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Pre-lens tear film on a contact lens: Model and Dynamics

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ABSTRACT

Human tear film plays a vital role in the proper vision and the overall health of the eye. As tear film helps in proper functioning of the contact lens, the presence of sufficient tear film between the cornea and the contact lens (post-lens tear film) and the tear film between the contact lens and the exterior environment (pre-lens tear film) are important for contact lens wearers. The knowledge of the behaviour of pre-contact lens tear film is essential to understand several issues that include dry eye syndrome, oxygen transport to the cornea and increased evaporation and thinning rates of pre-lens tear films. In view of this requirement, in the present study, the behaviour of pre-contact lens tear film of a human eye is analyzed using a mathematical model that describes a thin liquid film (the pre-lens tear film) on a fluid saturated porous layer of constant finite thickness (permeable contact lens). The model is based on the assumptions considered by Nong and Anderson (2010) but differs in two aspects: the present study incorporates (1) evaporation of the pre-lens film; (2) the porous layer is either governed by Darcy-Brinkman equations with stress-jump condition at the interface of the lens and the pre-lens tear film or the porous layer/pre-lens tear film is a three layer model proposed by Hill and Straughan (2008). The advantage of the above choices for the porous layer models is that they provide a regularization of the governing equations in the porous layer (contact lens) and the pre-lens tear film, and this is in contrast to that considered by Nong and Anderson (2010) where there is a discontinuity in the tangential velocity at the interface. Further, the present choice accounts for the viscous-viscous interactions that become important near the interface. A nonlinear evolution equation of the tear film thickness is derived using a lubrication approximation and is solved numerically subject to boundary and initial conditions appropriate for post-blink film evolution (Braun and King-Smith, 2007) for both the porous layer models. The results are compared with the available slip- models used for modeling a tear film on a contact lens (Nong and Anderson, 2010). The results predict an increase in the rate of thinning of the film with increase in the thickness of the contact lens or permeability of the contact lens and this is further enhanced by the evaporation effects. It is interesting to observe that the presence of the contact lens changes the dynamics in that there is rupture of the tear film in finite time rather than in infinite time in the absence of contact lens.

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