Contact lens wetting and biocompatibility

Catherine A Scheuer and **Susan E Burke** look at what influences wettability and how BioTrue multipurpose solution may influence the property during lens wear

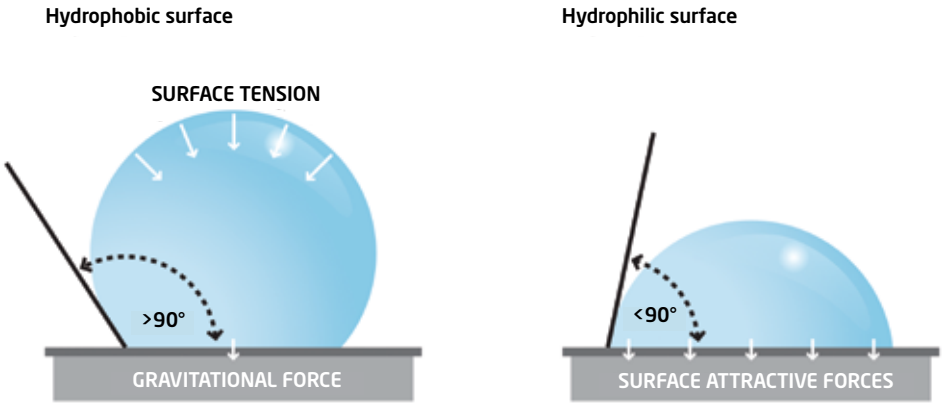
The tear film, a specialised system comprised of highly interdependent components, provides a smooth, lubricated optical surface. Its close relationship with surrounding ocular tissues is essential to maintain a healthy ocular surface.[1] Contact lenses have been shown to interfere with this relationship, altering the thickness and physicochemical properties of the tear film.[2] Recent advances in soft contact lens technology with the introduction of silicone hydrogel lenses and the inclusion of wetting agents in lens care solutions have been made to enhance the biocompatibility and wettability of contact lenses in an attempt to improve the relationship between contact lenses and the ocular surface.

For the best patient outcome, a contact lens must be biocompatible with surrounding ocular tissue. This success depends heavily on the interactions of the surface of the contact lens with the tear film and corneal tissues. A highly biocompatible surface has a very low tear-lens surface interfacial tension, therefore creating a highly wettable surface on which tears spread readily (Figure 1). The surfaces of hydrogel and silicone hydrogel contact lenses are composed of polymer chains which are both hydrophilic (water-loving) and hydrophobic (water-repelling). Portions of these chains have the ability to rotate, to shift position around a chemical bond, a process called hydrophilic-hydrophobic transition. Hydrogel surfaces exposed to water will tend to be populated in hydrophilic groups, while those surfaces exposed to air or nonpolar fluid can collect hydrophobic groups.[3]

The presence of a hydrophilic environment will stabilise hydrophilic groups. A surface in contact with predominantly hydrophobic components will contain stabilised hydrophobic groups (methyl or silicone). This process, as dynamic as it is, becomes relatively constant shortly after a contact lens is placed on the ocular surface. A contact lens placed on the eye is immersed in tear fluids and becomes coated with a complete tear film. The tear film on the posterior side of the lens is quite similar to the pre-corneal tear film, from mucous layer to lipid. Within minutes of wear, a contact lens becomes coated with hydrophilic tear film mucins. This mucin coated surface is no longer capable of such dynamic hydrophilic-hydrophobic transition.[3,4] Despite recent advances in contact lens materials, comfort and dryness at the end of the day continues to be a concern.

To address concerns of dryness and comfort, contact lens disinfecting solution technology has also advanced with the introduction of new products geared toward improved lens wettability. The use of conditioning agents in contact lens disinfecting solutions is one strategy for further stabilising the hydrophilicity of a contact lens surface and enhances surface wetting. A contact lens disinfecting solution formulated with ingredients that work like components of tear film may help improve wettability and biocompatibility of contact lenses. For example, Biotrue multi-purpose solution contains both surfactants and the lubricant, hyaluronan, found naturally in the eye, to work together to help improve wettability, biocompatibility, and patient comfort.

Surfactants have the ability to reduce surface tension because they contain both hydrophilic and hydrophobic regions (Figure 2a). As the surface tension of a liquid decreases with the addition of surfactant, the energy required for the liquid to spread across a surface decreases, providing a more wettable surface. When the surfactants used in ▶



Liquid on a non-wettable surface; surface tension dominating attractive forces on surface

When attractive forces to surface exceed surface tension, the liquid wets the surface

Figure 1

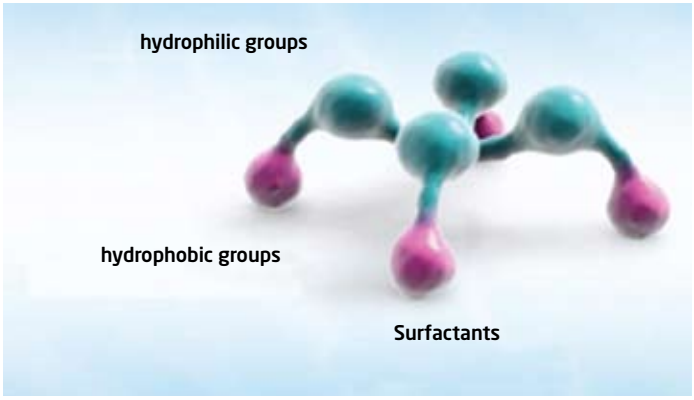


Figure 2a The surfactants in Biotrue multi-purpose solution have both hydrophilic and hydrophobic groups

Figure 2b The hydrophobic groups of the surfactant molecules attach to the hydrophobic areas of the lens. The molecules form a layer, creating a hydrophilic environment that attracts moisture[5,6]

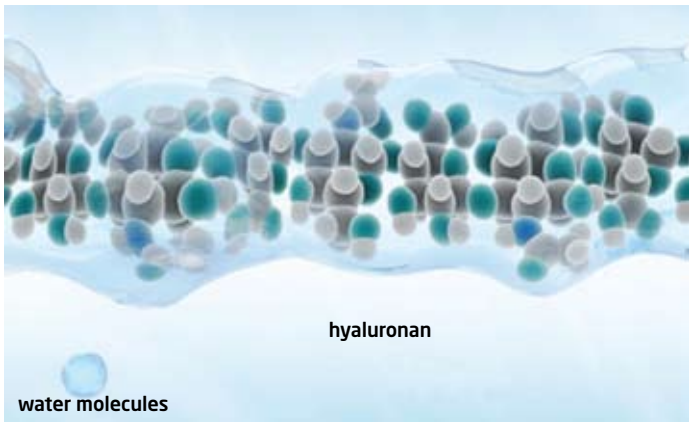


Figure 3a Hyaluronan is a lubricant found naturally throughout the body,[11] which works in combination with the surfactants. The random coil structure of HA results in unique water-retention properties. HA holds up to 1,000X its weight in water[12,13]

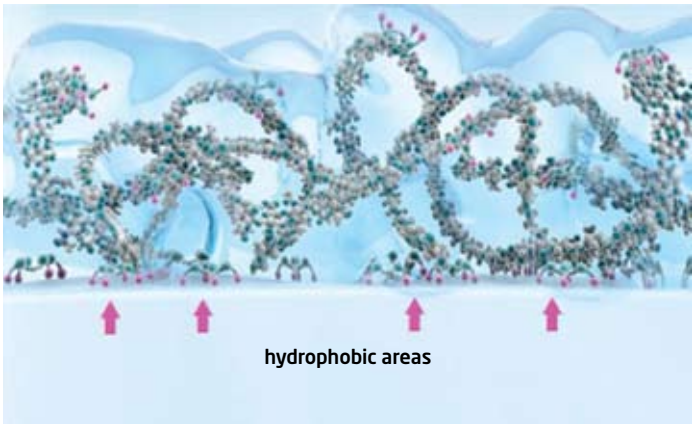


Figure 3b HA forms a free-flowing network on the lens surface and develops a matrix with the surfactants

Biotrue (poloxamine and sulfobetaine) interact with the lens surface, the hydrophobic regions can interact with any hydrophobic portions of the surface while the hydrophilic region of the surfactant presents itself to hydrophilic tear fluid, aiding in the stabilisation of a hydrophilic, water-loving, more wettable lens surface (Figure 2b). This adsorption and release of surfactant from the lens can be monitored over time with the measurement of surface tension.

Hyaluronan (HA), a high molecular weight glycosaminoglycan biopolymer, is a lubricant found naturally throughout the body, particularly in the eye.[7,8] While hyaluronan is not surface active, it has been included as a conditioning agent in Biotrue for its remarkable water retention and viscoelastic properties. A high capacity for hydrogen bonding allows HA to attract and to retain moisture within its coiled polymer chains (Figure 3a). Under high shear force, such as the blink of an eye, HA polymers align, decrease viscosity and spread evenly across the ocular surface.[9] Additionally, HA has been shown to have specific affinity for ocular mucins,[10] which can further enhance the wettability of contact lenses.

The inclusion of two types of conditioning agents in Biotrue, surfactants and the polymer hyaluronan, creates a unique system designed to improve surface wettability and boost hydration. The surfactants and hyaluronan interact both with each other and with the surface chemistry of the lens resulting in a matrix that attracts water to envelop the lens in a moisture rich cushion (Figure 3b).

It has been shown that good biocompatibility for biomaterials, such as contact lenses, requires moisture to readily spread across the surface which means the interfacial tension (surface tension) must be as low as possible. Many methods have been employed in attempt to indirectly measure this interfacial tension, including contact angle measurements. Sessile drop, one of the most commonly used techniques, relies on interactions between a liquid drop and the contact lens. However, the disadvantage is that the lenses must be blot dried which may lead to reduced wetting and lens dehydration prior to measurement.[14,15] The captive bubble method of measuring contact angle, utilising the angle created by an air bubble placed at the lens surface, has also been used. Critical to this measurement is the ability of the air bubble to displace liquid from the surface, creating opportunity for error in measurement.[16] An alternative to these methods is to directly measure the surface tension of fluids released from contact lenses. A decrease in the surface tension of these fluids indicates a decrease in the energy needed to wet the surface interface.

The surface tension of fluids released from lenses soaked in contact lens disinfecting solution can be measured over time to evaluate the release of surfactant wetting agents. Contact lenses were soaked for eight hours in a variety of multipurpose solutions and then rinsed with

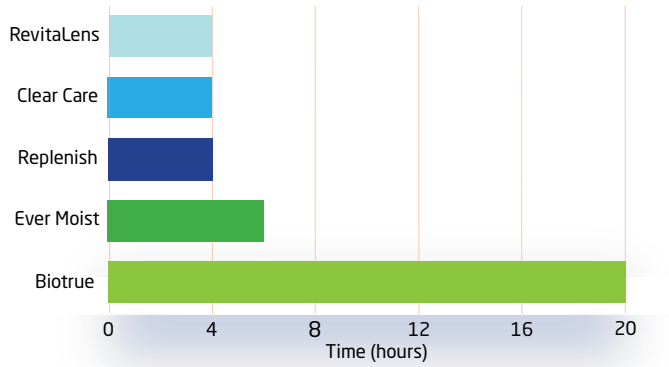


Figure 4 Hours of continuous wetting agent release from silicone hydrogel lenses tested

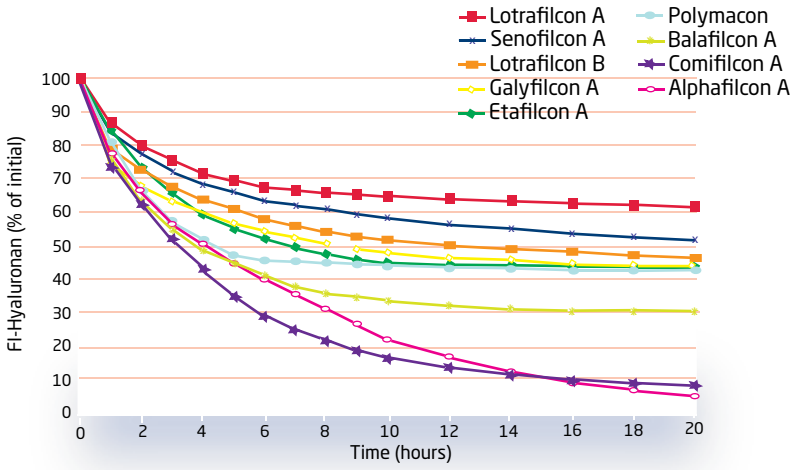


Figure 5 Hyaluronan release from hydrogel and silicone hydrogel contact lenses

a buffer solution at a rate that approximates tear secretions. Rinse solutions were collected every two hours and the surface tensions of diluted samples were measured. A reduction of surface tension compared to the control indicates the release of surfactant. Results from testing silicone hydrogel lenses showed that release of surfactant adsorbed from Biotrue could be detected for up to 20 hours (Figure 4).[17]

A similar method was used to evaluate the release of hyaluronan over time from Biotrue soaked contact lenses. Contact lenses were soaked overnight in Biotrue made with a tagged HA. The lenses were rinsed with a buffer solution at a rate that approximates tear secretions. Rinse solutions were collected and HA concentrations were extrapolated from a tagged HA standard curve. The release of HA from these lenses could be detected for up to 20 hours (Figure 5).[18]

A healthy ocular surface is lubricated by the tear film. Contact lens wear can alter the functioning of the tear film, so it is essential that attention is given to minimising effects of contact lenses and contact lens disinfecting solutions on the fairly narrow limits naturally maintained at the ocular surface. The surfactants and HA in Biotrue can remain on the contact lens surface for up to 20 hours and work together to increase contact lens wettability and help improve biocompatibility and comfort of contact lens wear.

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