Kinematics of eyelid movement and eye retraction in the blinking

Summary

A non-invasive technique is used to measure the eyelid closure and simultaneous eye retraction. We have fitted the displacement of the eyelid to an analytical function and have extended the kinematic model to the eye retraction movements. As a result, some dynamic parameters have been presented.

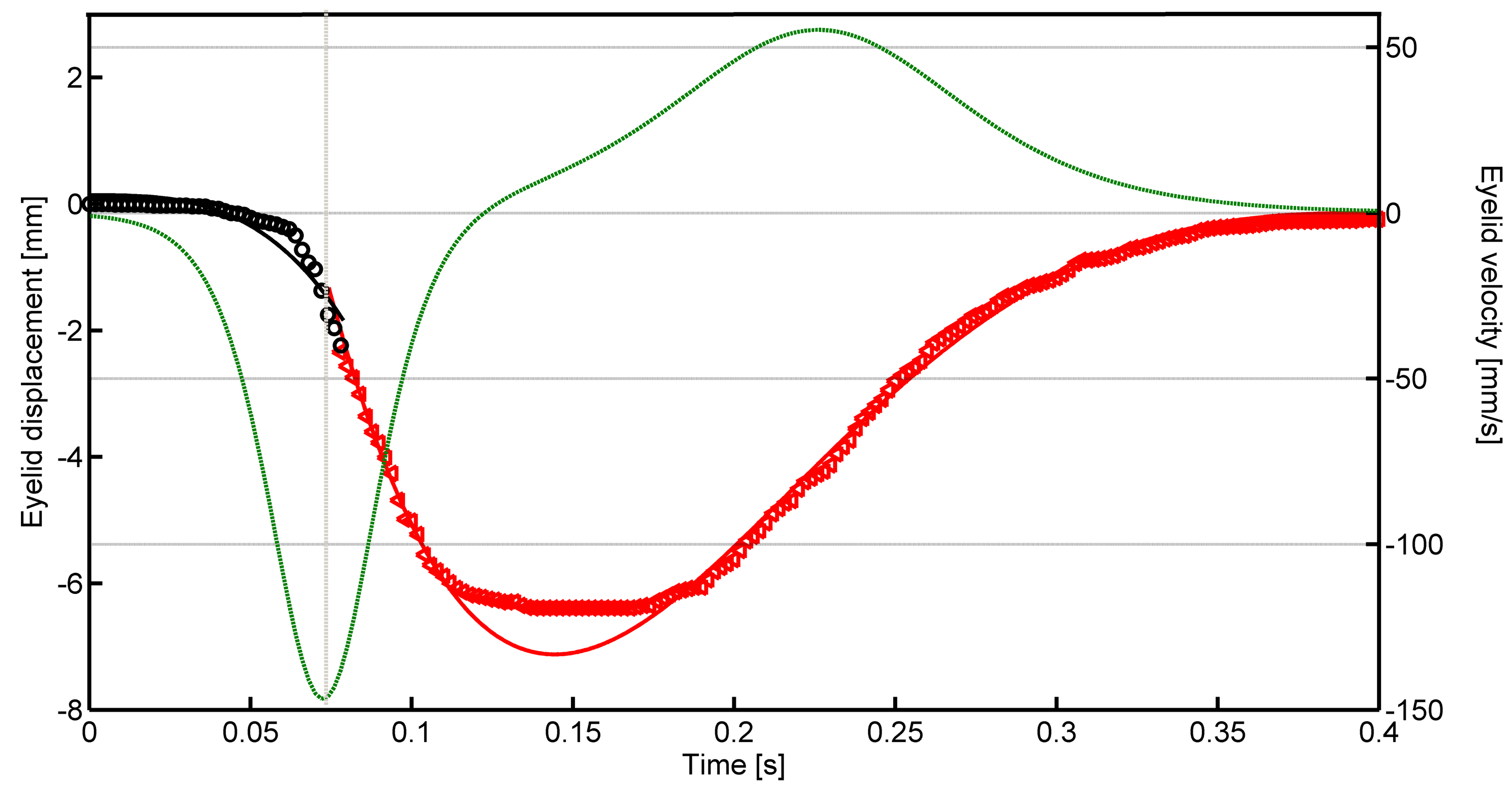
Introduction

A technique used to simultaneous high speed measuring of corneal retraction and the eyelid motion during a blink was described in [1]. Briefly, lid displacement was monitored by studying the saturation of the frames in the sequence whereas eye retraction was evaluated by analysing a scanning line perpendicular to the inferior part of the cornea. We propose here an analytical model of the eye blinking including lid movement and ocular retraction.

Discussion

Upper eyelid motion starts when the Levator Palpebral Superioris muscle (LPSM) is inhibited and the eyelid passively moves downwards. Simultaneously, the Orbicularis Oculi muscle (OOM) fastly contracts. This combination of inhibition and activation of muscles produces the eyelid closure phase. After, LPSM starts a force to the initial position. Nevertheless, when OOM ceases, the upper lid keeps moving down by its inertia. Acceleration in the opposite direction makes that the velocity decreases until the movement is reversed (Figure 1a).

Fig. 1a



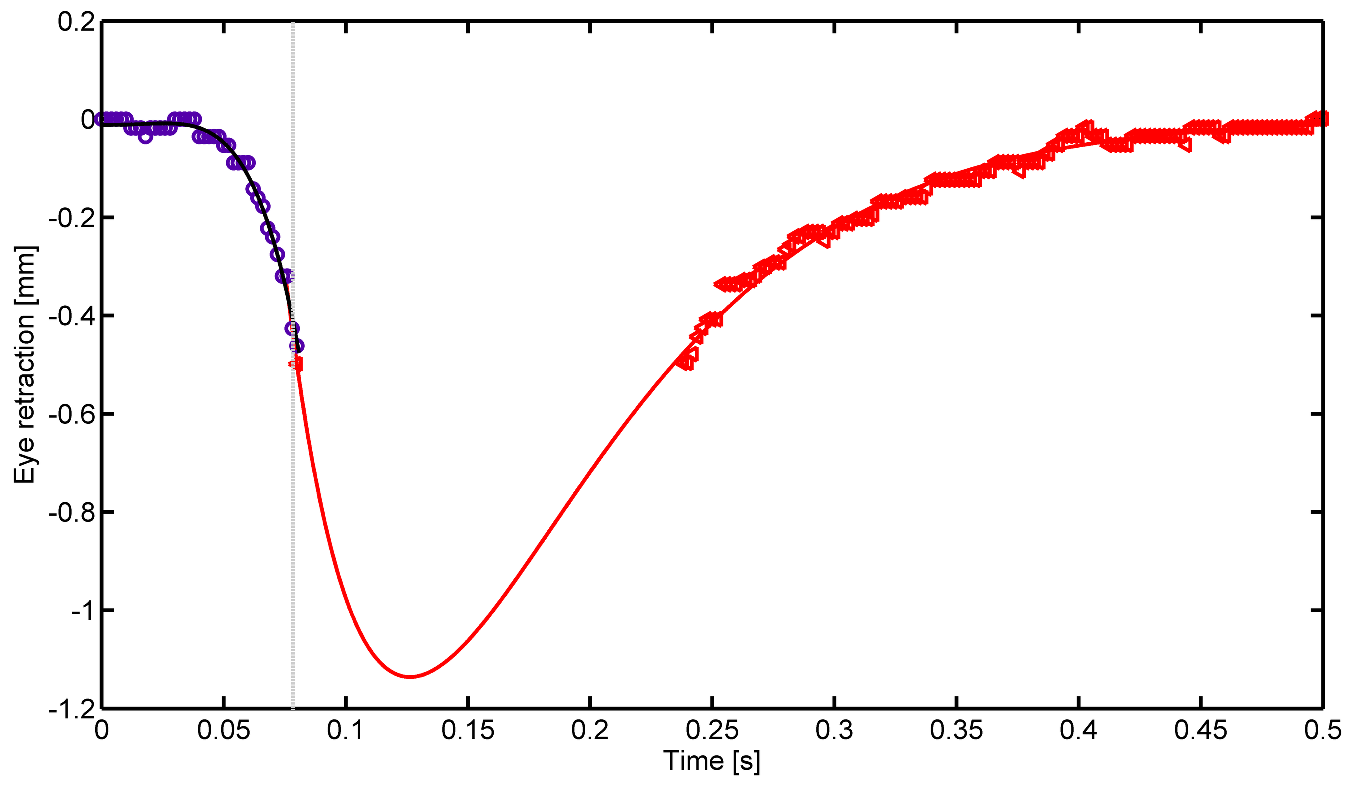


Fig. 1b

Figure 1 a)Eyelid position and fitting to the model for one typical case. Green line shows eyelid velocity during blinking. b) Anterior corneal position and fitting to the model for one typical case. Vertical lines marks the link between two fitting curves (active and the recovery phases).

We divide the process in two parts. The active part goes from the start to the point of maximum absolute velocity. The recovery part covers the time from the peak velocity to the end of the blinking. The mechanism for eye retraction inside the orbit is not so well known. We assume the presence of an active and a recovery phases. Both eyelid movement and eye retraction are therefore divided in two according to the sign of the acceleration (1)

$$X_l^a(t)=\frac{1}{12}bt^3(t-2\tau); \qquad X_e^a(t)=\frac{1}{12}bt^4; \qquad X_{e,l}^r(t)=A\exp(-\mu t)\cos(\omega t+\varphi) \tag{1}$$

Parameters b, τ, ω and μ represent the strength of the muscle force, its actuation time, frequency of the oscillation and the attenuation constant of the system. Indexes l and e stand for lid and eye retraction, and a and r refer to active and recovery phase, respectively. The lack of data in the eye retraction analysis (Figure 1b) impedes the determination of the point with maximum velocity.

Results

Data from blinking of six subjects have been fitted to (1). Results (mean ± standard deviation) are shown in (2). According to Figures 1a and 1b, matching between active and recovery phases occurred at the same time, but, while at that moment the eyelid has started the recovery phase, the eye is still under the effect of a pulling force.

$$\begin{aligned} &b_l=(11.7\pm15.4)\times10^3\,mm/s^4; && b_e=(-0.488\pm0.471)\times10^3\,mm/s^4;\\ &\tau_l=(51.1\pm16.5)\,ms; && \mu_e=(17.0\pm2.7)\,s^{-1};\\ &\mu_l=(10.8\pm2.4)\,s^{-1}; && \omega_e=(2.2\pm0.9)\,s^{-1};\\ &\omega_l=(12.5\pm2.6)\,s^{-1}; && \end{aligned} \tag{2}$$

Acknowledgements

Thanks to Spanish Ministerio de Ciencia e Innovación through the project FIS2009-05639-ET and BIA2011-22704, the Generalitat Valenciana through the project PROMETEO/2011/021 and theUniversity of Alicante through the project GRE10-09. A.B. Roig thanks Fundación Cajamurcia the grant"Beca de investigación Cajamurcia 2010

References

[1] D. Mas, B. Domenech, J. Espinosa, J. Perez, C., Hernandez, C. Illueca, Opt. Lett., 35, 1884–1886, 2010

J. Pérez, J. Espinosa, A.B. Roig, B. Domenech, D. Mas
Dept. Optics, Pharmacology and Anatomy. IUFACyT. University of Alicante
San Vicente del Raspeig - Alicante, 03690, Spain
OCIVIS: http://web.ua.es/es/ocivis/