



LATHE CUT SILICONE HYDROGELS

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After many years silicone hydrogels have now truly started to gain significant market share and in the future their dominance is only set to increase. Until now these materials have only been available in a cast moulded format. Materials for lathe production are now starting to appear, and will help ensure the survival of the speciality lens manufacturer. Patients requiring specialised lens designs will now be able to enjoy the comfort of a soft lens and benefit from the increased oxygen transmission that these materials have to offer.

Originally the primary interest in silicone hydrogel materials was for extended wear applications (EW) and the first lenses of this type became commercially available in 1999. To help ensure good ocular health during overnight wear lenses with a high oxygen transmission (Dk/t) are required. Holden-Mertz¹ recommended a Dk/t of 87×10^{-9} (cm/sec)(mlO₂/ml x mmHg) to prevent corneal swelling. However, more recently it has been suggested that 125×10^{-9} (cm/sec)(mlO₂/ml x mmHg)² would be more appropriate and it is this higher value that manufactures aim to reach. To achieve these high Dk/t values materials with oxygen permeability's (Dk) in the region of 110-140 barrers are required, and are obtained by incorporating significant quantities of large rubber like siloxane monomers known as macromers.

Following the introduction of these high Dk materials the take-up of EW modalities has been slow and some reports even show a recent decline in some countries such as the UK³. Undoubtedly the potential clinical complications associated with EW have had an impact. Some of the complications, such as superior epithelial arcuate lesions (SEALS) and corneal erosions have been linked to the increased modulus or stiffness of the materials compared to conventional hydrogels. For this reason it has been suggested that the lens fit is much more critical and custom lathe cut materials would be of advantage. Unfortunately the rubber like macromers used in these materials are not known for their good lathing properties. Furthermore, these custom designed macromers are prohibitively expensive to manufacture, and make a lathe cut lens financially non-viable.

The advantages of silicone hydrogels in a daily wear (DW) modality are now becoming apparent, and the market for silicone hydrogels has now shifted more towards the requirement for an enhanced DW lens. The proportion of silicone hydrogels prescribed for DW is rapidly increasing and already exceeds the proportion prescribed for EW. For lenses of this modality the drive for very high Dk is no longer the main concern. The Holden-Mertz criteria recommended a Dk/t of 24×10^{-9} (cm/sec)(mlO₂/ml x mmHg) whilst Harvitt and Bonanno recommend 35×10^{-9} (cm/sec)(mlO₂/ml x mmHg) to prevent anoxia through the corneal thickness. Consequently materials with an oxygen permeability (Dk) of 50-60 barrers are desirable for these applications.

One of the benefits of having a lower Dk is that water content can be increased, resulting in a material with a much lower modulus than its continuous wear counterparts. Because the materials are not worn overnight many of the associated clinical complications will not be present and the cornea will benefit from the improved oxygen delivery over conventional materials. Although modulus has been reduced it is still higher than might be desired and so a lathe cut lens will still be beneficial for numerous applications. With the ability to tailor each set of lenses to the patient, great improvements in ocular health and comfort should be possible.

Given the reduced Dk requirements a lathe cut material becomes more practical to achieve and a number of materials have now started to appear on the market. All of the materials have similar water contents, Dk, and modulus. A further challenge to the polymer chemist designing these materials is to ensure that they have good machining properties, perform consistently, and are stable once hydrated and during sterilisation. The difficulties of mixing hydrophilic monomer and hydrophobic silicones can lead to inconsistencies within the materials that cause uneven swells and unstable lenses. For these reasons the monomer components must be carefully selected, and the polymerisation conditions optimised and highly controlled.

Key to the clinical success of silicone hydrogels are the surface properties. It has been documented that the hydrophobic surfaces of silicone containing materials can suffer from increased deposition of lipids. The extent of the problem will depend upon both the patient and the design of the material. To overcome these problems and to help ensure a more consistent clinical performance current lenses on the market rely on surface modification techniques. The common techniques currently in use today include plasma oxidation⁴, plasma induced coating⁵, and the use of internal wetting agents⁶. The effect of plasma treatment can be elegantly shown by comparing the following two pictures. Figure 1 shows a drop of saline on an untreated lens and Figure 2 shows a treated lens.

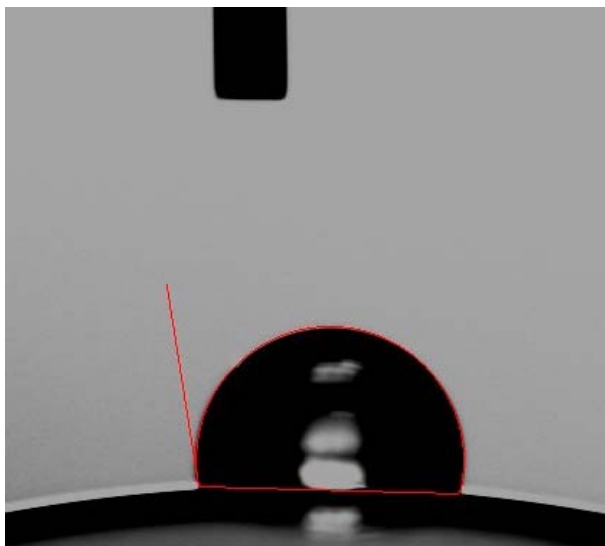


Figure 1. Drop of saline on an untreated lens. Figure 2. Drop of saline on a plasma treated lens

Lathe cut silicone hydrogels will need to overcome the same challenges. The above DW materials have much higher water contents than EW materials and contain chemistries that may help reduce interaction with lipids. However, their clinical performance is yet to be established but it is possible that some description of surface modification might be required to ensure consistent clinical performance.

Now the door to latheable silicone hydrogels has been opened, further developments are likely. The main drive is likely to be towards improvements in surface wetting followed closely by increased oxygen permeability. Some of the monomers required to impart these improved properties are potentially expensive, and a semi-finished format might be necessary to maintain cost-effectiveness. Undoubtedly these materials will become an important part of the speciality lens market.

¹ Holden B. A. and Mertz, G. W. 'Critical Oxygen Level to Avoid Corneal Edema for Daily and Extended Wear Contact Lenses.' *Invest. Ophthalmol. Vis. Sci.*, **25**, 1161-1167, (1984).

² Sweeney D. et al. 'Clinical Performance of silicone Hydrogel Lenses.' In 'Silicone Hydrogels.' ED Sweeney D. Butterworth-Heinemann, 90-94, (2000).

³ Morgan P. B., 'Is Daily Wear the Principal Use for Silicone Hydrogel Materials?' <http://siliconehydrogels.org>. Editorial, December, (2005).

⁴ Yokoyama Y. et al. 'Surface Treatment of Water-Containing Contact Lens and Water-Containing Contact Lens Obtained by Method Thereof' JP8227001, (1996).

⁵ Lohmann D. et al. 'Plasma Induced Polymer Coating' US6169127, (2001).

⁶ Maiden A. C. et al. 'Hydrogel With Internal Wetting Agent' US6367929, (2002).