Experiment on PMMA models to predict the impact of corneal refractive surgery on corneal shape: Comment

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Abstract: Recently, two papers "Dorronsoro *et al.*, Experiment on PMMA models to predict the impact of corneal refractive surgery on corneal shape, Opt. Express **14**, 6142 (2006)" and "JR Jiménez *et al.*, Deviations of Lambert-Beer's law affect corneal refractive parameters after refractive surgery, Opt. Express **14**, 5411 (2006)" have been published on an important question in corneal refractive surgery: to explain the differences between post-surgical corneal elevation maps and those predicted after theoretical ablation. An analysis of Dorronsoro *et al.* data demonstrates that the failures in Lambert-Beer's law could be in the origin of shape discrepancies. New models and experimental data on deviations of Lambert-Beer's law might help to minimize post-surgical corneal discrepancies and thus optimise eye emmetropization.

OCIS codes: (170.1020) Ablation of tissue; (170.4470) Ophthalmology

References and links

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The outcome of wavefront-guided laser surgery is affected by the limited ability to transfer the aimed ablation profile onto the cornea [1-5]. Many variables such as, physical aspects of ablation, corneal biomechanics, hydration, influence the predictability of laser surgery. The work by Dorronsoro *et al.* [5] has experimentally analysed the real and expected ablation shape on spherical and flat surfaces of PMMA (polymethyl-methacrylate) finding post-operative shape discrepancies between measured shapes and those simulated by simple subtraction on the programmed ablation profile.

In a previous work, Jiménez *et al.* [4] proposed that deviations from Lambert-Beer's law may partially explain deviations from the expected post-operative corneal shape. Lambert-Beer's law [4,6-7] is given by $d_p = m \ln(F/F_{th})$, with d_p being the ablation depth per pulse, F the incident exposure, F_{th} the threshold exposure, and m a constant. An analysis of data published by Dorronsoro *et al.* [5] could offer evidence supporting this hypothesis. These

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authors measured an experimental ablation efficiency factor on PMMA, obtained as the ratio between two ablation profiles, one from a spherical surface and the other from a flat surface. Ablations were made by programming the same correction in the laser (-12 *D*).

This ablation-efficiency factor was analysed (experimental data were provided by the authors) considering possible deviations of Lambert-Beer's law. The ablation profile measured on PMMA with a flat surface is given by $Nd_p(0,y)$, where N indicates the number of pulses and $d_p(0, y)$ the depth ablation per pulse on the flat surface at height y. The ablation profile on the spherical surface is given by $Nd_p(\theta,y)$ (θ indicates the incidence angle). Dividing the two profiles for the same y value, we would obtain the ablation efficiency factor, $d_p(\theta,y)/d_p(0,y)$, denoted as $d_p(F(\theta))$. The geometry of spherical surfaces results in ablation efficiency changes from the centre to the periphery. The exposure on the sphere is given by [4]: $F = F_0 \cos\theta(1-R)$, R being the reflectivity, with F_0=120mJ/cm^2 [5]. The key for studying possible deviations of Lambert-Beer's law is to analyse $d_p(F(\theta))$ as a function of $ln(F/F_{th})$ with F_{th} being 80mJ/cm^2 [5].

Figure 1 shows the experimental efficiency factor, $d_p(F(\theta))$, as a function of $ln(F/F_{th})$ and the best linear fit. The departure from the linear fit is greater at higher exposure levels. Differences between experimental data and best linear fit are significant for visual performance. We can compute the difference in refractive power between experimental and linear fit data assuming for computations on cornea (see procedure in Ref. [4]) the values from fittings here obtained for PMMA. In this case, the average difference of refractive power is 0.8*D*, reducing the effective visual acuity, contrast sensitivity and exceeding the quarter-aberration criterion [4]. A degree of myopia lower than -12D would provide a lower refractive-power difference. One important point shown in this analysis is that the range of exposure variations represents a real situation during the ablation. Most analyses of Lambert-Beer's law [4] have used a broad range of exposure variations that do not correspond to the real situation during surgery. In light of this analysis of the experimental data, we believe that new experiments and models on PMMA and corneal ablations are needed to explain shape differences. These experiments and models should not assume Lambert-Beer's law, but should consider different exposure levels and include dynamic optical properties (for polymers and corneas) that occur during ablation [6,7] with the aim of minimizing failures of shape prediction that interfere with a total emmetropization of the eye.

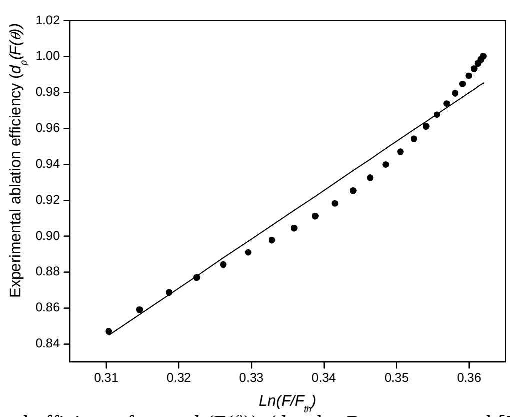

Fig. 1. Experimental efficiency factor, $d_p(F(\theta))$, (data by *Dorronsoro et al.[5]*) as a function of $ln(F/F_{th})$, with F being the incident exposure and F_{th} being the threshold exposure. Best linear fit (solid line, R^2=0.97) is also shown. Optical zone is.5 mm.

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