CHAPTER 5

CONTACT LENS MATERIALS AVAILABLE IN SOUTH AFRICA

A thorough understanding of the various contact lens materials is essential to help a practitioner's trouble-shooting ability and can perhaps even be the difference between maintaining and losing borderline contact lens patients. Often the success of many contact lens patients depends on determining the most appropriate contact lens material for each patient's eye.

Since their introduction in the 1970s, hydrogel contact lenses have become the lens of choice for many contact lens practitioners and therefore comprising as much as 85% of the contact lens market share. The number of different hydrogel materials available has grown to accommodate nearly any physical or physiological fitting need. At the same time, several different replacement schedules in addition to conventional wear have evolved adding frequent replacement, planned replacement, disposable use and extended wear to today's soft contact lens vocabulary. The choices are so numerous that many practitioners become familiar with only a few contact lenses and use them exclusively. But disregarding the less familiar lenses isn't always in every patient's best interest.

SOFT LENS MATERIALS AND THEIR PROPERTIES

The US Food and Drug Administration (FDA) classification system for hydrogel materials is based on the water content and the ionic nature of the lens matrix of the contact lens material. This system is outlined in the following Table 16.

Table 16: Contact lens materials and their composition [111]

FDA Lens Group	US Adopted name	Dk or oxygen Permeability ($x10^{-11}$)	Water content %	Chemical composition
I non-ionic, low water content (<50%)	Polymacon Tetrafilcon Lotrafilcon A Lotrafilcon B Galyfilcon A	7.5 9.0 140 110 60	36% 43.5% 24% 33% 47%	HEMA HEMA, MMA, NVP DMA, TRIS, siloxane DMA, TRIS, siloxane Unpublished
II non-ionic, high water content (>50%)	Omafilcon A Alphafilcon A Hilafilcon A	19.6 22.9 26.9	62% 66% 70%	HEM, PC HEMA, NVP HEMA, NVP
III ionic, low water content (<50%)	Bufilcon A Balafilcon A	16.0 99	45% 36%	HEMA, DA, NAA NVP, TPVC, NCVE, PBVC
IV ionic, high water content (>50%)	Ocufilcon D Etafilcon A Vifilcon A	19.7 17.0 16.0	55% 58% 55%	HEMA, MAA HEMA, MAA HEMA, PVP, MAA

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FDA Lens Group	US Adopted name	Dk or oxygen Permeability (x10^{-11})	Water content %	Chemical composition
Legend: HEMA – 2-hydroxyethyl methacrylate DMA – N$_1$N – dimthylacrylamide DA – Diacetone acrylamide MMA – Methyl methacrylate MAA – Methacrylic acid NVCE – N-carboxyl vinyl ester NVP – N-vinyl pyrrolidone PBVC – Poly(dimethylsiloxyl) di (silybutanol) bis (vinylcarbmate) PC – Phosphorylcholine TPVC – Tris-(trimethylsiloxsilyl) propylvinyl carbamate TRIS – Tris (hydroxylmethyl) aminomethane				

Water Content

High water content material is defined as having greater than 50% water content and typically contains negatively charged carboxylic acid. Low water content material is defined as having less than 50% water content and contains more than 0.2% methacrylic acid making them ionic [88]. Hydrogel lens materials derive their oxygen permeability from their water content. Higher water content materials have higher oxygen permeability and *vice versa.* In order to increase water content, small quantities of charged groups such as methacrylic acid or neutral groups such as polyvinyl alcohol (PVA) or N-vinyl pyrrolidone (NVP) are added to the base material [polyHEMA or methyl methacrylate (MMA)]. This increases water content up to 60% or greater. Typical hydrogel materials are available in water contents ranging from 37.5–79%. However, as water content increases, lens thickness must also increase in order to preserve lens strength and to prevent lenses from tearing easily [112]. On the eye water is lost due to a rise in temperature and evaporation which leads to a tightening of the fit [70].

Silicone Hydrogels

The newest type of contact lens material**,** the silicone hydrogel, is designed specifically for the extended wear patients and incorporates the best characteristics of both RGP and hydrogel materials. By incorporating silicone into the hydrogel matrix, extremely high oxygen transmission or hyper transmissibility is combined with the comfort and dehydration resistance of conventional hydrogels. Bausch & Lomb's PureVision lens was the first lens of this type to acquire FDA approval for extended wear. Its material, balafilcon A has been shown to outperform conventional hydrogel extended wear contact lenses on key performance parameters including overnight corneal swelling, hypoxia-related effects and the level of microbial adherence to exfoliated corneal cells. The Dk/t of PureVision is 110 and its water content is 36%. CIBA Vision's Focus Night & Day material lotrafilcon A, is a biphasic block co-polymer compromised of a highly permeable fluorosiloxane-based polymeric phase coupled with a water phase. The Dk/t of lotrafilcon A is 175 and its water content 24% [38, 112].

These new hybrid contact lenses offer oxygen permeability in the ranges previously seen only in hyper Dk/t RGP materials, making them ideal for patients with hypoxia-related conditions or patients wanting an extended wear option. The following table lists the silicone hydrogel lenses currently available in South Africa.

Table 17: Silicone hydrogel materials and their properties

Silicone hydrogel materials and properties						
Material	Trade name Manufacturer	Water content (%)	Dk/t ($x10^{-11}$) @ -3.00	Modulus (MPa)	Coefficienct of friction, Ross et al., 2005. Corneal CoF = 0.0153	UV Blocking
Balafilcon A	PureVision (Bausch & Lomb)	36	110	1.5	0.05	No
Balaficon A	PureVision 2HD (Bausch & Lomb)	36	130	1.1	0.05	No
Samfilcon A	Ultra (Bausch & Lomb)	46	136	0.70	Not availible	No
Comfilcon A	Biofinity (Coopervision)	48	160	0.75	Not availible	No
Fanfilcon A	Avaira Vitality (Coopervision)	55	110	0.60	Not availible	No
Stenfilcon A	MyDay (coopervision)	54	100	0.40	Not availible	No
Lotrafilcon A	AirOptix Night & Day, Aqua EX (CIBA Vision – Alcon)	24	175	1.52	0.07	No
Lotrafilcon B	AirOptix Aqua, Aqua Hydraglyde (CIBA Vision – Alcon)	33	138	1.00	0.03	No
Delifilcon A	Dailies Total 1	33	156	0.7	0.04	No
Senofilcon A	Acuvue Oasys (Johnson & Johnson)	38	147	0.72	0.0104	FDA Class 1
Narafilcon A	1-Day Acuvue TrueEye (Johnson & Johnson)	46	118	0.66	0.008	FDA Class 1

Wettability and Wetting Angle (WA)

The degree of wetting is determined by the balance between adhesive and cohesive forces acting on a lens surface. Contact lenses must sustain complete wetting to allow a thick coverage of the tear film, a smooth recovery of the tear layer after eye closure and good visual acuity. Wettability is determined by measuring the contact or the wetting angle, the smaller the contact angle the greater the wettability. Wetting angles can be classified as dynamic or static, advancing or receding. 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 [113, 114, 115].

Coefficient of Friction (CoF)

Coefficient of friction is an important property of a contact lens that closely correlates to lens comfort. The coefficient of friction (CoF) refers to how lubricious the surface of the contact lens is. It is sometimes referred to as lubricity and a lower CoF helps to give lenses a silky and smooth feel. A contact lens's lubricity determines how it moves on the eye and more importantly how the lids blink over the surface of the lens. We blink up to 14000 times each day and therefore the dry ocular or lens surface experiences increased friction with the eyelid, elevating the potential to damage either the lid (lid wiper epitheliopathy) or the ocular surface. Traumatised lid wiper epithelium may have exposed nerve endings and increased sensitivity, lowering the threshold for dry eye symptoms and reducing comfort. The CoF is mainly affected by the wettability of the lens surface. Therefore, increasing the wettability of the lens surface by using surfactants or wetting solutions has been a long-standing strategy for enhancing patient comfort throughout the entire wear period, as a consequence, keeping patients in contact lenses. Lubricity can be quantitatively measured via micro-tribometry (tribology is derived from the Greek tribos meaning "to rub"). The set-up is designed to mimic *in vivo* eyelid interactions. The coefficient of friction of the human cornea is 0.0153 [113–115].

Dehydration

Among the currently available hydrogel lens materials, those with higher water content are thought to dehydrate more upon exposure to low humidity environments. This is especially true for thin and high-water content lenses as compared to their thicker counterparts. People who are constantly in low humidity, air-conditioned environments and those who live in colder climates, where hot air heating systems often lower humidity, tend to experience the most discomfort. The anterior surface drying associated with this dehydration also contributes to binding lens deposits, while overall soft contact lens dehydration may bind the lens to the eye and reduce the lubricity of the lens. It is believed that in addition to the overall water content of a lens other factors including the structure of the water within the lens matrix, determine the rates of dehydration among various contact lenses. Hydrogel contact lenses containing more bound water as opposed to free water, are believed to dehydrate more slowly because the more structured bound water is less likely to evaporate [113–115].

Deposits [103, 112, 116, 117]

Surface deposits on hydrogel materials have been extensively researched. The tendency of different material groups to collect protein and lipid deposits has been examined in detail, which produced some interesting results. FDA group I materials, including polymacon, tetrafilcon A and glycerol methacrylate comprise the group of polymers which are found to collect lesser amounts of protein. Due to their low water content, these polymers are typically involved in the manufacturing of the thinnest types of lenses. It's interesting to note that polymacon (polyHEMA 38% water), the original soft lens material is still used in the manufacture of nearly 50% of all soft contact lens types.

FDA group IV materials are relatively porous and have negatively charged networks that are more susceptible to tear film constituents entering the lens matrix. They are the only group of contact lens materials into which the low molecular weight, positively- charged protein and lysozyme is able to diffuse. Group IV materials predominantly deposit protein mostly due to the ionic carboxylate groups of the matrix. This material charge also influences the location of the protein with deposition occurring deep within the material matrix of group IV materials and more on the surface of group II materials. With protein deposition, the charge and the water content of the lens material are the main influencing factors with minimal inter-subject differences. Furthermore, protein deposits can be detected almost immediately upon insertion of these contact lenses. However, deposition has been shown to reach a plateau between 1 and 7 days post-insertion.

FDA group II materials predominantly deposit lipids mainly due to the presence of hydrophobic N-vinyl pyrrolidone. Contrary to the protein deposition seen with group IV materials, group II materials show considerable inter-subject differences in lipid deposition. The deposition of lipids is cumulative in these materials and does not reach a plateau, unlike the protein deposition of group IV materials.

Silicone hydrogel lenses primarily deposit low levels of relatively denatured protein and are more prone to deposit lipids.

Modulus of Elasticity [113–115]

The modulus of elasticity (modulus) or "stiffness" was not something we used to think about with hydrogel lenses. However, with silicone hydrogel materials the addition of silicone often results in a lower amount of water in the lens, which then results in silicone hydrogel lenses generally having a higher modulus of elasticity than hydrogel lenses. Modulus is a measure of how a material will deform and strain when put under pressure. Modulus can be described as the ability of a lens material to align to the ocular surface and resist deformation under tension. Modulus is therefore clinically relevant. A lens with too low a modulus would be more difficult to handle for the wearer and give insufficient movement on blink leading to poor tear exchange. However, too high a modulus can lead to mechanically induced pathology such as SEALs and CLIPC. Comfort with a high-modulus silicone hydrogel lens can also be problematic. Stiffer, high-modulus lenses may need a larger diameter or several base curve options to achieve a good physical fit. Improper peripheral alignment may result in edge fluting [113].