

Exploring the Relationship Between Materials and Ocular Comfort and Health

As the debate continues, this expert shares the latest thinking on the most important properties.

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May any contact lens material be described as truly biocompatible? One definition suggests that a biocompatible contact lens material should have minimal impact on comfort and ocular physiology and, at the same time, be minimally affected by the ocular environment, as evidenced by deposits on the lens.¹ Given that so many contact lens complications can be traced to material properties, there is an obvious shortfall in material biocompatibility.

Conventional hydrogels commonly can induce hyperemia, corneal swelling and symptoms of dryness. Although first-generation silicone hydrogel lenses somewhat alleviated these problems, other aspects of performance suffered. As we see with high-Dk gas permeable materials, subtle differences in silicone hydrogel materials can have significant effects on clinical performance.

In this article, I will explore the most

important contact lens material properties affecting clinical performance and how these relate to comfort.

Modulus

Elastic modulus or, as I prefer, Young's modulus, is an index of a contact lens material's ability to drape and align to the ocular surface. There is relatively little variation in the moduli of conventional hydrogels. However, early silicone hydrogel lens materials, with moduli up to five times greater than conventional hydrogels (Table 1), showed that stiffer lenses can affect lens performance. On the positive side, handling is easier, and silicone hydrogel lenses are sometimes prescribed for this reason alone. Regarding lens fit, centration is generally better with a higher modulus lens, however, a single design is less likely to fit a wide range of ocular shapes. Some clinicians have noted cases of poor edge alignment in terms of edge stand-off and indentation, which can cause discomfort. As a result, some silicone hydrogel lenses may require longer



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Table 1

Silicone Hydrogel Material Properties						
MATERIAL	LENS (MANUFACTURER)	WATER CONTENT (%)	DK/T (X10-11)	MODULUS (MPA)	LUBRICITY (FRICTION COEFF. X1000)	UV-BLOCKING
balafilcon A	PureVision (Bausch & Lomb)	36	110	1.50	22	No
comfilcon A	Biofinity (CooperVision)	48	160	0.75	-	No
galyfilcon A	Acuvue Advance (Vistakon)	47	86	0.43	17	FDA Class 1
lotrafilcon A	Night & Day (CIBA Vision)	24	175	1.52	47	No
lotrafilcon B	O ₂ Optix (CIBA Vision)	33	138	1.00	6	No
senofilcon A	Acuvue Oasys (Vistakon)	38	147	0.72	3	FDA Class 1

N.B. Most measurements undertaken by Biomaterials Research Unit, Aston University, Birmingham, UK.

adaptation periods. This makes assessing a patient’s success with these lenses more difficult because the absence of lens awareness is a useful clinical indicator of fitting success.

High modulus also has been implicated in a growing list of contact lens complications. Our study of silicone hydrogel lenses has shed some light on the previously perplexing problem of superior epithelial arcuate lesions (SEALs). On some eye shapes, relatively stiff lenses are unable to flex enough to align with the peripheral cornea and the limbal area. As a result, when clamped by the upper lid, the lens is forced against the cornea, exerting extreme pressure in the area of greatest misalignment (Fig. 1).

Slightly higher rates of papillary conjunctivitis also

lus, second-generation silicone hydrogels.

Corneal molding also has been described with high modulus silicone hydrogel lenses, particularly when inadvertently worn inside out.⁷ These lenses may prove useful in orthokeratology.

Hydration

Contact lens dehydration is poorly understood, despite many opinions on this subject. To suggest that lower water content lenses are inherently less prone to dehydration is probably an oversimplification. Similarly, to suggest that materials showing the least on-eye dehydration are superior also can be misleading because hydration is affected by a

range of variables, such as eye temperature, osmolarity and tear film stability.⁸ Nevertheless, a relationship does seem to exist between dehydration and corneal desiccation staining and symptoms. Figure 3 summarizes some of the correlations noted in clinical studies. Although no direct correlation has been noted between dehydration and corneal staining, the link is implied by the

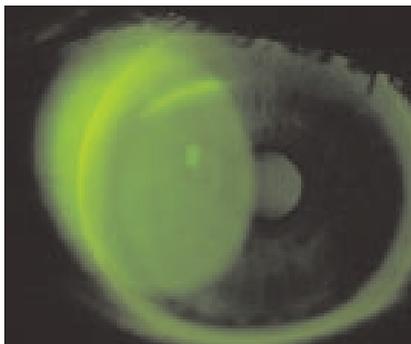


Figure 1: Superior arcuate corneal staining in a silicone hydrogel-wearing eye. Post-lens fluorescein indicates area of pressure and corresponding staining.

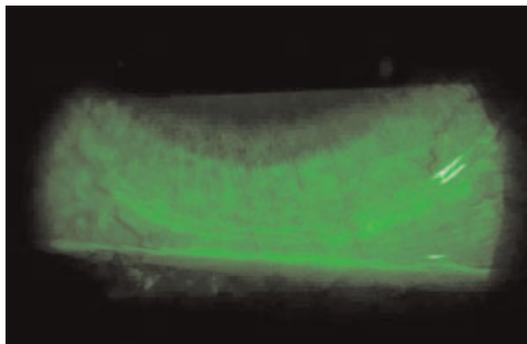


Figure 2. Conjunctival flap following wear of first-generation silicone hydrogel lens. Photo courtesy of Lofstrom & Kruse.

have been noted with silicone hydrogel lenses,^{2,3} particularly in some studies of extended wear, suggesting the importance of mechanical as well as immunological stress in susceptible patients. Silicone hydrogel lenses also have been responsible for two new complications: mucin balls and conjunctival flaps (Figure 2). Post lens mucin balls have been noted in extended wear and rubbing of the inferior lens edge against the conjunctiva has been found to generate thin flaps of tissue.⁴⁻⁶ Both of these appear to be innocuous and likely to be reduced with the lower modu-

fact that staining can be induced by lowering humidity, increasing evaporation or reducing lens thickness.

A direct correlation between dehydration and discomfort have proved difficult to replicate. One reason for this difficulty is that dehydration is probably localized in problem areas, such as areas showing “smile” staining. Also, there are probably several mechanisms for symptoms of dryness; pre-lens drying can result in discomfort due to friction during blinking, while post-lens desiccation can cause corneal irritation through disruption of

the corneal epithelium.

Several reports have suggested symptoms of dryness and end-of-day discomfort are reduced with silicone hydrogel lenses.⁹⁻¹¹ Early work suggests that, once equilibrated in the eye, silicone hydrogel lenses maintain lens hydration through the wearing period. However, further work is needed to elucidate differences between materials and to determine the relative importance of this versus surface wettability.

Lubricity

The wide range of measurements used to characterize contact lens wetting is an indication of the complexity of this topic. Wetting angle has limited relevance because it relates to saline, not tears. Researchers in the Biomaterials Group at Aston University in Birmingham, England, have measured dynamic contact angle with a procedure that simulates tear film breakup and consequent dehydration. Some materials, such as lotrafilcon B, show better maintenance of wetting angle under these conditions than others.¹²

Surface lubricity (coefficient of friction) has been used recently to compare contact lens materials (Table 1).¹² It is thought to relate to the level of friction sustained by the eyelid crossing the lens surface, with higher lubricity allowing the lens to cross the ocular surface with less awareness or irritation. Senofilcon A has been measured as having lubricity approaching that of the cornea. Given that during the average wearing period, the eyelid can travel a distance longer than the length of a soccer field, minimizing friction must be a factor in maintaining comfort. Vistakon has suggested that practitioners try a “touch test” with patients to demonstrate the lubricity of senofilcon A compared with other materials.

Oxygen Permeability

The oxygen transmissibility recommended for daily contact lens wear has been variously estimated between 24 and 35.¹³ This debate has spilled out of the laboratories and educational arenas and into the courts, and I, for one, don’t intend to be caught in the crossfire. Suffice it to say, those of us who saw ultrathin polymacon lenses as a big step forward for cornea-kind are bemused at the concern shown for corneas exposed to Dk/t of a mere 80 or so. Wherever the threshold lies, I believe it is time for low water-content hydrogel lenses to be given a dignified retirement.

In general, raising the Dk of silicone hydrogel materials has involved increasing silicone content and decreasing water content at the expense of other properties, modulus in particular. The imminent launch of the comfilcon A lens (CooperVision) appears to be an exception. Early clinical trial reports suggest reduced adverse events; however, we await the results of ongoing clinical studies to give a fuller picture.

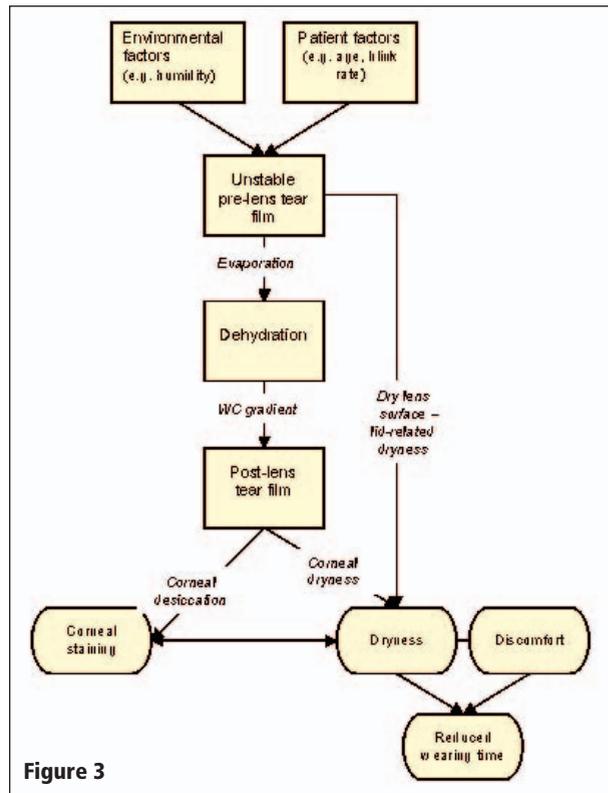


Figure 3

It seems likely that as we move to newer generations of silicone hydrogel contact lenses, we will see improvements in the balance of material properties. However, there may be more oxygen to be had from hydrogels other than silicone-containing materials. With methacrylate-containing hydrogels, the strict correlation between water content and Dk and its limitations are well understood. Other families of hydrogels, such as ethylene glycols, show a similar link but with higher permeability (k), enabling hydrogels of higher Dk. One development group (Ocutec, United Kingdom) has overcome the problem of producing stable, transparent polyethylene glycol materials and is working on contact lens applications.

Deposit Resistance

Silicone hydrogel materials have been shown to attract relatively low levels of lysozyme but high levels of lipid compared with ionic hydrogel lens materials. As a result, we have seen a reappearance of white-spot deposits (Figure 4), having previously celebrated their demise in conventional hydrogels with the introduction of frequent replacement. Even when these deposits are barely visible to the naked eye, patients begin to notice a foreign body sensation. The prevalence of deposition varies among the silicone hydrogel materials, depending on the type of system used to retain wettability: inherent wettability or sur-

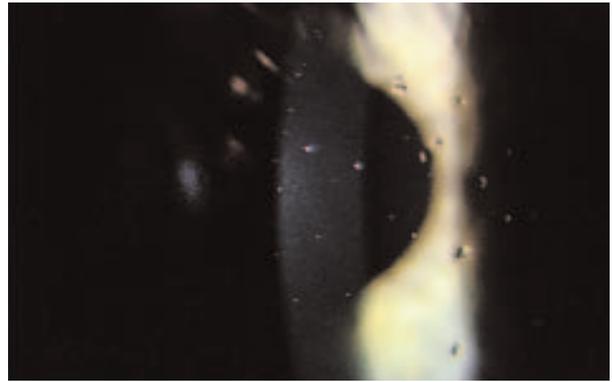
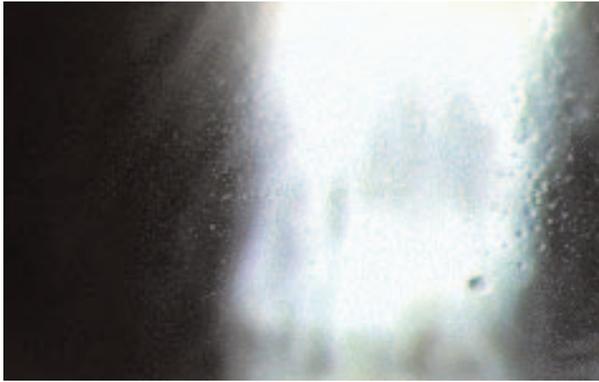


Figure 4. Silicone hydrogel materials have been shown to attract high levels of lipid compared with ionic hydrogel lens materials.

face treatment. However, it has been shown with galyfilcon A that most lipid deposition can be avoided by the use of a rub-and-rinse step in the care regimen.¹⁴

UV Inhibition

Finally, an often overlooked material property that influences ocular health is UV inhibition. This can reduce one of the risk factors for patients developing chronic UV-induced pathology such as pinguecula, cataract and macular problems. Ho and colleagues¹⁵ have shown that even when people wear sunglasses (non-wrap-around types), UV radiation entering the eye obliquely is focused on the nasal sclera, risking the formation of pterygium. Two currently available silicone hydrogel contact lenses contain a UV inhibitor: galyfilcon A and senofilcon A. These lenses

should be used with, not as a substitute for, UV-blocking sunglasses. (For an in-depth discussion of the effects of UV radiation and protection methods, see “When a Contact Lens Is the Healthier Choice” on page 30.)

Goal: True Biocompatibility

The relative performance of contact lens materials differs, in some cases, gaining one advantage at the expense of other aspects of clinical performance. Often these are only evident by clinical experience, and it is clear that we need to improve our ability to predict clinical performance from measurement of material properties. This is particularly important given that further improvements in contact lens materials on the horizon will bring us closer to the goal of true biocompatibility. **CLS**

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