Solution Optimization and Physical Properties of Healthy Human Tears

A multipurpose solution that exhibits the properties of of normal human tears would be ideal.

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Multipurpose solution (MPS) products for contact lens care have come a long way over lens care regimens requiring two or more products or steps. This can be attributed to various factors including convenience, simplicity, cost efficiency, safety and efficacy.[1] The main functions of a contact lens care solution are to clean the lens by removing proteins and lipids deposited by the tear film, to disinfect the lens, and to make lens wear as comfortable as possible. These functions are interrelated, as proper lens cleaning and disinfection are vital to comfort, which is a key factor in continued lens use and satisfaction.[2] Lens solutions differ in their physical properties, and it has been suggested that several of these differences may influence patient comfort and preference for one product over another.[3]

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A relatively new discipline known as biomimicry uses lessons from nature to enhance existing technology and solve problems.[4] The study of natural mechanisms and processes sometimes leads to scientific innovation. Examples of recent research in biomimicry include the replacement of damaged joints with biologically inspired materials,[5] as well as the development of cell-sized lipid-based containers[6] and proteins attached to biomimetic nanocrystals[7] that may one day be used for drug delivery. In the care of contact lenses, an MPS product that exhibits the properties of normal human tears is considered an optimal target formula.[3] Such properties include pH, osmolality, viscosity and surface tension. If any of these properties differ significantly from those of normal tears, patient discomfort may result.[3] An important consideration for bio-inspired products is that their de-

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velopment is firmly rooted in science. It is not enough for contact lens care solutions and formulas to simply have properties that mimic tears. For example, disinfection efficacy should never be compromised; as new contact lens solutions are developed, eyecare practitioners should look for better disinfection efficacy given what is known about patient compliance and the development of "superbugs" like methicillin-resistant *Staphylococcus aureus*.

Importance of the Tear Film

The tear film consists of a lipid component, a mucinous component and an aqueous component.[8] Each component is important in the physiology of the ocular surface. The lipid component contains wax esters, sterol esters, fatty acids, and fatty alcohols.[9] The mucinous component is comprised of mucins that are constituted largely of sugars.[9,10] The aqueous component, which constitutes the bulk of the tear film, is composed of 98% water but also contains salts, mucins, and proteins including hyaluronan, lysozyme, lactoferrin, lipocalin, and secretory immunoglobulin A.[9,11-13]

The composition of the tear film is maintained within narrow limits, as any perturbations can interfere with health and function.[14,15] Abnormalities of the tear film are the main cause of conditions such as dry eye syndrome.[16] Disruption of the homeostasis of the tear film results in ocular surface inflammation, which may lead to cell damage. Abnormalities of any tear component can result in tear film instability and hyperosmolarity.[17] The formation and stability of the tear film in both health and disease are dependent upon the physical properties of tears.[18,19]

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Characteristics of Human Tears

A solution's acidity or alkalinity is measured in pH units.[3] In general, the pH of healthy tears is reported to range from 7.3 to 7.7,[20] with a mean value ± standard deviation of 7.5 ± 0.23.[21] pH is influenced by dissolved substances, especially by the bicarbonate–carbon dioxide buffer system.[22] Tear pH is lowest upon wakening due to acid byproducts associated with prolonged eyelid closure.[23] When the eyelids are open, pH increases rapidly due to carbon dioxide loss.[22]

The pH of a contact lens solution is affected by the buffering agents used in the solution.[3] Patient comfort is a function of the buffering capacity of a solution.[24,25] Solutions instilled with a pH below 6.6 and above 7.8 can cause irritation, rapid blinking, and reflex tears.[22,23] Stinging and ocular discomfort have also been reported with solutions that have a pH beyond the ocular comfort zone of 6.6 to 7.8.[3,25,26]

Osmolality is defined as the total concentration of dissolved particles in a solution irrespective of size, density, configuration, or electrical charge.[23] Normal tear osmolality is approximately 305 mOsm/kg.[3,27] The osmolality of healthy tears varies from 244 to 344 mOsm/kg, depending on the method and the location in the eye from which the tear sample was collected.[28,29] Osmolality decreases at night due to decreased tear film evaporation. When the eyes are open, osmolality rises due to increased evaporation of the tear film.[22,23,27] Osmolality increases in diseases such as dry eye, signifying an increased concentration of electrolytes.[23]

Osmolality levels play a vital role in the discomfort experienced by patients with dry eye, as higher osmolality levels result in higher patient discomfort.[30-32] Therefore, it has been suggested that patients with dry eye could be more sensitive to the osmolality of contact lens solutions compared with normal subjects.[3] Early contact lens wear causes decreased osmolality, but osmolality increases following lens adaptation due to increased evaporation from the disrupted lipid component of the tear film.[23]

Viscosity is a measure of the resistance of a fluid to flow.[33,34] Human tears have a viscosity in the range of 1 to 10 cP, and viscosity decreases with an increasing rate of shear stress (this property is known as "shear thinning").[35,36] In the open eye, higher viscosity resists damage and tear film break up. Blinking, conversely, requires low tear viscosity to avoid damage to epithelial surfaces.[37] Viscosity may affect patient discomfort due to interactions between the solution, the lens and the tear film.[3]

Surface tension is the inward attraction of molecules at the surface of a solution. The surface tension of water is approximately 72 millinewtons per meter (mN/m).[3] The combination of proteins, lipids, mucins, and electrolytes, among other substances found in human tears[3] results in a lower surface tension (42 to 46 mN/m).[38] Surface tension influences the formation and stability of the preocular tear film. Patients with conditions such as dry eye have a higher mean surface tension than healthy individuals.[18,39] Contact lenses remain on the cornea because of the surface tension of the tear film.[40] Surfactants, a common component of contact lens care solutions, tend to reduce surface tension[3] and therefore, may add to contact lens movement and discomfort to the user. Surface tension outside a normal range can lead to an imbalance in the composition and instability in the tear film, which could result in patient discomfort.

Optimizing a Formula

The above characteristics of human tears are important for ocular health; therefore, a contact lens care solution with a pH, osmolality, viscosity, and surface tension within the ranges observed in normal human tears would be considered an optimal formula. Such a product would be expected to provide superior comfort for daily lens wear.[3]

Within the field of biomimicry, the development of an optimal formula for an MPS product should take into account all of the above physical properties, as well as superior disinfection efficacy. Each property should be adjusted, if possible, to fall within the reported range of that property for normal human tears to ensure maximal health and ocular harmony for contact lens wearers. In the crowded and competitive contact lens care market, a biologically inspired MPS product engineered to resemble human tears with unsurpassed disinfection efficacy would stand out as a significant development. **CLS**

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