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Physicists working to cure 'dry eye' disease

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The eye is an exquisitely sensitive system with many aspects that remain somewhat of a mystery—both in the laboratory and in the clinic. A U.S.-based team of mathematicians and optometrists is working to change this by gaining a better understanding of the inner workings of tear film distribution over the eye's surface. This, in turn, may lead to better treatments or a cure for the tear film disease known as "dry eye." They describe their work in the journal *Physics of Fluids*.

Dry eye disease afflicts millions of people worldwide, with symptoms such as pain, dryness, redness, reduced visual acuity, and feelings of grittiness. While drops can provide some temporary relief, dry eye conditions can damage the cornea and, over time, result in reduced visual function.

When the tear film functions properly, a thin liquid film coats the eye surface during a blink by the upper eyelid, creating a smooth optical surface for vision and allowing us to see clearly.

"With dry eye, this optical function is disrupted by either insufficient tear volume or by excessively rapid evaporation of water from the tear film," explains Richard Braun, a professor in the University of Delaware's Department of Mathematical Sciences. "In either case, the tear film may not be able to form a smooth optical interface for a sufficiently long time to allow normal eye function."

The tear film on the surface of the eye is a very thin fluid layer—only a few millionths of a meter thick. This thickness is less than 1,000 times the size of the eye opening, which is approximately 1 centimeter.

Braun and colleagues "took advantage of this difference in sizes to develop simplified mathematical models that work quite well to capture experimentally observed phenomena in vivo," he said.

Once the team created a mathematical model, they were able to solve it using numerical methods in the computer appropriate for solving the equations on irregularly shaped domains like the shape of the exposed area of the eye. "We use and extend a computational framework called 'Overture,' which was originally developed at Lawrence Livermore National Laboratory," Braun added.

Under the assumptions of their model, the team quantified the dynamics all over the exposed ocular surface, and the results agreed well with in vivo observations of the tear film gained from fluorescence imaging. "Our mathematical results captured how tear fluid makes its way around the eyelids to the drainage holes called 'puncta,' in the inside corner of the eye," he said.

Among the team's key findings was verifying that it takes "a blink" to redistribute tear film. "The evaporated tear film on the front of the eye can't be replenished by simply supplying more new tear fluid from the lacrimal gland," Braun noted.

Braun believes their results "may aid in the development of better treatments for dry eye, and also add valuable context and understanding for current imaging techniques used to observe tear film dynamics."

More information: The article, "Tear Film Dynamics with Evaporation, Wetting, and Time-Dependent Flux Boundary Condition on an Eye-Shaped Domain" is authored by Longfei Li, Richard J. Braun, Kara L. Maki, William Henshaw, and P.E. King-Smith. It will be published in the journal *Physics of Fluids* on May 6, 2014. DOI: 10.1063/1.4871714

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