Specific examination of the cornea

Examination at high magnification may be undertaken either because general examination has detected an anomaly, or because the history or symptoms of the patient suggest that a specific anomaly may be present. For example, an existing soft contact lens wearer might have microcysts or neovascularisation. However, even patients with no history of contact lens wear may have microcysts or vacuoles, and it is important to note their presences in order to differentiate them from those caused by lenses.

Any anomaly of the cornea should be recorded in detail:

● **Where is it?** Accurate recording of the distance from the limbus (or centre) and the clock position makes it easier to find the anomaly again. The estimation of distances when the eye is under magnification is a challenge to the inexperienced microscopist, and this can cause unnecessary alarm when applied to suspect neovascularisation, for example. Some slit-lamp microscopes have a graticule eyepiece, which can be useful when making quantitative observations. However, some observers (including the author) find the graticule distracting. Reasonable estimates of dimensions may be made with a little practice by comparing the size of the object of attention with a known dimension. The visible diameter of the cornea is 11-12mm, and the amount a normal soft lens exceeds it by about a millimetre all round. Alternatively, one can always hold a millimetre rule close to the anomaly (but be careful!)

● **How big and how many?** With a wide beam and lowish magnification, the size of a large opacity, or the number of a multiple one, may be determined. Large single opacities may be associated with bacterial infection, or the later stages of herpetic ulceration, whereas multiple smaller ones may be caused by a non-microbial agent, or by a viral or protozoan infection.

● **Colour and density** are best assessed with direct illumination. Though most corneal lesions tend towards the monochrome, a haemorrhage within the cornea would give rise to a red lesion, and a rust stain might betray a ferrous foreign body. Some of the less dense lesions are more or less invisible under direct illumination and may only appear under indirect or retro illumination, the classic example being ghost vessels (see below). Oscillation of the beam so that the type of illumination alternates may be useful, and can be achieved either by use of the joystick or by decoupling the instrument and swung the illumination system independently.

● The depth of an infiltrate or scar tends to correlate with the seriousness of its cause. Intraepithelial infiltrates are usually a response to a non-microbial trigger, though this may include bacterial exotoxins. The deeper, sub-epithelial and stromal infiltrates are more likely to be associated with infection, and may lead to scarring. Depth perception through a biomicroscope is a result of a composite impression from a series of observations and it improves with practice. Experienced microscopists often appear to fidget with both the illuminator and the microscope, seemingly at random to the casual observer. However, valuable information can be gleaned from these manoeuvres, even though much of it may be subliminal to the microscopist.

a) Varying the position of the light source will affect the degree to which the scattered light from layers near to the surface will interfere with the clear resolution of objects in the deeper layers. Parallax between the object and the leading edge of the parallelepiped is also induced
b) Swinging the microscope will also create parallax between structures at different levels (see below)
c) The microscope allows binocular fixation, so stereopsis may be used provided that the array is sufficiently detailed
d) Not all layers of the cornea will be in focus at the same time, particularly at high magnification when the depth of focus is small
e) However, by far the best way to determine the depth of a lesion within the cornea is to narrow the beam, and observe the resultant thin optical section through a microscope set at a considerable angle to the illuminating system
f) The other very useful property of a thin sectionisthat elevations and depressions in an interface or surface will cause the beam to deviate. Elevations move the beam towards the side that the light beam is coming from; depressions bend it away from the source. Where the cornea is perforated, there will be a gap in the corneal section. To make the most of this effect, an angled beam is essential.
Blue light examination of the cornea

The use of fluorescein to examine epithelial integrity is a vital part of every corneal examination, and there is no valid reason not to do it. If concerned that a patient’s soft lenses will be discoloured, the patient can always be given a daily lens to wear home. Fluorescein colours the tear film rather than staining the tissue. Normally the lipid membranes of the epithelial cells prevent ingress of the substance, but if this is breached by trauma or disease, the tear layer gains access to deeper layers. The absorption spectrum and the degree of fluorescence depend on pH peaking when the pH is 8. The underlying tissues, because they have a different pH to the surface, will fluoresce more, so the defect is shown up as a green area. In the deeper layers, the fluorescein does diffuse sideways, tending to exaggerate the area of the lesion and this spread of fluorescein in the stroma may be a useful clue in itself when evaluating epithelial defects. When using the cobalt filter, it should be remembered that considerable light has been filtered out, and the rheostat adjusted to give a bright beam. Contrast may be considerably enhanced by the use of a yellow filter (Wratten #12 or #15) to eliminate reflected blue light from the cornea (Figure 1 a and b) though recently a lemon yellow filter has been found to be even more effective.

Magnification should also be appropriate. Fine punctate staining cannot be detected at low magnification and may be significant. Fluorescein in the tear film may make corneal staining more difficult to see. It helps if the instillation is frugal, as fluorescein will dye the patient’s face or clothing at least as well as their corneas. A short delay (a minute or two) between installation and observation is useful, to allow the tears to dilute the fluorescein. Fluorescein staining is best recorded as a diagram to illustrate its distribution, along with a grading to indicate severity.

Once a thorough assessment of the eye of the patient has been undertaken, the practitioner must now choose the first lens to insert. It is most likely that a soft lens will be selected and is most typically expected or requested by the patient. For completeness however, we are going to firstly consider rigid gas-permeable (RGP) materials. There are still significant numbers of rigid lens wearers out there and all practitioners should feel comfortable both fitting and reassessing them.

Rigid lens materials

An understanding of the material that an RGP lens is manufactured from is vital these days, as it can affect the on-eye performance of the lens dramatically. A brief glance at the ACLM manual will reveal a bewildering list of different lenses and it is easy to wonder where to begin. However, it’s not quite as complex as it looks. For a start, there are only a limited number of materials produced, and most contact lens suppliers source their material from the same few places. If you look at the actual material in the ACLM manual the number of choices starts to come down, as one manufacturer’s range will be pretty similar to another’s at least for the bread-and-butter lenses. Secondly many of the materials on offer are obsolete, and only still offered because practitioners still order them. Better options are arriving on the market at regular intervals and the manufacturers are rarely reticent about announcing their arrival both in the professional journals and via their own publicity mechanisms. A brief tour through the materials available today will also place the materials in their historical context.

PMMA, TPX and CAB

The ancestor of all RGP lenses emerged in 1947, a lens with a single back surface curve made of polymethyl methacrylate. As befits a parent, it had half of the characteristics that we would associate with its RGP offspring in that it was rigid, but not permeable to oxygen. It had very good optical clarity, dimensional stability and durability and it wetted quite well. It was easy to use in manufacturing and was used to make a diverse range of products, from toothbrush handles to geometry sets.

By the 1960s research and clinical experience had shown that PMMA lenses were not able to deliver adequate levels of oxygen to the cornea to ensure long-term corneal health, and the search was on to find a permeable alternative. In addition, it was believed at the time that a more flexible material than PMMA would improve lens comfort. Most thermoplastics are both more permeable and more flexible than PMMA. Materials such as cellulose acetate butyrate (CAB) and poly4-methyl pentylene (TPX) were initially promising but lacked dimensional stability. This would not have been a major problem, but neither material transmitted a great deal of oxygen, and the emergence of the silicone acrylates soon eclipsed them.

Silicone acrylates

Silicone rubber has an oxygen permeability of approximately 100 times that of PMMA. However it shares with all its fellow elastomers a surface which is inherently hydrophobic. Surface treatments have never properly overcome this, and the treated surfaces have a nasty habit of reverting to their previous state. Secondly, the rapid elastic recovery of the materials makes the lens ‘grab’ the cornea after a blink, rather like a suction cup. This can damage the cornea mechanically and cause the lens to bind. There are stories that some of the early clinical trials ended with lenses having to be removed under anaesthetic.
From this less than promising start it is perhaps no surprise that no true elastomer has been used successfully as a contact lens material.

It would therefore seem an obvious step to combine the virtues of PMMA with the permeability of silicone rubber. The problem is that the two have inherently incompatible chemistries associated with their molecular structure. The solution was to attach units of silicone rubber to a modified methyl methacrylate molecule, which produced the siloxymethacrylate monomer, generally known as TRIS.

The first well known silicone acrylate (SA) lens to emerge was Polycon (Wesley-Jessen) which arrived in the late 1970s. By modern standards it had a very low Dk of 8, so it had to be made very thin, which made it rather flexible. It was generally seen as a ‘lid attachment’ fit, large and flat. In the 1980s, the silicone content was increased as manufacturers engaged in the ‘great Dk race’. Paraperm (Paragon Vision) and Boston (Bausch & Lomb) emerged at this time. However, increased permeability was obtained at the cost of increased scratching and surface deposition. Dimensional stability also suffered, with minus lenses flattening and plus ones steepening. Crazing of the lens surface was also reported, though this may have been as much due to manufacturing methods as to the material itself, as too-rapid polishing can heat up the lens surface and produce this effect. The surface of a SA lens is largely hydrophobic, so hydrophilic components such as methacrylic acid were added to improve wetting. The inherent flexibility of lenses with high silicone rubber content could cause suction on the cornea and there can be adherence and corneal damage.

Fluorosilicone acrylates (FSAs)
The addition of fluorine to the mix was the way to address some of the problems associated with SAs. Fluorine is quite oxygen permeable, though not as permeable as silicone. Unlike silicone, which relies on diffusion for oxygen transmission, fluorinated polymers allow solubility, soaking up oxygen molecules like a sponge. FSAs are harder than SAs, allowing a better polish. Fluorine also has a low coefficient of friction and low surface tension, which prevents deposits adhering to the lens. After all, a fluoropolymer related to those molecules like a sponge. FSAs are therefore resistant to protein deposition, and the weekly enzyme cleaning needed with SAs is rarely needed. Lipid deposits do occur, and certain solutions such as Boston Advance (Bausch & Lomb) are formulated to be effective against lipid deposits on FSA lenses. Mucus also has an affinity to fluorine and a layer of tear film mucin (glycocalyx) forms round the lens. This reduces dehydration and improves tear break up time, and may allow shorter adaptation times. The only slight problem with them is that for a given Dk they tend to flex more than lenses that contain no fluorine. FSAs are the first choice lenses for many practitioners and examples include Fluoroperm (Paragon Vision Sciences) and Boston Equalens and RXD.

HDS (Hyperpurified delivery system)
This is a spin-off of NASA’s space shuttle research. Hyperpurified silicone is used, which allows a lens of higher permeability and surface wetting, without sacrificing lens stability or ease of manufacture. HDS (Paragon Vision Sciences) is available in versions with Dks of 40 and 100 ISO barrers units.

Boston EO
Boston EO (Bausch & Lomb) uses a polymer backbone known as Aerocor which allows oxygen permeability independent of silicone, and the replacement of impermeable PMMA with ‘bulky esters’. This allows the reduction in silicone content by up to 50 per cent, resulting in better wetting while improving dimensional stability. The Dk is 82.

High index
One of the drawbacks to increased oxygen permeability is that refractive index has tended to drop, so lenses must be made thicker. With high-powered lenses this can be a problem and a lens with a refractive index of 1.513 as opposed to the more usual 1.455 will allow lenses of about 13 per cent less mass, while maintaining oxygen delivery to the eye.

Surface-treated lenses
Surface treatment may be achieved by bombarding the surface with oxygen ions in a plasma chamber as in the case various Menicon RGP materials. It can also be done by a process called graft polymerisation, where a more hydrophilic polymer coating is applied, as in the Millenium (Vista Optics) lens. The result of either is a lens that will wet more easily and be more comfortable. However, a heavy-handed approach

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**TABLE 1**

| Prefix | This is administered by USAN and is optional outside the US. The prefix denotes the polymer used |
| Stem | This is always fcon for rigid lenses, filcon for soft lenses |
| Series suffix | Administered by USAN. A indicates the original formulation, B the second version, C the third etc |
| Group suffix | I Does not contain silicon or fluorine |
| | II Contains silicon but not fluorine |
| | III Contains both silicon and fluorine |
| | IV contains fluorine but no silicon |
| Dk range | A numerical code which identifies the permeability in ranges. The units are (cm2/s.[mlO2/(ml.hPa)]) |
| Modification code | A lower case letter denoting that the surface has been modified and has different characteristics to the bulk material |

**TABLE 2**

<table>
<thead>
<tr>
<th>Group code</th>
<th>Dk range</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-15</td>
<td>Boston ES/IV</td>
</tr>
<tr>
<td>2</td>
<td>16-30</td>
<td>Quantum 1</td>
</tr>
<tr>
<td>3</td>
<td>31-60</td>
<td>Boston EO/7/Equalens/Paragon HDS</td>
</tr>
<tr>
<td>4</td>
<td>61-100</td>
<td>Boston XO/Quantum 2/Paragon HDS 100</td>
</tr>
<tr>
<td>5</td>
<td>101-150</td>
<td>Europerm 120/CIBA Aquila</td>
</tr>
<tr>
<td>6</td>
<td>151-200</td>
<td>Fluoroperm 151</td>
</tr>
<tr>
<td>7</td>
<td>200-250</td>
<td>Menicon Z</td>
</tr>
<tr>
<td>Higher codes can be added in bands of 50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
to cleaning (not a common problem admittedly) could wear the surface in time, adversely affecting the lens performance. It is possible that in time surface treatments will emerge with other desirable characteristics, such as bacteria-static properties.

‘Hybrid’ lenses
Hybrid FS and Hybrid FS Plus (Contamac) are made of an innovative mixture of FSA and a hydrophilic component, whose unhydrated form is distributed throughout the lens matrix. In contact with solution, the surface hydrophilic molecules bind with the solution, creating an extremely wettable surface. The ‘FS’ part of the name refers to this Fluid Surface Technology. Because the hydrophilic component is not confined to the surface, wearing out is not an issue. There are obvious applications for this type of lens in patients with less than ideal tear films, but lenses of this type may well become first choice lenses in time, as they seem to offer no obvious drawbacks.

Classification of RGP materials
EN ISO 11539: 1999 sets out the international standard method for the classification of contact lens materials and as a published European Standard (EN) it has the status of a British Standard and supersedes those BS classifications in previous use. Each material is classified by a six-part code as shown in Table 1.

As an example, let us consider the material Paflufocoen B III 3. Its classification says that it consists of a polymer with the USAN prefix Parflu, and that it is a rigid lens material (focon) The suffix B indicates that is the second generation of this polymer and III that it contains both silicon and fluorine. The suffix 3 shows its Dk to be between 31 and 60. It is in fact the classification for Paragon HDS, mentioned above. Boston IV, a silicon acrylate with a Dk of 14 is classified as Itafocoen B II 1. Table 2 shows the properties of some RGP lenses.

In the past, published information on lens characteristics has tended to be contradictory and confusing. Dks can be measured by a number of methods and manufacturers were fond of quoting the highest figure found for their own lenses by any method. They tended to develop a more conservative approach when quoting the DK of a rival’s lenses. This is basic marketing practice but does cause confusion among practitioners and less qualified internet browsers. The ISO classification specifies methods to be used for RGP and soft lenses and the ACLM manual lists Dks in ‘New Fatt units’ which give Dk values approximately 75 per cent of those previously specified. When comparing lenses, make sure that you are comparing like with like, as there is still a bit of creative classification encountered from time to time.

Planned replacement
One of the perceived benefits of rigid lenses is that they have a greater lifespan than soft lenses, and many patients keep the same lenses for several years. In the days of PMMA, lenses would last for years, and could be repolished easily to restore them to working order. However, modern high-Dk materials don’t last as long. Guillou et al found a measurable decrease in surface wettability after six months. Woods and Efron found that planned replacement of the lenses reduced surface scratching, drying and deposition as well as mucus coating. Additionally corneal staining, limbal hyperaemia and tarsal conjunctival changes might be reduced.

Over time the lenses become gradually less comfortable and the vision may decline gradually. Surface deposition will increase the chances of an immunological reaction. Often these changes are barely imperceptible, and the patient is surprised how good a new lens performs in comparison with the old one. With modern materials, repolishing is rarely a practical proposition. They are constructed to be as thin as possible to begin with, and some are surface-treated. Furthermore, over-polishing can render the surface hydrophobic.

Planned replacement of the lenses is therefore a useful strategy. The published evidence suggests that the optimum replacement interval might be less than six months, but given the cost of manufacturing rigid lenses six months or 12 months is a more practical proposition. In 2003 about half of all RGP lenses in the UK were replaced annually. For extended wear, 3–6 months might be a good idea, as lenses over six months old have been found to be more likely to bind.

Next month we will consider soft lens materials.

References

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