LEARNING DOMAINS

CLINICAL PRACTICE

SPECIALTY: CONTACT LENS OPTICIANS

COMMUNICATION

PROFESSIONAL GROUPS

Dispensing opticians — CPD PROVIDER — General Optical Council

Optometrists — CPD PROVIDER — General Optical Council

Contact lens opticians — CPD PROVIDER — General Optical Council

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CPD CODE: C-111587

Silicone hydrogel lenses:

an evidence-based update

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In 1999, the first silicone hydrogel (SiHy) lenses became commercially available in the UK. The high oxygen transmission of the material has made it very popular and in the most recent (2023) global survey of contact lens prescribing, it was found that 84 per cent of all disposable contact lenses fitted in the UK were SiHy[1]. This is in spite of the fact that a recent Cochrane review found that there was insufficient evidence to recommend a SiHy lens over a hydrogel lens or vice versa[2]. Also, the prescribing of SiHy lenses does not appear to have improved contact lens drop-out rates.

The first SiHy lenses were designed for extended wear. A recent analysis of extended wear prescribing trends found that there had been a small increase in patients being fitted with extended wear contact lenses after the introduction of SiHy lenses from 2000 to 2007. However, this trend declined due to concerns about the increased risk of microbial keratitis with overnight wear – and in 2023 the rate of extended wear prescribing (5.2 per cent) was very similar to that seen in 2000 (5.8 per cent)[3].

The first generation SiHy lenses were licensed for 30 days of continuous wear, but currently only Air Optix night and day is licensed for 30 days' wear. CooperVision's Biofinity contact lens did have a continuous wearing schedule of 30 days, but as of May 2024, the lens's wearing schedule is a maximum of six nights, seven days. Johnson & Johnson Vision's Acuvue Oasys and Menicon's Premio contact lenses can also be worn for up to seven days. Interestingly, the manufacturers' websites do not highlight the possibility of extended wear with their lenses, so while overnight wear is possible, it is not actively promoted by manufacturers.

It has previously been suggested that the risk of adverse events with overnight wear of contact lenses could be reduced if the patient were to remove the lenses each morning and rub and rinse them with cleaning solution before reapplying them[4]. A 2019 study looked at several interventions that could potentially improve the safety of overnight contact lens wear[5]. These interventions included: lens cleaning, lens replacement at night, lens replacement in the morning, and the use of an antibiotic drop daily. None of the interventions showed a significant improvement in safety compared to the control group. For now, overnight wear of any contact lens, including SiHy, continues to pose the increased risk of an adverse event.

HOW MUCH OXYGEN IS REQUIRED TO AVOID CORNEAL HYPOXIC SIDE-EFFECTS?

Several studies examining requirements for overnight contact lens wear found that Dk/t values of 75 to 87 were required in the closed eye to keep overnight swelling to four per cent, which is the same as it would be without a contact lens in place[6-8]. For daily wear, Morgan *et al* found that Dk/t values of 20 at the centre of a contact lens and 33 at the periphery were required to prevent oedema[9].

The Morgan study only had a very small sample size of seven subjects (six male and one female). The subjects in this study also only wore the lenses for three hours. The researchers explained that the time of three hours was chosen because corneal oedema had been shown to increase in the first two hours of contact lens wear and then plateau.

However, corneal oedema may not be the best way to measure the cornea's response to hypoxia in the corneal periphery because the anatomy of the peripheral cornea means that it has less capacity for swelling[10]. It is possible that the values given by Morgan for daily wear may be adequate for most patients – but certainly not all.

One reason why some patients may still experience at best limbal hyperaemia and, at worst, limbal vessel encroachment, is the fact that individuals' responses to hypoxia vary considerably[11].

A 1998 paper by Papas estimated from a sample of 39 subjects that a Dk/t of 125 was needed to avoid limbal hyperaemia in contact lens wearers but the 95 per cent confidence limits for this estimate were 56 to 274, which shows a very large range of oxygen requirements between subjects[12]. Dk/t values for any material are normally quoted for the centre of a -3.00D lens. The centre thickness of a -3.00D lens would be expected to be around 85 microns. Clearly the centre thickness will be much greater on a plus powered lens. Minus powered lenses will have additional thickness towards the periphery.

We measured the centre thickness of a +8.50D one day Clariti lens on an eye using an anterior segment optical coherence tomographer (OCT) and found it to be 283 microns. The Dk of the Clariti material (somofilcon A) is 60 and therefore the Dk/t for a +8.50D Clariti lens would be 21, considerably less than the Dk/t of 86 quoted for the -3.00D lens. Similarly, we measured the peripheral thickness on a -12.00D My Day lens and found it to be 234 microns. Its material (stenfilcon A) has a Dk of 80, which calculates to a Dk/t of 34 for the -12.00D lens.

All of this suggests that patients with moderate prescriptions and an *average* critical oxygen requirement will probably never show signs of hypoxia with daily wear of SiHy lenses, but patients who have high prescriptions (particularly plus) and/or a high critical oxygen requirement would still be better served by being fitted with a rigid corneal lens.

It is easy to identify patients with high prescriptions but very difficult to identify those with a high oxygen requirement (unless they have a history of hypoxic signs with previous contact lens wear). The important point to note is that it is possible for patients with moderate prescriptions wearing SiHy lenses to show signs of chronic hypoxia, and if those signs are observed then the patient should be changed out of soft lenses.

ARE DAILY REPLACEMENT LENSES BEST?

In a recent editorial in *Clinical and Experimental Optometry*, the respected contact lens researcher Professor Nathan Efron makes a strong case that all soft lens patients should be fitted with SiHy daily disposables[13]. What evidence is there for the advantage of daily disposables over daily wear reusable lenses?

Two studies[14, 15] have previously found that after a contact lens is removed from its blister pack and worn for a few days, its surface wetting decreases. This decrease is more pronounced in patients with dry eye and discomfort symptoms. Changing a patient from other modalities to a daily disposable may help with surface wettability, which in turn may help to reduce the development of lid parallel conjunctival folds (LIPCOF): a common development in contact lens wearers.

However, changing to daily disposables is unlikely to show an improvement in comfort, as a study by Papas[16] showed that the replacement of contact lenses halfway through a day did not improve comfort – and the CLEAR biochemistry report found that there is no clear association between wettability and comfort[17].

Daily disposables can help to reduce the incidence of papillary conjunctivitis as only two per cent of patients in this modality seem to develop these changes[18]. This compares favourably with research that has shown that six to 12 per cent of patients wearing hydrogel lenses on a daily wear basis and 18 per cent of those wearing lenses overnight are likely to present with contact lens-induced papillary conjunctivitis at some stage in their lens wearing lifetime[19].

When weighing up the choice of daily disposable lenses versus monthly disposable lenses, patients and practitioners may wish to consider a recent study that has determined that where lenses are worn full-time, daily disposable lenses and their packaging generate 27 per cent more waste than that of monthly disposable lenses[20]. The analysis included care products used in conjunction with the monthly disposable lenses.

SILICONE ALLERGY

It is biologically impossible to be allergic to the siloxane monomers that are within SiHy materials. Anything that looks like a silicone allergy is likely to be a reaction to deposits on the lens, microbes or care solutions used with the lenses[21].

WHAT IS DK/T?

Atmospheric oxygen dissolved in tears is the main source of oxygen for the anterior cornea. Because there is very little tear exchange underneath a soft contact lens, it is important that oxygen can diffuse through the soft lens in order to reach the anterior cornea.

Dk is a measure of a contact lens material's oxygen permeability – or how much oxygen is transmitted through the contact lens material. Dk/t is a measure of how much oxygen is transmitted through the contact lens itself. It is the oxygen permeability of the material divided by the thickness of the lens.

FIGURE 1: Mechanically induced contact lens papillary conjunctivitis

FIGURE 2: Mucin balls

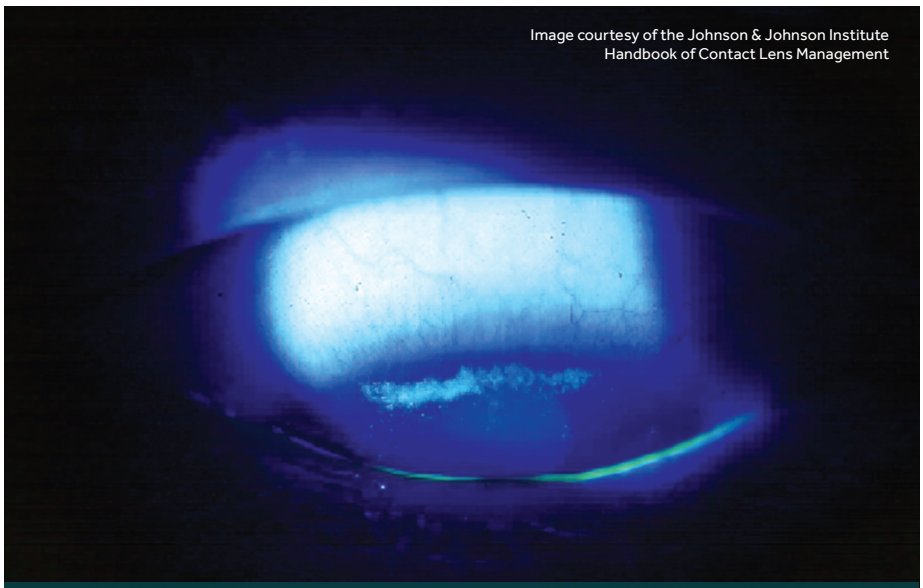

FIGURE 3: Superior epithelial arcuate lesions

WATER CONTENT

The water content of a hydrogel lens determines its oxygen transmission. In a SiHy lens, it is the silicone that determines the oxygen transmission. For this reason, SiHy lenses have tended to have lower water contents than hydrogel lenses.

A 2003 study, comparing the dehydration of a hydrogel lens after two weeks of wear with that of a SiHy lens after four weeks of wear, found the dehydration in the SiHy lens to be far less than that of the hydrogel[22]. The focus in newer SiHy materials has been on retention of hydration throughout the wearing schedule, presumably with a view to improving comfort.

In 2014, Bausch + Lomb launched the Ultra lens, which is made from a fourth generation SiHy material: samfilcon A. The Ultra lens has Bausch + Lomb's MoistureSeal Technology, which is polyvinylpyrrolidone (PVP) on the lens surface and within the lens matrix. This allows more water to be stored within the lens and gives a very hydrophilic surface.

In one study by Bausch + Lomb, the dehydration of the Ultra lens after four hours of wear was found to be 5.07 per cent[23]. In a study that examined the dehydration of daily disposable lenses after 12 hours of wear, researchers found that the average decrease in water content for delefilcon A (Dailies Total One) and stenfilcon A (MyDay) after 12 hours of wear were 2.91 per cent and 2.82 per cent respectively[24].

This study also found a statistically significant negative correlation between comfort and relative dehydration for the Dailies Total One lens but not for the MyDay lens. However, there were only 18 subjects in the study and the correlation coefficient of -0.475 is not a strong negative correlation.

There does not appear to be any research on the effect that a loss of water content from a SiHy lens has on the lens itself or the eye. It might be assumed that a loss of water content could affect a change in lens parameters which, in turn, could affect lens fit – but with such small percentage losses, it is difficult to say that any change in lens parameters would cause a clinically significant change in lens fit.

Material	Brand	Manufacturer	Dk/t (for a -3.00D lens)	Modulus	Water content	Packaging solution
Kalifilcon A	Infuse/Ultra One Day	Bausch + Lomb	134	0.5	55%	Phosphate buffered saline with potassium chloride, poloxamine 1107, poloxamer 181, glycerin, and erythritol
Stenfilcon A	MyDay	CooperVision	80	0.4	54%	Phosphate buffered saline solution with polysorbate
Somofilcon A	Clariti 1 day	CooperVision	86	0.5	56%	Borate buffered saline solution containing 0.005% w/v poloxamer 407
Delefilcon A	Dailies Total 1	Alcon	156	0.7	33% - core 80% - surface	Phosphate buffered saline solution with approximately 0.3% of polymeric wetting agents consisting of copolymers of polyamidoamine and poly (acrylamide-acrylic acid)
Senofilcon A	Acuvue Oasys 1 Day	Johnson & Johnson Vision	121	0.72	38%	Borate buffered saline with methyl ether cellulose

TABLE 1: Silicone hydrogel lens materials and packaging solutions

MODULUS

First generation SiHy lenses had quite high moduli (greater than 1MPa) which meant that the lenses were a little more rigid than previous hydrogel lenses. As a result, there were reports of mechanically-induced contact lens papillary conjunctivitis, mucin balls and superior epithelial arcuate lesions (SEALs)[25] (**Figures 1-3**).

Improvements in modulus were made in second and third generation lenses, and modern silicone hydrogel lenses have moduli as low as 0.4 MPa as found in stenfilcon A (MyDay lenses). The low modulus of MyDay lenses is due to CooperVision's Smart Silicone technology. This is where the silicone is shaped into channels, which allows a much more efficient transport of oxygen. In turn, this means that less silicone is required in the material, keeping the modulus low.

Alcon states that the modulus of its water gradient SiHy lens is 0.76MPa at the core but 0.025MPa at the surface. Although there are multiple factors that feed into contact lens comfort, a review of published research has found that contact lenses with a low modulus and a tight fit are more likely to be reported as comfortable by the patient[26].

Table 1 shows the modulus of various SiHy daily disposable lenses.

WATER GRADIENT LENSES

Since 2014, Alcon has produced water gradient lenses made from the material – delefilcon A. These are lenses with a lower water content (33 per cent) in the lens core increasing to a much higher water content (greater than 80 per cent) at the lens surface. Several independent studies have found these lenses to be popular with patients who have previously had problems with contact lens discomfort[27-29].

In a 2015 study, 39 patients wore three brands of soft contact lenses – including water gradient lenses – in a crossover trial investigating the effect of the lenses on the tear film. Most tear film metrics were better with the water gradient lenses when compared to the other lenses[30]. Water gradient lenses do appear to be a good choice for patients with dry eye issues. The one drawback the author has seen with these lenses is that some patients struggle with removal of the lens, because the lens surface provides very little friction for those trying to remove it using the pinch method (**Figure 4**).

PACKAGING SOLUTION

The Tear Film and Ocular Surface Society (TFOS) published a report on contact lens discomfort. Within the report, they found two studies supporting the hypothesis that rewetting drops have only a temporary (up to 10 minutes) effect on blinking rates, whereas contact lens care solutions containing wetting agents could restore normal blinking frequency for longer periods of time[31,32]. Contact lens wear has been shown to increase blinking frequency – presumably because of a disrupted tear film. A reduction in blinking back to a normal blinking rate implies that the tear film is improved.

Patients wearing daily disposable lenses are not using care solutions and, for these patients, it may be the packaging solution in which the lenses are supplied that holds the key to improved blinking (and by extension, improved tears).

Table 1 shows the packaging solutions in which various lenses are supplied. Bausch + Lomb's Infuse lenses are provided in packaging solution containing ingredients based on TFOS findings including osmoprotectants[33]. The company calls this Probalance technology. Johnson & Johnson Vision's

FIGURE 4: Pinch method of contact lens removal

Acuvue Oasys lens is in a solution that the manufacturer describes as an electrolyte-balanced packaging solution designed to mimic human tears[34].

A 2010 lab study of the effect of buffered contact lens packaging solution on human corneal epithelial cells found that cells exhibited more damage when placed in borate buffered solution when compared to when in contact with phosphate buffered solution, but this study was only lab-based[35]. It remains to be seen if these results would be replicated in vivo.

CO-EFFICIENT OF FRICTION

There does appear to be some association between lens surface smoothness and patient comfort[36]. However, a recent review has found that it is not possible to compare co-efficients of friction measured across various contact lenses because there is no standardised test for this measurement[37].

LENS EDGE STAINING

An article on SiHy, published in *Dispensing Optics* in 2015, mentioned a study from 2012[38] which had found that contact lenses with a knife edge design were found to be more comfortable than those with a chisel or round edge, but also more likely to cause lens edge staining. At the time, it cautioned that patients with this pattern of circumlimbal staining should be monitored, as it is not known what the possible long-term impacts of this staining might be.

After conducting a review of current literature, no further studies into this phenomenon were found apart from a small one in 2013[39]. More importantly, no reports of any long-term ocular effects occurring secondary to circumlimbal staining were found.

SUMMARY

Modern SiHy lenses have improved moduli and water content, and are packaged in solutions designed to complement the natural tear film. For patients with high prescriptions or a history of hypoxia, SiHy lenses should be the first choice of soft lens and, notwithstanding environmental waste concerns, the daily disposable modality is probably the best choice for patients.

However, SiHy lenses are slightly more expensive than hydrogel lenses and the recent Cochrane review concluded that in the absence of larger and better clinical trials comparing the two different soft lens materials, there is currently insufficient evidence to recommend one material over the other[2]. Patient and practitioner preference remain key.

REFERENCES

References can be found when completing this CPD module. For a PDF of this article with references email, abdocpd@abdo.org.uk

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LEARNING OUTCOMES FOR THIS CPD ARTICLE

DOMAIN: Communication

1.7, 2.1: *Explain the properties of silicone hydrogel contact lenses to patients in a way they can understand, using professional judgment to adapt language and communication approach accordingly ensuring informed decision making.*

DOMAIN: Clinical practice

5.3: *Recognise the benefits and limitations of silicone hydrogel contact lenses integrating the latest research evidence to inform the care you provide.*

DOMAIN: Specialty CPD – contact lens optician

Critically evaluate the latest clinical research on silicone hydrogel lenses and apply an evidenced-based approach to contact lens selection relevant to knowledge skills and scope of practice.

COMMUNICATION

CLINICAL PRACTICE

SPECIALITY: CONTACT LENS

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