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THE SILICONE RUBBER CONTACT LENS: CLINICAL INDICATIONS AND FITTING TECHNIQUE

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Abstract — *Although the silicone rubber contact lens (SRCL) is not used frequently, there are a number of clinical indications for its use which include paediatric and adult aphakia, decompensated cornea, dry eye, irregular cornea, eyelid defects, corneal ulcer and corneal perforation. The properties of silicone rubber are reviewed and the fitting technique of the SRCL is described.*

KEY WORDS: silicone rubber contact lens, fitting techniques, clinical indications, aphakia, dry eye, decompensated eye, irregular cornea, eyelid defects, ulcer, perforation

Introduction

Silicone rubber has been used for over 35 years in several medical applications, particularly by plastic surgeons who have used it as a tissue implantation material. The first patent for the use of silicone rubber as contact lens material was granted to Becker in the USA in 1959 but it was not until 1972 that Müller Welt introduced silicone rubber contact lenses for use on human eyes in that country.[1] In April 1977, silicone rubber lenses were marketed in Europe by the firm of Wöhlk under the tradename of Silflex.[2] This lens is still available, together with the Silsoft silicone lens from Bausch & Lomb which has been supplied since 1991.

This paper provides a review of current indications for the use of the silicone rubber contact lens (SRCL), and is based upon a survey of the literature complemented by personal experience gained at Moorfields Eye Hospital, London and in a private practice in Nijmegen, the Netherlands.

Properties of Silicone Rubber

Silicone rubber is a hydrophobic material which, in the final stage of manufacture, requires surface treatment by ion bombardment to make its surface hydrophilic.[3,4] Irrespective of lens thickness, silicone rubber has the highest oxygen and carbon dioxide permeability of all contact lens materials — the oxygen permeability having a value of 300–400 $\times 10^{-11}$ $(cm^2/sec)(ml \times mm\ Hg)$. Various properties of silicone rubber are listed in *Table 1*.

Table 1. *Properties of silicone rubber*

Specific gravity	1.13 ± 0.03
Refractive index at 25° C	n = 1.435 to 1.436
Shore A Durometer	72–77
Penetration power	47–53%
Oxygen permeability	Dk = 300 to 400 $\times 10^{-11}$ $(cm^2/sec)(ml\ O_2/ml \times mm\ Hg)$
Density at 22° C	1.19–1.20 g/cm^3
Water content	0–0.5%
Elasticity	100%
Light transmission	85%

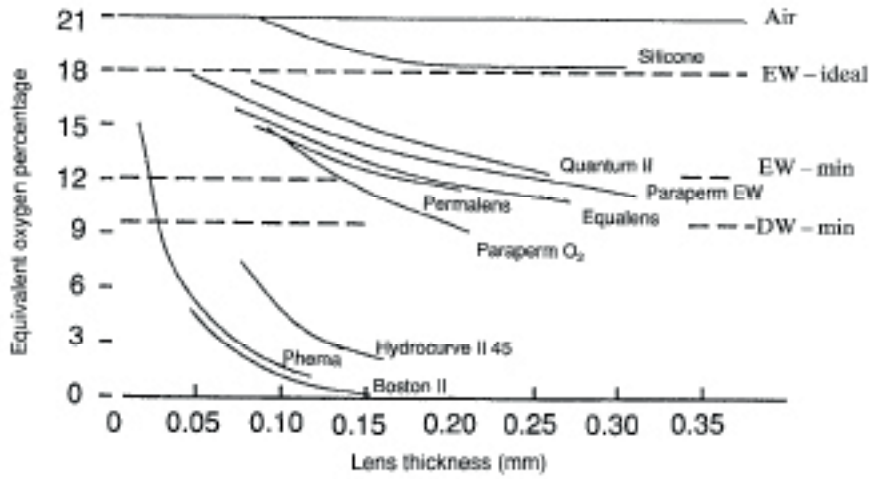

Figure 1. *Equivalent oxygen percentages (after Hill) for various rigid gas-permeable, soft and silicone rubber contact lenses of different thicknesses. EW-ideal, EW-min and DW-min are the oxygen levels corresponding to the ideal requirement for extended wear, and the minimum requirement for daily wear, respectively.*

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The equivalent oxygen performance is 18%, which is also higher than that of other contact lens materials (*Figure 1*).[5] The material is non-toxic, biologically inert and resistant to fungus and bacterial colonisation[2,4,6,7] which might suggest that complete sterilisation of lenses is not necessary. Since silicone rubber is an excellent thermal conductor, there can be no build-up of heat between the lens and the corneal epithelium.[8,9] The water absorption is very low (0–0.5%) and there is no absorption of extraneous chemicals or other substances.[4,5,7,10,11] This property permits the use of topical medication during wear and allows use of fluorescein in order to examine the fit. However, the preservative chlorbutanol and lipophilic components of tears such as cholesterol (esters) can be absorbed.[3,14,15] The high dimensional stability and high refractive index provide good optical quality. The reproducibility of lens manufacture is good and the fit can be determined as reliably as that of a rigid gas-permeable lens. The flexibility of the material makes the lens comfortable and reduces the adaptation period compared with that required for a rigid lens.[6,10] The material makes the lens resistant to scratches up to a certain level.[4,12,13]

There are, however, some disadvantages of silicone rubber which account for the fact that this type of lens is not fitted frequently. Firstly, mucus can adhere easily to the material[2,3,13,15–17] and because of this the lens can dry out and the chance of mucus adhesion and protein depositions will be greater. The surface of the lens loses its hydrophilic property and can dry out.[2,18] The consequences for the patient of adherence of deposits to the lens is reduction in clarity and discomfort. Protein deposits constitute a lesser problem and are easier to remove with a suitable cleaning agent.[3,13] A yellow discoloration of the lens can appear after a period of wear but this does not signify any change in its properties.[2]

Effects of the Silicone Rubber Contact Lens on the Cornea

Silicone rubber causes the least tissue reaction of all contact lens materials and no allergic reactions are known to be caused by the material.[6,9,16,20]

Burns *et al.*[21] examined the physiological compatibility of the SRCL on the corneas of rabbits and found that after a wearing time of 8, 16 and 168h the percentages of epithelial glucose, glycogen, adenosine triphosphate and lactate remained constant. Consequently, it is evident that aerobic glycolysis of the corneal epithelium is maintained and that no hypoxic signs or symptoms arise as with other contact lens materials.

If the lens fits correctly, fluorescein staining is seldom seen but any adherent mucus particles can leave an impression on the cornea.[6,17,22]

Various authors have reported that corneal vascularisation does not arise as a result of SRCL wear.[2,9,10] Nevertheless, this complication has been observed several times and Holden concluded that vascularisation can also appear as a result of mechanical irritation combined with lens stasis.[23]

There is evidence that wearing a SRCL has a negligible effect on the corneal curvature and consequently there is no spectacle blur.[5,9,10,16] The high oxygen transmissibility of the SRCL ensures that normal corneal thickness is maintained.[2,5,13,17,24]

Adverse effects on the cornea as a result of wearing a SRCL only appear when the lens fitting is not satisfactory.[11] If there is excessive lens movement, irritation of the conjunctiva, recurrent epithelial lesions and disturbance of the cornea at the limbal area can ensue.[6,11] On the other hand, if the lens fits too tightly, a fine punctate staining of the cornea may be seen together with transient steepening of the corneal curvature.[6,9] If the lens adheres tightly to the ocular surface for some time (the "suction cup syndrome') other complications such as milky-like dots that stain with fluorescein will arise on the cornea and hyperaemia of the conjunctiva at 3 and 9 o'clock can appear.[6] Microtraumas can occur which may be accompanied by erosions, cloudiness and lesions of the epithelium.[11]

Suction of the lens to the cornea obstructs tear circulation and epithelial lesions can arise followed by a decreased resistance of the epithelium barrier.[11,25] According to Fatt, the epithelium just above Bowman's membrane can be lifted and deformed as a result of the negative pressure under the adherent lens.[26] Finally, such a poorly fitting lens is difficult to remove, which may lead to epithelial abrasions.[9,15,16]

Fitting Technique for the Silicone Rubber Contact Lens

Generally, the back optic zone radius (BOZR) is selected as shown in *Table 2*. The BOZR chosen will be 0.20, 0.30 or 0.40 flatter than the mean keratometry reading (K).[2,6]

Table 2. *To select the back optic zone radius (BOZR) as suggested by Wöhlk, the 'addition' is added to the corresponding keratometry value.*

Mean keratometry value (mm)	*Addition (mm)*
7.10–7.60	0.40
7.70–8.40	0.30
>8.40	0.20

In the presence of corneal astigmatism, the BOZR is fitted steeper to create a little central pooling. At Moorfields Eye Hospital, the BOZR is chosen 0.20 flatter than K with spherical corneas and close to the flatter keratometry reading when corneal astigmatism is present. Mountford[2] advocated fitting astigmatic corneas with smaller diameters.

The optimum total diameter is 0.50–0.70mm larger than the corneal diameter.[2,6,27] If the lens is used as a bandage lens the diameter should be even larger to ensure minimal movement of the lens.[11]

At Moorfields Eye Hospital it is customary to evaluate the fluorescein pattern directly after inserting the lens in order to exclude the existence of lens suction to

Table 3. *Availability of the silicone rubber lenses*

	Silflex (Wöhlk)	*Silsoft aphakic series (Bausch & Lomb)*	*Silsoft super plus series (Bausch & Lomb)*
Back optic zone radius (mm)	7.20 to 9.00 (0.10mm steps)	7.50, 7.70, 7.90, 8.10 8.30	7.50, 7.70, 7.90
Back vertex power (D)	Plano to ±30.00 (0.25 D steps)	+7.50 to +20.00 (0.50 D steps)	+23.00 to +32.00 (3.00 D steps)
Total diameter (mm)	11.20, 11.70, 12.20, 12.70, 13.20, 13.70	11.30, 12.50	11.30

the cornea. Another check is made 10min later and the final assessment is undertaken after at least 50–60min. Some contact lens practitioners advise verification of the lens fitting after a further 6h.[10,27] Lens modifications, such as polishing, blending and change of diameter and power are not possible and an accurate duplication of the lens edge is difficult.[17] Finally, the SRCL is expensive and only available in a limited range of powers and diameters (see *Table 3*).[19]

The Optimum Fit

The ideal fluorescein pattern shows an edge clearance of 0.5–0.75mm wide followed by a contact zone of 0.50–1.00mm (see *Figure 2*). An intermediate ring of fluorescein divides this zone from the central part which shows minimal apical clearance.[1,3,6,27]

It is important to assess tear exchange behind the lens because only peripheral tear exchange is possible owing to the impermeability of the lens to water. The lens needs to move 1mm with blinking[5] and the centration may be slightly inferior.[17,20] Finally, the over-refraction should be stable.[1,6,10,27]

The Steep Fit

A steep fit shows excessive clearance and sometimes even air bubbles are seen behind the lens (see *Figure 3*). There is minimal or no edge clearance and lens movement.

The Flat Fit

If the lens is too flat there will be excessive movement initially (see *Figure 4*). However, after some time the lens may become immobile with too much central touch and edge clearance. Fluorescein can only be introduced behind the lens by massage.

Adherence

Lens suction is only seen in steep fits,[26–28] or when a flat lens decentres and forms a steep fit on the sclera. Refojo[15] reported that lens suction can arise because of the high water vapour permeability of silicone rubber. Tear film vapour diffuses through the lens and evaporates at its surface (an effect known as pervaporation) which results in lens adherence. Lubricants can be instilled or a suction holder used to lift the edge of a lens which adheres to the cornea.

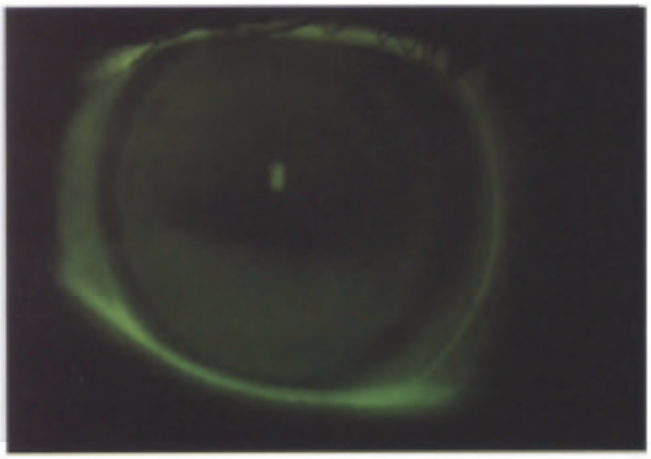

Figure 2. *Ideal fit of the silicone rubber contact lens.*

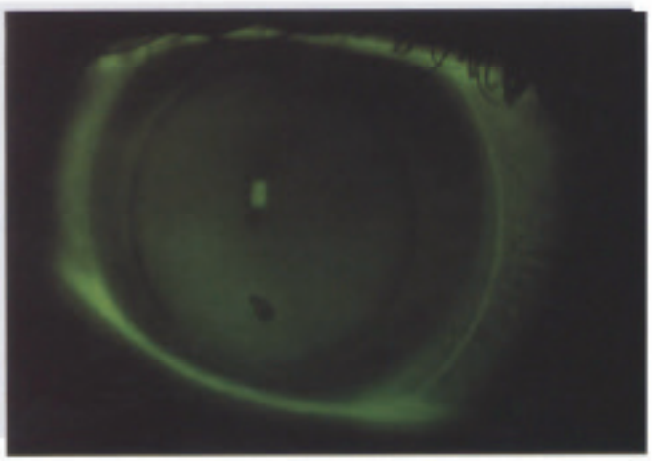

Figure 3. *Steep fitting silicone rubber contact lens.*

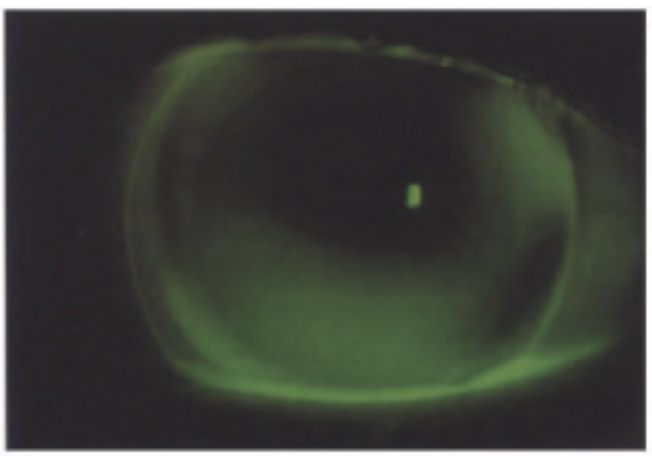

Figure 4. *Flat fitting silicone rubber contact lens.*

Lens Care and Handling

Silicone rubber lenses should be stored in a suitable rigid gas-permeable (RGP) lens solution.[4] The lens can be cleaned with a non-abrasive cleaning agent but the preservative chlorbutanol should be avoided. If there are mucus or lipid deposits on the lens, a cleaner that contains alcohol can be used.[2,14] Inserting and removing the lens can be performed in the same manner as for RGP lenses. If necessary, a suction holder can be used to insert the lens in children.

Indications for the Silicone Rubber Contact Lens

Paediatric Aphakia

Contact lenses are the preferred form of correction in aphakic children in their first years of life.[29,30] Early optical rehabilitation is essential to reduce the incidence of amblyopia, strabismus and poor fusion.[31]

Various authors have reported that the SRCL can be used successfully for extended wear by aphakic children because of the high oxygen permeability and low water content of the material.[4,11,14,27,29] As mentioned previously, the risk of complications is reduced by the fact that the SRCL does not absorb foreign substances and it is resistant to bacterial colonisation, a combination of properties which is shared by no other contact lens material. A further advantage of the SRCL is that topical medication can be used when this is necessary after cataract surgery.

In contrast with soft lenses, the SRCL can correct corneal astigmatism up to 2 dioptres which is an important advantage because astigmatism is often seen following cataract surgery. The visual acuity tends to be better with SRCLs than with soft lenses. Insertion and removal of the lenses in children compares favourably with RGPs.[9] Silicone lenses are smaller and less flexible than soft lenses which facilitates insertion and makes it unlikely that blinking or rubbing eyes will lead to accidental loss.[32] The foregoing considerations explain why the SRCL is the first choice of correction in young aphakics.[29] Some contact lens practitioners prefer to fit RGPs because they provide a better optical correction with astigmatism, cost less and are available in a wide range of materials and designs. RGPs are usually fitted for daily wear[19] and this constraint together with the fact that they need cleaning on a more regular basis are disadvantages in comparison with the SRCL.

During the first year of life, the infant patient needs to be followed up every 4 to 6 weeks and the lenses are cleaned at these visits. If cleaning is necessary between the visits, the parents are instructed to undertake this. Good cooperation with the parents is necessary to ensure compliance with good, hygienic care of the lenses.

Children of 1 to 5 years of age can be checked every 3 to 4 months. Mucus production increases with age so the lenses need to be cleaned more frequently, generally every 1 to 2 weeks. The need to change the specification of the lens and the problem of accidental loss of the lens can increase costs. Problems such as surface damage, changed fitting and loss necessitate replacement of the lens, the average rate being one SRCL every 8 months. Silicone lenses should be fitted as soon after the surgery as possible directly after the wound healing which occurs about 1 week after surgery.[29] Corneal curvature can be measured with a hand-held keratometer (see *Figure 5*). This information together with measurement of the axial length of the eye allows computation of the required back vertex power.[33] These procedures can, if necessary, be undertaken under anaesthesia. When these data are not available, retinoscopy can be used to determine the lens power. If keratometric readings are impossible to obtain, the fitting of the lens can be accomplished easily by observation of fluorescein pattern and lens movement.

Figure 5. *Keratometry with a hand-held keratometer.*

The power determined by computation or retinoscopy should be increased by 3 dioptres because the child's visual interest in the first few months of life is centred on a short distance from the eyes. During growth, this initial over-correction will be decreased. Bifocal glasses can be prescribed from the age of 18 months, but normally these will be worn successfully only from the age of 4 years.[29]

Aphakia in Adults

The SRCL is also indicated in aphakia in adults, that is, in senile aphakia or aphakia subsequent to trauma.[11,18,27] The lens can be used on an extended wear basis, for example, by manually handicapped patients because of the excellent oxygen transmissibility properties and the fact that both in open and closed eyelid circumstances the level of available oxygen is adequate.[11,18] Dahl and Brocks[18] found that the visual results, comfort and patient acceptance were good when the silicone lens was worn continuously. Nevertheless, mucus adhesion and dry spots on the lens surface occurred.

In aphakia following perforating trauma, the SRCL is the only option[11] because of its resistance to bacterial colonisation and the ability of the lens to correct irregular corneal shape.

The lenses can be fitted according to the technique previously described. The lenses need to be cleaned more regularly than with children if used for extended wear, because the higher mucus production in adults will contaminate the lenses more easily.

Dry Eyes

There are a great variety of dry eye conditions and depending upon the signs there are different modes of therapy. Soft lenses, scleral lenses and silicone lenses are used but sometimes all are contraindicated.

There are several reasons why the SRCL can be fitted in the dry-eye conditions. Firstly, extended wear is possible and, in contrast with the soft lens, dehydration is impossible which is beneficial for eyes with insufficient tears.[11,34–36] Secondly, lubricants and other topical therapeutics can be used during wearing whereas this is impossible with soft lenses owing to problems of absorption and binding. Since the silicone rubber is impermeable to water it helps to conserve the tear film.[7] This is an advantage in corneal exposure, for example, because the silicone lens can moisten the entire cornea (see *Figure 6*). The toughness of the material protects the cornea from eyelid or conjunctival irregularities.

Sometimes dry-eye is accompanied by conditions that can lead to a decrease in surface wetting because of corneal changes. Insufficient wetting of the cornea may result in epithelial defects and scarring with subsequent loss of vision.[37] In Stevens–Johnson syndrome, metaplasia as keratinisation of the cornea, can occur. The SRCL is indicated in these cases because of its rigidity but use of scleral lenses can also be successful.[34,37–39]

Figure 6. *Corneal exposure with a silicone rubber contact lens.*

Because of the dryness and consequent evaporation of tears, there is a higher risk of lens adherence which can be avoided by the use of lubricants. This condition necessitates frequent replacement of the lenses. In a study by Bacon *et al.*,[34] it appeared that with moderately dry eyes an average of 1.84 (range 0.8–2.4) lenses were used per year. With extremely dry eyes and poor wetting, this varied from 0.9 to 5.33 lenses per year with a mean value of 3.87.

Decompensated Corneas

An important use of the SRCL is in the condition of decompensated cornea which is sometimes caused by the wearing of other types of contact lenses. Corneas complicated by vascularisation and oedema need optimum physiological circumstances to achieve good corneal metabolism. Owing to its high oxygen permeability (*Dk*), lenses made from silicone rubber are very suitable for decreasing hypoxia.[10,34] The SRCL can be used to resolve corneal oedema and can arrest the process of vascularisation. Bacon *et al.* investigated 15 patients who had been fitted with the SRCL because of corneal decompensation and found that they needed a total of 2.54 lenses with a variation of 2.0 to 2.86 lenses per year on average. No serious complications were seen in these patients.[34]

Irregular Corneas

The SRCL is normally not the first lens choice in irregular corneas. However, because the lens maintains its shape it can provide a useful improvement in visual acuity when other lenses fail to provide a satisfactory result.[22,34,36]

Keratoconus patients can, for example, wear the lens successfully.[22,34] Many of these patients have an associated atopic constitution and since the lens does not absorb fluids this constitutes an advantage.

A maximum of 2 dioptres of astigmatism can be corrected with a spherical SRCL (toric designs are not available). Bacon *et al.*[34] advised fitting the lens tightly but lens adherence must be avoided.

Eyelid Defects

Several eyelid disorders such as trichiasis and scarring can be followed by the development of corneal erosions. Compared with a soft lens, the SRCL provides better corneal protection in these cases because of its rigid qualities.[10,11,34] The material is also very suitable because of its elastic properties. During blinking the lens can deform as a result of the deviant eyelids but after blinking the lens will return in its original shape (see *Figure 7*). The lens may even stay in the eye

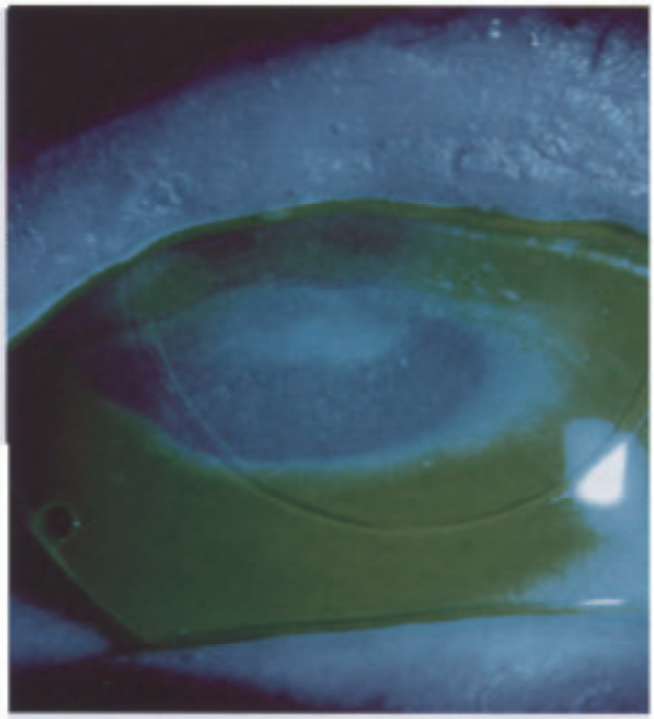

Figure 7. *Deformation of the silicone rubber contact lens during blinking.*

despite a considerable shortening of the fornix as in symblepharon[34] whereas a rigid lens would be displaced from the eye by blinking. Unfortunately, in this condition the lens will need to be replaced regularly because the surface of the lens can be easily damaged. The occurrence of hydrophobic regions on the lens encourages the formations of deposits.

Ulcers and Perforations

The SRCL can be fitted in patients with corneal defects such as ulcers and perforations.[7,11,24] Resistance of the material against fungus and bacterial colonisation protects damaged eyes that are vulnerable to infection or re-infection. In epithelial wound healing, the SRCL has the advantage that it can be left in place, thus avoiding the disruption of recently healed cornea which would be caused by the removal of other types of lens. Fluorescein can be instilled behind the SRCL in order to examine the cornea whereas it would be necessary to remove a soft lens to carry out such an examination. The relatively rigid nature of the SRCL encourages reformation of the anterior chamber following corneal perforation.[4,7,24] For this purpose, the flattest available SRCL should be inserted first. As the perforation seals and the anterior chamber reforms, the lens becomes flat and must be exchanged for a steeper fitting.

Summary

Silicone rubber has been used as a contact lens material for more than 20 years because of its unique physical properties. These properties allow the SRCL to be used successfully in the following conditions:

Aphakia in infants and children
Aphakia in adults
Decompensated cornea
Dry eye
Irregular cornea
Corneal ulcers and perforation
Eyelid defects

A sound fitting technique is necessary in order to avoid lens-induced complications. Problems such as affinity for mucus deposits, loss of its hydrophilic surface character and high cost have limited the more widespread use of the silicone rubber lens.

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