What’s the best contact lens for my patient?

Anna Sulley caught up with Australian researcher Professor Noel Brennan at the Tear Film and Ocular Surface Society meeting in Florence to discuss how the latest research can inform our choice of contact lens material and modality.

KEY POINTS

• While oxygen is important for corneal physiology, it is not the most important criterion in SiH lens selection
• Oxygen consumption is the most useful measure of oxygen delivery, not Dk/t
• All current SiHs meet the Dk/t level required for daily wear and provide nearly 100% oxygen consumption compared to normal across the cornea for daily wear
• Other lens and material properties essential for CL performance include the surface (lubricity, or coefficient of friction, and wettability), modulus, and lens and edge design
• Comfort is the most important feature of contact lens wear for the patient and is related to an optimal balance of lens properties
• There is no relationship between Dk/t and comfort, but there is between comfort and surface lubricity, modulus and water content, with the strongest link with comfort being lubricity

What are the important properties of contact lenses and how can clinicians use them to choose the best lenses for patients?

It’s a seemingly simple question but one that has occupied contact lens researchers and clinicians for decades.

Since the early 80s, Noel Brennan has been at the forefront of that research and involved in some of the most important debates in contact lenses, such as: Does oxygen matter? Why are some lenses more comfortable than others? And how can we make contact lens wear safer?

From his first cited paper in 1982 on oxygen availability under hydrogel lenses, Brennan’s name appears on many of the key publications in this area, alongside a veritable Who’s Who of contact lens research. Leo Carney, Irving Fatt, Brien Holden and Nathan Efron are just some of his many collaborators over the years.
In his Melbourne-based consultancy and practice, working with his wife Chantal Coles, Brennan has carried out research for most of the major multinational contact lens and solutions companies, and has published more than 300 scientific papers, educational articles and refereed conference abstracts.

From his early work on oxygen performance and initial comfort, much of Brennan’s work has been on the properties of soft contact lenses. Most recently, he has been influential in questioning the oxygen transmissibility (Dk/t) race and the purported need for higher and higher contact lens Dk/t values.

Oxygen: the more the better?

While there is consensus on the benefits to corneal physiology of silicone hydrogel (SiH) lenses over conventional hydrogels, it is less clear how high Dk/t needs to be to achieve an optimal physiological result. Some authors argue that we should expect continuing benefits by increasing Dk/t while others suggest there will be little difference between any of the SiH lenses, in particular during open-eye daily wear.

So is oxygen, and Dk/t, that important and is it the first factor to consider when choosing a lens?

‘I think oxygen delivery per se is important but not as impactful as we thought,’ Brennan observes. ‘When SiH lenses were introduced we thought that the extra oxygen they provided would solve the extended wear infection problem, and even perhaps the infiltrates issue with continuous wear. It fails to do that.’

But if high Dk eliminates the limbal and conjunctival redness seen with hydrogel lenses and reduces the level of cellular changes such as polymegathism, isn’t it worth having? ‘These benefits are all nice to have and on balance it’s better to have them than not. So certainly you’d want to go with a SiH lens instead of a hydrogel.’

For Brennan, one of the greatest benefits of SiHs is that they solve neovascularisation. ‘Neovascularisation, along with infection, is a sight-threatening condition - albeit chronic rather than acute. However a peripheral Dk/t of only around 8 units is actually needed to avoid significant neovascularisation in daily wear.

‘If you look at the Dk/t of hydrogel lenses in the periphery, the best most of them manage for minus powered lenses is around 8 units. There are a few that do a little better, but a hydrogel lens like ACUVUE® 2, for example, will rarely cause significant neovascularisation even at moderately high powers.’ But he acknowledges that, for patients and practitioners alike, avoiding conjunctival and limbal redness (Figure 1) is probably a more appreciated benefit to high Dk/t as the eyes overall simply look whiter.

So is oxygen still the most important criterion? Not necessarily, says Brennan, although a good balance of properties is needed when deciding which lens to choose. ‘You wouldn’t want to have zero oxygen – there is a threshold you need to get to. But it’s a lot lower than some have suggested.

‘Thresholds quoted, in my opinion, are very misleading – the science behind those thresholds is also not strong. A peripheral Dk/t in the low 30s is about where you need to be for daily wear. Once you get into the SiH category, you’re there. As far as I can tell, all SiHs we have today meet that Dk/t level.’

What’s the best way to compare oxygen delivery?

Recent debate has focused on the different ways in which manufacturers report oxygen performance, the pros and cons of each approach, and which is the most relevant and useful. Brennan has been at the forefront of the debate and has challenged the traditionally quoted value.

‘Dk/t is the most familiar measure. Irving Fatt introduced it in 1969 and it took him 20 years to get researchers and practitioners to buy into the concept, although by then he’d realised it wasn’t all it was
cracked up to be. If you have cornea under a lens of Dk/t 200, we don’t know whether it’s receiving twice as much oxygen as a lens with a Dk/t of 100. It almost certainly doesn’t. And if you have a Dk/t of 100, how does this lens compare to how an eye behaves without a contact lens? We don’t really know.

‘Fatt suggested oxygen flux as the way of determining corneal oxygenation but it’s a tricky thing to measure and calculate. You need to have an idea of what the consumption rate of the cornea is, or what partial pressure of oxygen is under a lens, to make those estimates.’ (Table 1)

For Brennan, calculations used for flux and consumption seem to be relatively robust but, importantly, consumption fits in with the observations we see clinically. ‘The reason consumption is the ultimate indicator is because that’s the amount of oxygen that’s actually being metabolised and so it directly relates to the amount of energy that’s produced for corneal function. It’s essential we look at it this way if we want to know what the cornea is doing physiologically. Such calculations also allow us to test whether experimental results actually make sense and, as it turns out, not all results have made sense in the past.’

If oxygen consumption is the most useful measure, what does it tell us about current SiH lenses for daily wear? ‘All SiHs will provide essentially 100 percent oxygen consumption compared to normal across the cornea for daily wear,’ says Brennan. ‘Towards the periphery it may dip to 95 percent for higher minus lenses with a lower Dk overall, but a 95 percent consumption rate right across the cornea is probably reasonable. The central part of the corneal stroma may have less oxygen in very high plus powers but so far in the lenses we have looked at up to +6.00D, all silicone hydrogel lenses allow normal corneal respiration underneath them.

‘There are great parallels in the relationships between oxygen consumption and Dk/t, and between corneal swelling and Dk/t. Above a Dk/t of about 20 to 24, you don’t see any corneal swelling in daily wear (the Holden & Mertz criterion). This corresponds very well to the Dk/t value at which corneal oxygen consumption under a contact lens matches that without a contact lens in place.

Professors Noel Brennan and the late Irving Fatt engage in a meaningful intellectual debate on the topic of oxygen transmissibility (photo courtesy of Professor Nathan Efron)

Just as it took 20 years for Dk/t to take hold, Brennan acknowledges that it may be some time before clinicians and researchers accept the consumption model. But he believes that many are receptive to this new way of showing oxygen performance. ‘Initially there was a desire for “the more oxygen the better” – I think people have now realised that by doing that you have to compromise on other parameters.

He points out that the first SiH to enter the market is still the one with the highest Dk/t; all lenses introduced since then have lower Dk/t. ‘One further significant nullification of the argument for higher and higher Dk/t values is that oxygen level apparently doesn’t relate to risk of infection. SiHs didn’t reduce the infection rate, showing that oxygen isn’t the be all and end all,’ he adds. ‘It is true that we tend to see a decreased severity of keratitis with silicone hydrogels compared to hydrogels, but to date we see no evidence of variation within the category on the basis of Dk/t.’

Have SiHs reduced inflammation and infection rates for extended wear?

If Brennan’s position on oxygen requirements for daily wear is clear, he is less sure that SiHs meet all needs for extended lens wear. ‘As high as we’ve gone with Dk/t so far, we still get corneal swelling in overnight wear. We don’t know exactly what that means but my personal view is that we probably shouldn’t be doing extended wear when the annualised risk of infection is still 20 in 10,000 with SiHs. This was considered unsatisfactory with hydrogels. so what’s changed with SiHs?’
Brennan also questions whether there has been enough public debate on this issue and points out that the rate of inflammation in extended wear is greater with SiHs than with hydrogels. So what is needed to reduce infection and inflammation rates?

‘We tried disposables in the belief that soiling of lenses created an environment where microbes could grow and increase the risk of infection. Disposables and SiHs are great for a bunch of other things but not for solving the infection problem. So now we’re moving towards antimicrobial surfaces. Again there’s good reason to believe this might help, and optimism within the research community.’

New research by Suzi Fleiszig’s group has shown that the length of time that bacteria reside on the eye influences their virulence. As Brennan explains, Fleiszig inoculated the back of a contact lens with Pseudomonas, put the lens on a mouse eye and then waited to see when infection would occur. ‘Finally, after seven days the eyes became infected. Researchers hadn’t achieved this before – it seems they’d just not waited long enough,’ says Brennan.

The researchers then took lenses from the infected eyes, put them onto other healthy eyes and waited to see how long it took for these eyes to become infected. Incredibly, they found that by living in an ocular environment the bacteria had become more virulent. It only took them two days to create infections. ‘So with extended wear, we offer the chance for bugs to stay in an environment for an extended period of time and undergo changes that make them more virulent, which is when they attack the eye. With daily wear, removing and disinfecting the lens seems to prevent this from happening.’

Consistent with the results from Fleiszig’s group, some suggest that periods of extended wear shorter than seven days, such as flexible wear for a few nights, could be considered safer. Early research with hydrogel lenses showed a lower risk of infection with fewer nights’ extended wear. Brennan says he was a strong advocate for shorter periods of extended wear from the outset. ‘At times, occasional extended wear or flexible wear can be useful.’

But is extended wear what patients and practitioners want, or are other attributes, such as comfort, more important? For Brennan, it is comfort and convenience that patients are looking for. ‘Daily disposables offer the ultimate in convenience – it’s not a big deal for most patients to insert and remove lenses. Cleaning them has proved to be the hassle that most patients don’t want.

‘We learnt some lessons with SiHs when they were launched – the demand for extended wear wasn’t as great as we thought it was going to be. Patients and practitioners didn’t jump on it when it was first made available with SiHs. Much of this was practitioner reluctance, but patients really didn’t demand it that strongly either.’

**What other properties are important?**

In fact higher Dk values in SiHs can be associated with a range of negative effects, as a consequence of the material properties necessary to achieve high transmissibility.

Other than oxygen, Brennan singles out modulus as the property that has most influence. ‘Clearly modulus has an effect – the higher you go with Dk, the higher the modulus, which causes a range of potentially adverse effects. SEALs, conjunctival epithelial splitting, contact lens papillary conjunctivitis (CLPC), and mucin balls are all associated with modulus, as is discomfort.

‘Also, the thickness of the material adds to the stiffness of a lens – remember that modulus applies to material, whereas stiffness applies to a lens. If you double the lens thickness, you actually get four times the stiffness, so higher power lenses are substantially stiffer and can lead to prescription changes and unwanted orthokeratology.’
However, having an adequate modulus may be important because it adds sufficient stiffness to a lens, enabling it to move on blinking. ‘If it’s too soft it drapes over the eye and doesn’t move, leading to inadequate tear exchange.’ Lens movement also clears trapped debris, which is especially important for extended wear, he adds.

Surface properties are another factor to consider and are determined by the material itself. ‘Some of the surfaces are treated, others are not, but what we’ve found is that surface lubricity (coefficient of friction) is the major determinant of comfort with contact lenses. The lens surface can also influence mechanical effects such as SEALs, mucin balls, CLPC and lid wiper epitheliopathy (LWE).’

Among other material properties, water content probably only matters inasmuch as it relates to modulus, and dehydration is not a major issue with SiHs, says Brennan.

Lens design, however, is an important consideration since it relates to both comfort and lens movement. ‘A poorly fitting lens or badly designed edge tends to lead to discomfort and vision problems. I’m not sure we’ve yet got that right. There are new ways of designing lenses looking beyond the cornea – at the sclera, for example, using OCT (optical coherence tomography) – that will enable us to come up with better designs for the future.’

Why are some lenses more comfortable?

Ocular physiology may remain a concern for practitioners but comfort is the most important feature of contact lens wear for the patient. Is comfort related to a balance of lens properties or are there particular characteristics that you need to consider to choose the best performing lens?

Brennan has looked at over 700 wearer trials to address this question and says there are myths about comfort he would like to dispel. ‘One is that SiHs are more comfortable than hydrogels – this isn’t always the case. Another is that Dk/t and oxygen influence comfort – again that’s not the case. Thirdly, that all SiHs give a similar level of comfort – our research definitely shows there are differences between materials, and feedback from clinicians supports this. ‘In our studies, subjects wore a range of lenses for one month and we measured comfort differences between materials. The most comfortable material was a SiH (senofilcon A, ACUVUE® OASYS®) but the next most comfortable was a hydrogel (etafilcon A, ACUVUE® 2). We then looked at the material properties, such as modulus, Dk/t and surface lubricity (i.e. coefficient of friction), and correlated each of these with the comfort data.

‘We found no relationship with Dk/t and comfort, but we did find a relationship between comfort and water content, modulus and surface lubricity. We put all the results into a multiple regression analysis and found that the one property that came out as providing the strongest link with comfort was lubricity. So it’s my belief that when we look at what makes a lens comfortable, the defining feature is the surface.

Various theories have been put forward for the mechanism of discomfort but recent research has changed our thinking, as Brennan explains: ‘One theory was that the tear film was disrupted and caused drying of the bulbar conjunctiva. Others were that the lens edge interacted with the upper lid, or that evaporation from the front surface of the lens led to the cornea drying out.

‘All these theories have been around for a while but I strongly believe it’s the relationship between the conjunctival palpebral surface and the surface of the lens that leads to discomfort. This fits well with work done by Don Korb, who found a strong association between staining of the lid wiper part of the conjunctiva (LWE, Figure 2) and comfort.

Figure 2: Lid wiper epitheliopathy (LWE) (Image courtesy of THE VISION CARE INSTITUTE™)
'When you think about how far that part of the lid travels across the lens: 1cm up, 1 cm down per blink, 6-10 times per minute, 60 minutes per hour, 16 hours per day, 365 days per year – that’s over 40km the eyelid travels in a year, scraping across the surface of a lens. Think about that, your eyelid scraping across a surface for 40km - even if the surface was perfectly clean and smooth, it still makes you wince. The key thing is that the surface needs to be slippery - really slippery. We didn’t realise this in the past, but can now understand what’s going on and do something about it.’

There are different approaches to making lens surfaces more wettable, such as coatings or built-in wetting agents, but are there differences between the resulting surface properties? ‘Plasma coatings do their job but are not always 100 percent durable. It doesn’t matter though what you do to the surface; lowering the coefficient of friction seems to give you the most desirable result.’

The latest findings on comfort may now help to predict which patients will be successful with contact lens wear. ‘Common slit-lamp findings such as redness, corneal staining and tear break-up time, that we traditionally assess prior to fitting, don’t seem to relate well to comfort. Good indices are lid wiper epithelopathy and lid parallel conjunctival folds. Look at the meibomian glands too, as expression and lid hygiene can make a big difference to comfort,’ he remarks.

Initial comfort is also a useful predictor of those who will drop out after 30 days’ wear. ‘It’s reliable enough that you can take an initial comfort score and use that as an expectation for success. If they rate lens comfort as less than 7 on a 0-10 scale, try a different lens.’

What material advances can we expect in the future?

Practitioners have come to expect a major advance in contact lenses every 10 years, so what is in store for the next decade? ‘You could argue there haven’t been that many great leaps in the past 30 years,’ observes Brennan. ‘We’ve had soft lenses, disposables and SiHs, but SiHs didn’t provide as big a leap as we’d hoped – an important step, but not a big leap.

‘We need to get multifocals right and we need to improve comfort and reduce dropout by optimising design and surface. Antimicrobial lens surfaces are now being tested but we don’t yet know if they’ll solve the problem of infection – there’s a long way to go before we get epidemiological data to say the infection rate has dropped. But if we can have contact lens wear with lower incidences of infection and inflammation, that changes the paradigm quite a bit.

New applications for contact lenses are also in prospect. Brennan is optimistic about future developments in ‘myopia containment’ that have the potential for preventing and treating refractive error.

The final opportunity is for medical treatment with contact lenses that gradually release drugs over time. ‘This has huge appeal – fitting contact lenses to deliver glaucoma, allergy, steroids and other anti-inflammatory drugs. We already have contact lenses that deliver lubricants but we need more sophisticated delivery systems to prevent the drugs from coming out too quickly,’ he says.

‘In the future I am most optimistic that we’ll see lenses which solve many of the current causes for people deciding against contact lens wear or dropping out after beginning. But until then, the way to practice success with contact lens wear is to choose lenses with an optimal balance of properties for a given patient, to minimise the impact on ocular physiology and provide high comfort levels.’

Whatever the future holds, this particular Australian researcher is likely to be at the forefront of developments and challenging current thinking, just as he has throughout all the major advances of the past three decades.

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