Contact lens materials

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The material that a particular contact lens is made from is possibly not something to which every optometrist gives a great deal of thought, but many contact lens-related problems can effectively be addressed with a change of material. This article discusses the different soft and RGP materials available, and when a patient may need to be changed from one type of material to another.

Course code C-31513 | Deadline: June 28, 2013

Learning objectives
Know how to change a patient’s soft lens material and/or modality if that patient is experiencing deposition or modulus-related problems (Group 5.2.1)
Know how to change a patient’s RGP lens material if that patient is experiencing deposition problems and know how to refit a PMMA wearer (Group 5.2.2)

Learning objectives
Understand how the contact lens fitter or optometrist refits a PMMA lens wearer into an RGP lens and any potential problems this may create (Group 5.1.1)
Be able to recommend an appropriate lens care system for a patient based on the lens material they are using (Group 5.2.1)
Understand how the contact lens fitter or optometrist might change a patient’s soft lens or RGP material and/or modality if that patient is experiencing deposition problems (Group 5.2.2)

Learning objectives
Know how to recommend an appropriate lens care system for a patient based on the lens material they are using (Group 5.2.1)
Know how to change a patient’s RGP or soft lens material and/or modality if that patient is experiencing deposition problems (Group 5.4.2)
Know how to refit a PMMA lens wearer into an RGP lens (Group 5.4.2)

About the author
Claire McDonnell works in private practice and lectures BSc Optometry undergraduates at the Dublin Institute of Technology in the areas of contact lenses, advanced clinical techniques and refractive surgery. She has given CET workshops and presentations in the UK, Ireland and at European conferences.
**History**

The first hydrogel contact lenses became available in 1957. In 1971, Bausch & Lomb produced the first ‘softlens’ made from polymacon (a low water content, non-ionic material). Originally Otto Wichterle (the inventor of hydrogel lenses) recommended that the lenses be cleaned by boiling them in physiological saline every two weeks. By 1985, as more companies began to develop newer hydrogel materials and proper lens care systems, it was necessary for the American FDA to categorise soft lenses into distinct groups. The groups were initially designed to deal with how different lenses interacted with various lens care products and to differentiate between lenses which attracted varying amounts of protein deposits from the tear film. Table 1 shows the original four FDA groupings.

While there are still some hydrogels available in low water content materials, the most popular disposable hydrogels mostly fall into either groups II or IV – that is high water content non-ionic or ionic.

**Deposition**

The ionic hydrogels tend to have a negatively charged surface which makes them sensitive to changes in pH and osmolarity and more likely to attract tear proteins such as lysozyme (which is positively charged). Non-ionic hydrogels, however, are treated to remove the negative charge. Studies have found that the ionic contact lenses (in particular those which contain methacrylic acid, for example 1day Acuvue) tend to attract more protein deposits than the non-ionic lenses. Natural protein from the tears is colourless and easily removed by normal lens cleaning. However, some deposition of proteins on lenses may be beneficial due to their antimicrobial effect. But, if the same proteins become denatured, they lose their antimicrobial efficacy. Denatured proteins can then cause clouding of the contact lenses and, as the body no longer recognises them, can lead to inflammatory responses – the most common one being contact lens papillary conjunctivitis (CLPC). Denaturing of protein can occur as a result of interaction with different lens materials, but a study in 2007 showed that, while ionic hydrogel lens materials with methacrylic acid can attract a considerable amount of protein, very little of that protein actually becomes denatured. Other lens materials can cause greater denaturation but they only deposit very small amounts of protein.

Multipurpose contact lens solutions are relatively effective at removing natural protein, but denatured proteins bind much more tightly to lenses and are far more difficult to remove. Biotrue multipurpose solution contains protein stabilisation agents which have been shown to minimise denaturation. Other solutions aim primarily to remove natural deposited protein before it can become denatured. With the popularity of disposable lenses, protein has very little opportunity to build up on lenses. The exception here is group IV lenses, but even these lenses show very little denaturation of protein. As a result, protein deposition tends not to be a significant source of patient discomfort. If it is thought to be a problem, changing the patient to a group II (non-ionic) lens or changing their solution to Biotrue may help to improve their symptoms.

**Oxygen transmission**

The water content in hydrogel contact lenses is an important factor in determining oxygen permeability. This is because the oxygen is able to pass through water while being unable to pass through the material itself. Oxygen permeability increases logarithmically with an increase in water content. However, refractive index decreases with an increase in water content because the refractive index of water is normally lower than that of the material itself. A lower refractive index means a thicker lens, which then offsets some of the gain in oxygen transmission.

Concern was raised about the effects of contact lens-induced corneal hypoxia as early as 1967. Interest in the possibility of overnight wear began in the early 1970s, and by the 1980s there was a considerable demand for extended wear lenses. These two factors combined meant that contact lens manufacturers needed to develop materials with much higher oxygen transmission.

Manufacturers knew that silicone has excellent oxygen transmission and silicone elastomer lenses had been available since the 1970s, but silicone is intrinsically hydrophobic. So, although this material can have Dks in the 200s, it still has problems with excessive lipid deposition and corneal adherence. The fact that it took over 20 years to eventually combine silicone and hydrogel together to produce a viable contact lens material is a testament to the enormity of the task. Finally, in 1999, CibaVision and Bausch & Lomb brought the first commercially available silicone hydrogel (SiHy) lenses to market. In 2001, the FDA approved the lenses for 30 days’ continuous wear. These first generation lenses had to have a special surface
SiHy lenses can be made with much lower water contents than hydrogels because the oxygen permeability of the material is not dependent on water content. However, water is what gives the material some of its flexibility and silicone is a relatively inflexible material. The new SiHy lenses showed a much higher modulus (rigidity) than the older hydrogels (see Table 2, page 55, for the moduli of some common hydrogel and SiHy lenses).

This increase in modulus (compared to hydrogels) led to an increase in some contact lens-related problems, such as contact lens papillary conjunctivitis (CLPC) (Figure 1) and superior epithelial arcuate lesions (SEALs) (Figure 2) in some cases. Patients exhibiting these problems should be changed to a lower modulus material. There are advantages to having a stiffer lens in that it allows for slightly more tear exchange underneath the lens and a stiff lens can mask some mild corneal irregularities.

Initially, SiHy lenses were placed in one of the original four FDA groups (mostly group I), but in 2007 the FDA made a fifth group specifically for SiHys. SiHy lenses are also divided into three different generations. Each generation has a different treatment to make the material hydrophilic and a different polymer.

The first generation SiHy lenses have surface treatments to make them hydrophilic. They tend to have high Dks and correspondingly high moduli. The second generation materials do not have a surface treatment. Instead, they have polyvinyl pyrrolidone (PVP) as an intrinsic wetting agent. The third generation lenses do not have surface treatments or intrinsic wetting agents. These lenses have a different polymer which is intrinsically hydrophilic.

All SiHy lenses attract lipid deposition from the tears because silicone is intrinsically lipophobic (Figure 3). Researchers have compared the amount of lipid deposition which occurs on the three different generations of SiHy lenses, but they have come up with conflicting results. In one paper, researchers found that second generation lenses adsorbed more lipids, while another paper found that first generation lenses adsorbed more. What researchers can agree on is that hydrogel lenses deposit fewer lipids than SiHy and group IV deposit fewer than group II. If excessive lipid deposition is a problem, the simplest solution is to change the patient into a hydrogel lens or, if this is not possible (due to oxygen requirements), change the patient to a one-day disposable SiHy lens.

RGP materials

The first hard lenses were made from PMMA, which is an optically excellent material but allows negligible oxygen transmission. Although gas permeable materials first became available in the late 1970s, there are still patients wearing PMMA lenses today. PMMA has almost no oxygen transmission and is quite inflexible and so long term wear usually causes corneal warpage (Figure 4) and problems related to hypoxia and, therefore, these patients should be refitted with RGPs. When refitting these patients, the recommendation is to fit with a lens which has parameters that match their original PMMA lens as closely as possible. Choose a low Dk material as this will keep flexure of the lens to a minimum. The lowest
Modern RGP materials are divided into four groups based on their silicone and fluorine content (see Table 3).

<table>
<thead>
<tr>
<th>Group</th>
<th>Description</th>
<th>Material</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Contains no silicone or fluorine</td>
<td>Cellulose acetate butyrate</td>
<td>Boston IV</td>
</tr>
<tr>
<td>II</td>
<td>Contains silicone but no fluorine</td>
<td>Silicone acrylate</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>Contains silicone and fluorine</td>
<td>Fluorosilicone acrylate</td>
<td>Fluoroperm</td>
</tr>
<tr>
<td>IV</td>
<td>Contains fluorine but no silicone</td>
<td>Fluorocarbon</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 Modern RGP materials, divided into four groups based on their silicone and fluorine content

Another problem with RGPs is the tendency for the material to flex with time. Flexure is when a rigid lens bends because of pressure from the lids and because the back surface of the lens does not conform perfectly to the front surface of the cornea. Thin RGP lenses can flex approximately one-third of the corneal thickness, with an increased chance of flexure with steeper and larger lenses and increasing oxygen transmission. To avoid problems with flexure, choose materials with slightly lower Dks and keep the total diameter as small as possible.

Conclusion

Many contact lens-related problems can be effectively addressed with a change of material. It is to the practitioner’s advantage to be familiar with the various available materials and their respective advantages and disadvantages.

Future CET articles in OT

Later in this series, OT will be bringing you more CET on contact lens materials. Look out for our article on corneal oxygenation and oxygen flux. There is still debate between researchers about solution induced corneal staining (SICS) and preservative-associated transient hyperfluorescence (PATH). We will therefore bring you the latest information on the compatibility of solutions with contact lens materials later in the year.

MORE INFORMATION

References
Visit www.optometry.co.uk/clinical, click on the article title and then on ‘references’ to download.

Exam questions
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