New frontiers in daily disposable contact lenses

Dr Tim Giles, Dr Inma Pérez-Gómez and **Dr Cameron Hudson** explain how balancing developments in comfort, ocular health and biocompatibility continue to make daily disposable wear an attractive option for patients

'We stand today on the edge of a new frontier …a frontier of unknown opportunities… The new frontier… is not a set of promises – it is a set of challenges.'

US president John F Kennedy made these statements as he anticipated the era of the 1960s.[1] But it also rings true today for those of us in the contact lens field, as we consider the status quo and anticipate future trends in the era of daily disposable contact lens wear.

Wearing a contact lens one time and discarding it at the end of the day is an appealing concept. Daily disposable (DD) lenses were designed to offer contact lens wearers comfort, convenience and ease of use. First introduced in 1994, daily disposable lenses have become an important modality with significant benefits and are the fastest growing contact lens modality in Europe.[2] Study data supports the positive clinical experience with these lenses, making them one of the most convenient types of contact lenses available.[3]

A question of balance

Contact lens wearers want convenience, comfort, clear vision and value. Eye care professionals want good ocular health, clear vision and satisfied wearers. Creating the ideal contact lens is similar to solving Rubik's Cube – several different factors need to align in a precise and predictable way in order to solve the puzzle. In the case of daily disposable contact lenses this means achieving the key objectives of health, comfort, vision and convenience – simultaneously.

It's not as easy at it might seem, because with each objective come pros and cons that must be balanced. Three important areas we will review in this article are:

- Optimising health
- Optimising comfort
- Optimising biocompatibility.

The challenge is to optimise the desired features while minimising the liabilities they bring to the equation.

'The new frontier... is not a set of promises - it is a set of challenges'

Optimising health

The case for oxygen and silicone hydrogel (SiH) lenses

Meeting the oxygen challenge was the driving force behind the development of silicone hydrogel (SiH) materials, and a decade of clinical experience has shown SiH lens wear to be a healthy and successful option. Findings from a three-year clinical study included significant reduction in signs and symptoms associated with corneal hypoxia in wearers of SiH lenses compared to low-Dk HEMA lenses.[4] There was significant improvement in limbal and conjunctival hyperaemia and corneal neovascularisation, and significantly fewer symptoms of lens awareness, redness, dryness, photophobia and blurred vision. Highly oxygen-permeable SiH materials have significantly reduced the number of hypoxia-related findings reported in daily wear; hypoxia-related conditions such as microcysts, striae, bulbar and limbal hyperaemia have been virtually eliminated for SiH lens wearers.[5]

One of the most visually dramatic benefits to refitting with SiH lenses is the marked improvement in limbal and conjunctival hyperaemia. Limbal hyperaemia results from oxygen deprivation at the peripheral cornea and causes limbal stem cell damage. This damage makes the cornea vulnerable to deficient epithelisation, which can lead to recurrent corneal erosions, chronic keratitis and vascularisation.[5]

However, the oxygen transmissibility required for 'normoxia' – the level that allows for normal corneal physiology – has been an elusive figure, and research continues to explore the minimum Dk/t levels needed to provide for 'normal' corneal oxygen demands.[6]

Further adding to the complexity is the fact that there is individual variation in corneal oxygen demand – some corneas can tolerate lower Dk lenses, while others have higher demands. Contributions to an individual's corneal swelling responses are multi-factorial and not only dependent on lens type.[7] This would suggest that the minimum Dk/t differs for each individual and published data shows some corneas exhibit more swelling than others under the same conditions.[7,8] Genetic predisposition to dystrophies, a history of trauma or toxicity, age, systemic disease, lens thickness profiles, even altitude differences are variables that may affect normoxia.[9]

With oxygen transmissibilities (Dk/t @ -3.00D) ranging from 86 to 175, currently available weekly and monthly SiH lenses offer lens wearers healthy options that better meet the cornea's oxygen demands than traditional hydrogel material lenses. Currently there are three SiH daily disposable lenses on the market, with Dk/t @ -3,00D ranging from 65 to 118. All other daily disposable contact lenses are either traditional hydrogel (HEMA) lenses or polyvinyl alcohol (PVA) lenses, with Dk/t @-3.00D ranging from 18 to 37.[10]

The bottom line is that corneas need oxygen; some need more than others, and the same cornea may have different oxygen needs under varying conditions. While we don't know the optimal Dk/t for each individual, we do know that

increased oxygen transmissibility is good. Therefore, it makes sense to use lenses that deliver the highest oxygen transmissibility available to help provide for the oxygen needs of the cornea.

● Implications in practice

The quest for higher Dk/t material is justified. The higher Dk/t the greater confidence that the critical minimum oxygen requirement of all lens wearers is met, across the entire corneal surface and for lens powers other than -3.00D.

Optimising comfort

Preventing contact lens dropouts

Lens comfort is a key issue for the estimated 125 million contact lens wearers around the globe. Decreased comfort during the wearing cycle affects large numbers of wearers and continues to be the major reason for discontinuation.[11,12] In the US, an estimated 10 per cent of the entire contact lens wearing population drop out of contact lens wear each year, with lens discomfort being the primary reason.[13] However, more recent research by Rumpakis *et al* estimated the dropout rates were much higher – 15.9 per cent in the US, 17 per cent in the Americas, 31 per cent in Asia, and 30.4 per cent in Europe/Middle East/Africa.[12] Again, the top reason for dropout from the Rumpakis study was discomfort, with 42-53 per cent of dropouts citing discomfort as the main reason.

Among contact lens wearers, ocular signs and symptoms of contact lens-related dryness are a major cause of discomfort and subsequent lens intolerance.[14] Contact lens wearers are 12 times more likely than emmetropes and five times more likely than spectacle wearers to report dry eye symptoms.[15]

If improvements were made to address comfort issues, specifically end of day comfort, could this help reduce contact lens dropouts and improve the contact lens wearing experience? Let's look at the role of water content, lens surface, and lens material in connection with comfort.

The role of water content

One factor often implicated with contact lens-related dry eye symptoms is lens dehydration. Studies have shown that conventional (poly-HEMA) lenses with higher water content dehydrate more than lower water content lenses.[16] On the other hand, SiH lenses with lower water content may improve contact lens-related dryness symptoms,[17] especially when associated with age.[18]

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Creating the ideal contact lens is compared to solving Rubik's Cube

However, factors other than water content may also contribute to lens dehydration such as lens power and resultant centre thickness,[19] the surrounding environment[16] and water binding properties of the lens material.[20] A recent study examined the bulk dehydration rates of several daily disposable and frequent replacement lenses (both SiH and poly-HEMA) and concluded that bulk dehydration is probably not directly related to comfort. Rather, other factors including surface hydration and surface wettability are probably more important.[21] (Wettability describes how a fluid spreads across a surface – the more wettable the lens, the lower the wetting angle which contributes to better comfort.)

The role of the lens surface

The surface of the contact lens *in vivo* is a complex interface that interacts with the precorneal tear film, the eyelids and the corneal epithelium. Ultimately, the comfort of a contact lens depends upon its biocompatibility with these ocular environments.[22] (Other factors like edge geometry and thickness profile also contribute.)

Surface properties of corneal epithelium and tear film

Tiny microvilli extending from the epithelial cells of the corneal surface act as foci for the attachment of mucin from the tear film, creating a hydrophilic glycocalyx that promotes wettability, and enhances the spread and continuity of the tear film.[23] Ideally, the contact lens surface should support this interface.

The tear film consists of three layers or phases: a thin mucin-rich layer adjacent to the corneal epithelium, a thicker middle aqueous layer and a lipid layer that interfaces with the air. Research suggests that disturbances in the lipid layer play a predominant role in tear film instability, leading to increased evaporation and osmolarity, which in turn causes a decrease in conjunctival goblet cells and corneal epithelial glycogen levels.[24] These changes may lead to ocular discomfort and dry eye symptoms. With contact lens wear, the tear physiology can be adversely affected by increasing evaporation rate and reducing tear thinning time, often seen in reduced tear film break-up time.[25] Efforts to address wettability and dehydration issues have included incorporating wetting and moisturising agents into SiH polymers.

A stable tear film is necessary for successful and comfortable contact lens wear. Tear film stability requires that both the pre-corneal and pre-lens tear film be supported in a way that maintains their natural integrity.

During each blink, the eyelids sweep across the cornea (or contact lens), clearing debris and replenishing the tear film. Intolerance to contact lens wear has been strongly correlated to reduced tear film stability (non-invasive tear film break-up time) and tear volume (tear meniscus area).[26]

● Implications in practice

Developing contact lens surfaces with the same properties as the surface of the cornea itself will enhance comfort and vision for wearers.

Optimising biocompatibility

The role of the lens material

Contact lens materials and designs should be innately biocompatible or rendered that way to provide ongoing comfort and ocular health. Ideally, the lens surface would mimic or support the essential features of the cornea and tear film and allow the lens to exist in a relationship of mutual benefit with the eye.

Greater biocompatibility may be achieved by a lens surface which mimics the cornea itself – a hydrophilic aqueous tear layer like the glycocalyx of the corneal epithelium, providing a lubricious and protective surface for the cornea and eyelids, supporting the tear film, and providing adequate oxygenation for a range of corneal oxygen demands.

Importance of surface properties of SiH lenses

Current SiH lens materials contain a mix of hydrophilic and hydrophobic polymers and polymer segments.

These polymers can re-orientate during lens wear so that the hydrophobic segments are present on the lens surface in the presence of lipids in the tear film or to the air (if the tear film is unstable). Under either of these conditions (usually both) the lens surface will become increasingly hydrophobic during wear.[27] Thus SiH materials, with their predominance of hydrophobic silicone elements, present a significant challenge in producing lens surfaces that are highly wettable.

● Implications in practice

Lenses which possess high and sustained wettability during wear and which demonstrate good lubricity represent the future of SiH lens innovation and create a new era of contact lenses.

According to an article by Drs Brien Holden and Desmond Fonn: 'Today, we have the best lenses ever – well-designed, with high oxygen transmissibility and good surfaces. What we need on top of that is a tear film that behaves as though the surface on the lens is like the eye's own surface… Our research indicates that the fundamental comfort barrier is creating a lubricious, wettable, long-lasting surface on the new generation of contact lenses.'[28]

Conclusion

Health and comfort continue to be the primary prerequisites for contact lens success. To achieve this, it is clear that successful contact lens wear requires not only adequate corneal oxygenation, but also lens surfaces with sustained wettability and good lubricity.

Contact lens wearers expect their lenses to be comfortable; ideally they want to feel as if they are wearing no lenses at all. Of course, they expect clear vision and convenience too, but these are of little value if they have to discontinue lens wear due to discomfort. It is dissatisfaction with contact lenses, primarily due to avoidable issues such as discomfort that drives many consumers each year to pursue alternative forms of refractive correction including surgery.

With this in mind, researchers and manufacturers continue the development of new approaches to improve contact lens materials, designs and surfaces. Further advances in polymer and surface chemistry will provide higher oxygen permeability, enhanced surfaces that are wettable and lubricious, and moisturising ingredients that release or migrate to the surface or into the tear film during wear.

The frontiers of SiH daily disposable lens technologies continue to expand and drive innovation. New technologies, chemistries, and clinical perspectives provide our industry with a bright and optimistic future with respect to the lenses that eye care professionals can provide to their customers. It is imperative that we, as eye care professionals, stay informed to meet the expectations of today's contact lens consumer for clear vision, convenience, safety and comfort.

The newest frontier is the combination of a daily disposable contact lens with the high oxygen transmissibility seen in SiH contact lenses to leverage the advantages of both technologies. And as the former US president said: 'But I tell you the new frontier is here, whether we seek it or not.'[1] ●

References

1 www.americanrhetoric.com/speeches/jfk1960dnc.htm
2 Third party industry report, Europe, 12 months ended 2010.
3 Davis, R. Customize your patients' lens wearing schedule. *Review of Cornea and Contact Lenses*, June 2008; 14-18.
4 Bergenske P, *et al.* Long-term clinical results: 3 Years of up to 30-night continuous wear of lotrafilcon A silicone hydrogel and daily wear of low-Dk/t hydrogel lenses. *Eye & Contact Lens*, 2007; 33(2):74-80.
5 Stapleton F, *et al.* Silicone hydrogel contact lenses and the ocular surface. *Ocul Surf*, 2006; 4(1): 24-43.
6 Fonn D, *et al.* Can overnight lens induced corneal swelling be minimised to equal no lens wear regardless of oxygen transmissibility? AAO Abstract, November 2010.
7 Moezzi A, *et al.* Distribution of overnight central corneal swelling across subjects with 4 different silicone hydrogel lenses. *Eye & Contact Lens*, 2011; 37(2): 61-65.
8 Mueller N, *et al.* A comparison of overnight swelling response with two high Dk silicone hydrogels. *Optom Vis Sci*, 2001; 78(125): 199-214.
9 Fonn, D, *et al.* Elemental need: achieving normoxia; measuring oxygen uptake; sustaining limbal health; oxygen measurements and needs. *CL Spectrum*, August 2005; (S) 1-15.
10 Reeder R. Daily disposable lenses: a look back and ahead. *CL Spectrum*. April 2010.
11 Young G, Veys J, *et al.* A multi-centre study of lapsed contact lens wearers. *Ophthalmic Physiol Opt*, 2002; 22(6): 516-527.
12 Rumpakis J. New Data on Contact Lens Dropouts: An International Perspective. *Review of Optometry*, 2010; 147(1): 37-42.
13 Barr JT. 2004 Contact Lens Spectrum Annual Report. *Cont Lens Spectrum*, 2005; Jan; 20(1): 26-31.
14 Chalmers RL, McNally JJ, McKenney CD, Robirds SR. The role of dryness symptoms in discontinuation of wear and unscheduled lens removals in extended wear of silicone hydrogel lenses. *Invest Ophthalmol Vis Sci*, 2002; 43s.
15 Nichols JJ, Ziegler C, *et al.* Self-reported dry eye disease across refractive modalities. *Invest Ophthalmol Vis Sci*, 2005; 46(6): 1911-1914.
16 Jones L, May C, *et al. In vitro* evaluation of the dehydration characteristics of silicone hydrogel and conventional hydrogel contact lens materials. *Cont Lens Anterior Eye*, 2002; 25(3): 147-156.
17 Chalmers R, *et al.* How much are symptoms of dryness in daily wear hydrogel contact lens wearers alleviated by silicone hydrogel lenses?. 2007; ARVO Abstract; 48: 5396/B642
18 Chalmers RL, Hunt C, *et al.* Struggle with hydrogel CL wear increases with age in young adults. *Cont Lens Anterior Eye*, 2009; 32(3): 113-119.
19 Helton DO, Watson LS. Hydrogel contact lens dehydration rates determined by thermogravimetricanalysis. *CLAO J*, 1991; 17(1): 59-61.
20 Larsen D, Huff J, *et al.* Proton NMR relaxation in hydrogel contact lenses: Correlation with in vivo lens dehydration data. *Curr Eye Res*, 1990; 9: 697-706.
21 Jones R, Jones LL. *In Vitro* Bulk Dehydration Rates of Hydrogel and Silicone Hydrogel Daily Disposable and Frequent Replacement Contact Lens Materials. www.siliconehydrogels.org/posters/dec_10.asp accessed 04/11/11.
22 Morris C. High technology contact lens materials and their biomimetic properties. *Optician*, 2008; April 4.
23 Nichols B, Dawson CR, Togni B. Surface features of the conjunctiva and cornea. *Invest Ophthal and Vis Sci*, May 1983; 24: 570-576.
24 Murube J. Tear osmolarity. *Ocul Surf*, 2006; 1: 62-73.
25 Thai LC, Tomlinson A, Doane M. The effect of contact lens materials on tear physiology. *Optom Vis Sci*, March 2004; 81: 194-204
26 Glasson MJ, Stapleton F, Keay L, *et al.* Differences in clinical parameters and tear film of tolerant and intolerant contact lens wearers. *Invest Ophthalmol Vis Sci*, 2003; 44: 5116-5124.
27 Epstein AB, Stone R. Surface and Polymer Chemistry: The Quest for Comfort. *Review of Cornea and Contact Lenses*, April 5, 2010; 147(1): 15-19.
28 Holden B. Minimizing discomfort. *Contact Lens Spectrum*, April 2005; Supplement: 3-4.

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