utmost importance to maintain the natural corneal curvature also during surgical interventions.

3 Modeling keratoplasty in porcine eyes

In this experiment we used 10 porcine eyes. The samples were harvested in the local slaughterhouse 2 hours before experiment. They were transported in a temperature controlled box and then delivered to the lab.

The experiments were performed by the corneal surgeon Luca Menabuoni (U.O. Oculistica, Asl 4 Prato, Italy).

During the experimental sessions two different approaches were considered: modelling penetrating keratoplasty (PK), with a half depth incision, and modelling the anterior lamellar keratoplasty, performing an horizontal cut.

In the PK model, the surgical incision was manually performed with a punch suitable for corneal surgery (Hessburg-Barron Vacuum trephine), as depicted in Figure 3.

All the surgical procedures were performed under the surgical microscope.

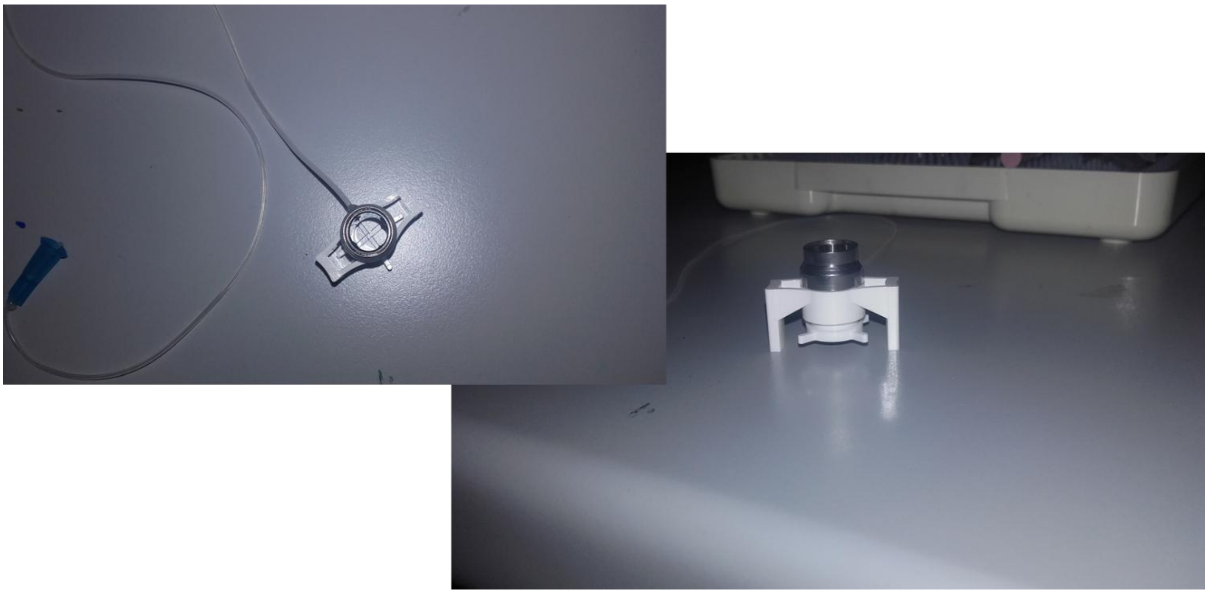


Figure 3: The Hessburg-Barron Vacuum trephine used to model pk in porcine eyes

In all the surgical wounds, Indocyanine green (ICG) was used to stain the wound walls. The ICG powder was dissolved in sterile water. The absorption spectrum of ICG is in the near infrared region. Subsequently the laser has been used to weld the corneal incision: the stained cornea absorbs the laser light (centered at 810 nm, i.e. in the NIR region of the spectrum). During the treatment a thermal camera was used to monitor the induced superficial temperature of the tissue and to control the welding effect.

Figure 4: The Chromophore used to stain the corneal tissue

Figure 5: Key passages of the surgical incision and of the staining procedure

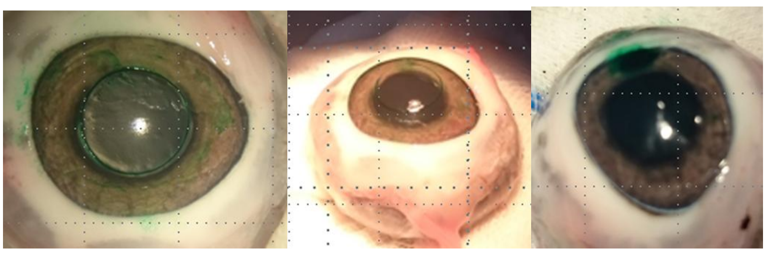


Figure 6: The stained corneas in PK (first left and middle images) and in ALK (first right image).

The tests were performed using a new compacta diode laser (purchased ad hoc from Laser 2000 Gmbh, Germany), with these specifications:

Model SL-810-1000-RS-D-SD
Streamline laser with external focusing
810 nm wavelength nominal
1000mW diode with 750mW on output
Reverse Synchro (RS) modulation
“D” focus option
Separate Driver option
5VDC input operation

The laser was driven by a specially developed controllers and interfaced with a personal computer, in order to be able to adjust the intensity and the modulation of the emitted radiation.

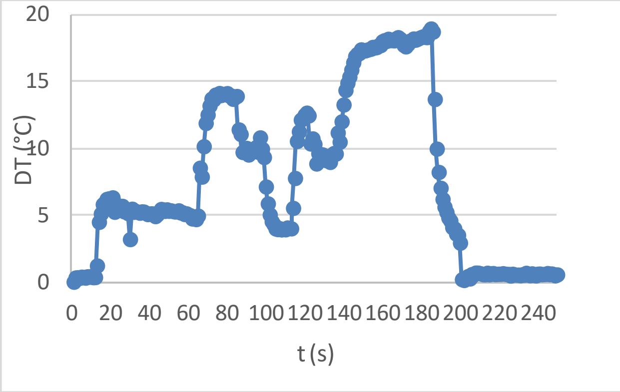
In particular, tests on pig eyes were performed with two different configurations of the laser, corresponding to those used in human surgery:

1) In "continuous" mode, where the laser is driven by a square wave signal with frequency 60 Hz and Ton = 2 ms;
2) In the "single pulse mode", where the laser is driven by a single pulse of duration equal to 70 ms.

Figure 7. The test setup on the porcine eyes. It is possible to see the laser diode and the electronic controlling system, together with the IR thermal camera used to monitor the welding effects.

4 Results

The experiments evidenced that we obtained a good welding effect with the new diode laser. The induced temperature was comparable with the effective welding temperature, measured in our previous research works [1].



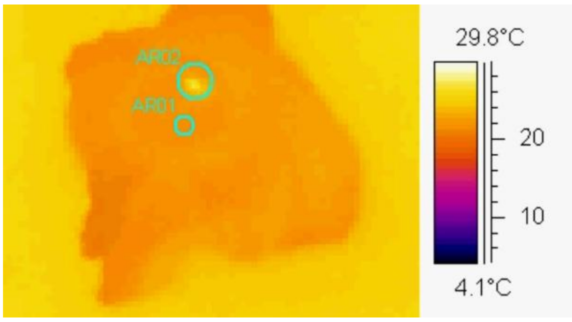


Figure 8: Temperature dynamics (left) and thermal image (right) of a welded cornea simulating PK.

The histological analysis (see D7.3) confirmed these results.

5 References

1. *Experimental and model analysis on the temperature dynamics during diode laser welding of the cornea,* F. Rossi, R. Pini, L. Menabuoni. Journal of Biomedical Optics 12(01), 014031, (2007).