CHAPTER 6

RGP MATERIALS

Much has changed with regard to rigid gas permeable materials since the days of PMMA, CAB and the first silicone/acrylates. Today's materials offer a wide range of options in parameters such as Dk, specific gravity, wettability and material stability. A broad understanding of these material characteristics is invaluable in fitting and refitting RGP contact lens patients. First generation RGP contact lenses were made of silicone and methacrylic acid polymers, known as silicone acrylates. At the time, this material offered some distinct advantages to its predecessors, PMMA and CAB, including higher oxygen permeability. Silicone acrylate was not only a better thermal conductor than PMMA, it also experienced less warpage than CAB. The sacrifices at the time were decreased optical quality, decreased wettability and greater protein deposition. In order to improve wettability and oxygen transmissibility, the use of fluoro siloxane methacrylates (fluorosilicone acrylates) became popular. These second-generation polymers combined the silicone acrylate material with fluorinated monomers, giving the material better wetting characteristics. This combination also helped reduce protein deposition and improve oxygen transmission, allowing for reduction in the siloxane component. Conversely, the material was more susceptible to lipid deposits and was found to be more sensitive to harsher cleaning agents.

In general, the silicone/fluorine part of the polymer gives the material its high oxygen transmissibility, while the methacrylate enhances optical quality and stability. As previously mentioned, higher amounts of silicone tend to have detrimental effects on lens performance including poor surface wettability, greater protein deposition, increased flexure and instability and decreased lens durability. The incorporation of fluorine helps to overcome many of these shortcomings [88, 118, 119].

RGP MATERIAL PROPERTIES

Oxygen Permeability (Dk & Dk/t)

When we think of the various RGP contact lens material properties, probably none is more considered than that of Dk. Hundreds of studies have been focused on this determination, its significance and the ideal value needed to maintain overall ocular health. Oxygen permeability or Dk, is defined as the product of the diffusion coefficient of oxygen in a material (D) and the solubility coefficient of oxygen in a material (k). It is a property inherent to any polymer matrix and is independent of lens thickness. Oxygen transmissibility or Dk/t, is defined as the oxygen permeability (Dk) per lens thickness (t) and varies for each particular contact lens [120].

A working knowledge of Dk issues and the ability to make an intelligent Dk lens material selection can make a significant difference for some patients. Patients being refit from PMMA lenses, for example, are typically happier in lower Dk materials which will more closely resemble their previous lenses in optical quality and durability. In moderate to high myopes, the dimensional stability provided by the low Dk fluorosilicone acrylates is advantageous as relatively thin centre thicknesses might otherwise result in lens flexure. Conversely, the increased permeability provided by the high Dk fluorosilicone acrylates can benefit hyperopes, where increased centre thicknesses minimise the need for the more dimensionally stable materials [121]. But how much permeability is enough? And who's to say that more is better?

Wetting Angle (WA)

As discussed previously, there are several methods to measure a material's wetting angle or surface wettability; sessile drop, captive bubble and dynamic contact angle. Each method results in different values that are difficult to compare directly. In addition, it has been shown that a material's WA does not necessarily correlate to on-eye surface wetting because it doesn't account for the eye's ability to coat the lens surface with a mucin "biofilm" that helps the lens surface attract and retain water. Despite these inconsistencies, WA can still be an important factor in GP lens success [121].

Refractive Index

Most GP materials have refractive indices ranging from 1.42 to 1.48 and in most cases these variances have little effect on lens design. However, high-index (1.51 to 1.54) materials can keep lens thickness to a minimum for high refractive errors and can create slightly more add effect in aspheric multifocal designs [121].

Specific Gravity (SG)

Specific gravity is the ratio of the mass of a solid to that of an equal volume of water. Therefore, a lens with SG greater than 1.00 will sink in water. Current materials have SGs ranging from 1.07 to 1.27. In most cases this has very little effect on the performance of a lens. But, when lenses are thick such as for high-plus powers or prism ballasted lenses, it can cause lens mass to vary by as much as 20%. Compared to lenticulation which reduces lens mass by only 10–15%, use of a lower SG in addition to lenticulation may help prevent RGP's from riding low. Specific gravity should be recognised as an additional property of RGP materials that influences rigid lens performance on the human eye [121]. The following examples illustrate how to use specific gravity to solve some fitting problems.

Moderate to High Plus Lenses

Fitting hyperopic patients is a special challenge because plus lenses have anteriorly located centres of gravity compared to minus lenses and these patients often have relatively flat corneas. Together, these factors may cause plus lenses to drop off the upper lid and seek an inferior position on the cornea. By combining minus lenticulation with a low specific gravity material, the mass of a plus lens can be maximally reduced, which minimises its tendency to ride inferiorly and lose its attachment to the upper lid. This is especially evident as plus power increases. In contrast, ordering a lenticular design in a high specific gravity material will be counterproductive.

Moderate to High Minus Lenses

Consider using low specific gravity materials when lenses ride too low. Combine a plus lenticular design with a low specific gravity material to create a lighter and thinner-edged lens that may now be captured by the upper lid. Recent studies have demonstrated that high specific gravity materials have little lowering effect on high riding minus lenses.

Prism Ballasted Bifocal or Toric Lenses

High specific gravity materials may help a lens position inferiorly by increasing its mass. Thus, improving performance. Consider ordering a high specific gravity material as an alternative to increased prism ballast when these designs position higher than desired. By choosing materials with high Dk and high specific gravity, lens position may be improved without creating a thicker lens that further reduces oxygen flow to the cornea.

Hardness and Toughness

Lens hardness is measured by the Rockwell R and Shore D methods. Rockwell determines a GP button's resistance to compression, while Shore predicts scratch resistance. Most package inserts report the Shore D value, which ranges from 75 to 85 units. Stiffness or modulus is determined by applying force to a lens until it breaks. This value is generally not listed in a package insert, but it can be important in influencing a lens' ability to mask corneal astigmatism and other irregularities [121].

Ultraviolet Blocking

Compounds such as benzotriazole and Uvinul D-49 can be incorporated into an RGP lens polymer to block ultraviolet light below 380 nm. This translates into roughly 70 percent to 90 percent blockage of UV-A light and up to 99 percent blockage of UV-B light. Though a GP lens does not fully cover the cornea, a UV-blocking lens can be of benefit to patients who spend a lot of time outdoors but do not wear sunglasses [121].

Table 18: RGP and scleral lens materials

Name	Material	Dk	Wetting angle	Equivalent to:	Specific gravity	Minimum CT
PMMA	PMMA	0.20	18		1.195	0.11
Boston II	SA	14.6	20	AccuCon, OP2, SA-18, SGP I	1.130	0.12
Boston IV	SA	28.7	17	AccuCon, Flosi, OP-3, SA–32, SGPII	1.110	0.13
Boston ES	FSA	36	52	AccuCon, Flosi, OP-2, Hydro2, Optimum Classic	1.220	0.08
Boston RXD	FSA	45	39		1.270	0.11
Boston 7	FSA	73	33		1.220	0.11
Boston EO	FSA	58	49	Hydro2, Optimum Comfort, Tyro 97, Onsi-56, OP-6, SGP III	1.230	0.10
Boston Equalens	FSA	71	30	Hydro2, Optimum Extra, Onsi-56, OP-6	1.196	0.13
Boston Equalens II	FSA	85	30	Optimum Extra	1.24	0.13
Boston XO	FSA	100	49	Optimum Extra, Tyro 97	1.27	0.13
Boston XO²	FSA	141	38	Menicon Z, Optimum Extreme	1.19	0.15
Paragon HDS	FSA	58	14.7	Hydro2, Onsi-56, OP-6, Optimum Comfort	1.160	0.13
Paragon HDS 100	FSA	101	42	Optimum Extra, Optimum Extreme, Tyro 97	1.10	0.15
Paragon Thin	FSA	29	61	AccuCon, Flosi, Optimum Classic	1.145	0.09

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Name	Material	Dk	Wetting angle	Equivalent to:	Specific gravity	Minimum CT
Paraperm EW	SA	15.6	26	Hydro2, Onsi-56, OP-6, SGP III	1.128	0.12
Paraperm O_2	SA	15.6	25	AccuCon, OP-2, SA-18, SGP-1	1.127	0.12
Fluoroperm 30	FSA	30	13	AccuCon, Flosi, Hydro2, Onsi-56, OP-3, Optimum Classic	1.140	0.12
Fluoroperm 60	FSA	60	15	Hydro2, Onsi-56, OP-6, Optimum Comfort, Tyro 97	1.150	0.13
Fluoroperm 92	FSA	92	16	Optimum Extra, Tyro 97	1.100	0.16
Fluoroperm 151	FSA	151	42	Menicon Z, Optimum Extra, Optimum Extreme	1.100	0.13
Optimum Classic	FSA	20	12		1.19	0.13
Optimum Comfort	FSA	65	6		1.17	0.13
Optimum Extra	FSA	100	3		1.16	0.13
Optimum Extreme	FSA	125	6		1.15	0.13
Optimum Hybrid FS	FSA	31	Immeasurable		1.183	0.13
Optimum HR **1.51** **1.53**	FSA	50 26	33 42			0.13 0.13
$Hydro_2$	FSA	50	5		1.146	0.13
Tyro 97	FSA		23		1.187	0.13
Menicon Z	FSA	163	24		1.20	0.15
F2Low	FSA	28	19		1.152	0.13
F2Mid	FSA	50	21		1.146	0.13
F2High	FSA	100	21		1.159	0.13
addValue 18	SA	18	<25	XL 40	1.12	0.10
addValue 35	SA	35	<30	SM38	1.11	0.10