Ocular prostheses and contact lenses. II—Contact lenses

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Although public awareness of contact lenses seems to be increasing, the number of people wearing them remains uncertain. A population survey in 1988 indicated that about 4% of the population of the United Kingdom aged between 16 and 60 were wearing lenses regularly—that is, about 2.32 million people. Most wearers have lenses for cosmetic reasons; they are usually people with mild ametropia who prefer not to wear spectacles.

A smaller number of people are unable to attain satisfactory vision with glasses and can see adequately only with the aid of contact lenses. This group tends to be managed from hospital contact lens units and includes people with the following conditions:

- **Severe ametropia**—In very long or short sighted people spectacles may be mechanically and optically unacceptable
- **Severe anisometropia**—Patients would experience intolerable aniseikonia with glasses. This group includes patients with unilateral aphakia
- **Severe regular astigmatism**—Patients experience disorientation and visual distortion with spectacles. The group includes patients with residual postoperative astigmatism, such as may occur after corneal transplantation
- **Irregular astigmatism**—In patients with this condition chaotic unevenness of the anterior corneal surface causes distortion of the ocular image. A rigid contact lens presents a smooth spherical anterior surface and the irregularity of the corneal surface behind the lens is filled in with tears. The lens may also mechanically flatten a thinned and distorted cornea. Patients with corneal ectasias, such as keratoconus, and corneal scarring fall into this category, as do some who have had corneal transplantation.

In addition, some people wear coloured lenses to disguise damaged and unsightly eyes. Corneoscleral, hard corneal, and soft lenses can have a hand painted pattern laminated into their substance. Soft lenses can also be made with a printed coloured pattern or with a homogeneous tint; both tend to sacrifice realism for economy. All such lenses may be powered for vision if required. Finally, therapeutic lenses may be needed to protect a diseased ocular surface.

Types of contact lenses

SCLERAL LENSES

Contact lenses were first clinically described by Fick in 1888¹ and Muller in 1889.² These early corneoscleral shells and lenses were blown in glass: a central lens vaulted the cornea and the peripheral skirt was supported by the sclera. The modern equivalents of these "scleral" or "haptic" lenses were made possible by the discovery of Perspex in 1934. Even though tear exchange behind such lenses can be facilitated by fenestrations, channels, or slots (fig 1), considerable hypoxic and metabolic stresses are placed on the cornea, which usually result in changes such as peripheral vascularisation and endothelial cell abnormality in the long term. Scleral lenses are nevertheless invaluable for managing extreme degrees of ametropia and astigmatism that cannot be corrected with corneal

FIG 1—Scleral lens with fenestration at top to aid tear flow under lens

lenses. Their large size makes for easy handling, which can benefit people with poor dexterity. Furthermore, recent experiments in their manufacture with modern gas permeable materials promises a much wider application in the future. Because of the special skills needed to make scleral lenses, the time involved, and the consequent high cost they are rarely fitted except in a few hospital contact lens units.

PERSPEX HARD LENSES

The lenses commonly in use today are described as hard corneal (hard, rigid) or soft (fig 2). The first hard lens was introduced in 1947 and was later developed into corneal microlenses of up to 9.5 mm in diameter.

FIG 2—Types of contact lenses. From left to right: scleral, Perspex (rigid), hydrogel (soft), and gas permeable rigid lenses

This type of lens was made from Perspex and continues to be used today in various modified forms. Perspex has a negligible maximum water content of 0.2% to 0.4% and is virtually impermeable to oxygen. Gas exchange with the corneal epithelium is therefore dependent on tears flowing behind the lens. To ensure that the central corneal surface is adequately supplied with oxygen the lens must be made quite small. Its posterior surface is formed into a curve, which allows good movement on the cornea and encourages tear exchange.

SOFT LENSES

Because Perspex lenses can be difficult to fit and may not be well tolerated the introduction of the hydrogel soft lens in the late 1960s represented an important

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advance (fig 3). The first lenses were made from polyhydroxyethylmethacrylate, although their modern descendants are cross linked with other compounds to improve their physical properties. The water content of soft lenses varies from 35% to 80%.

FIG 3—Hydrogel lens flexed between finger and thumb

Soft lenses are cheaper to produce and are much easier to fit than Perspex or gas permeable hard ones; they are comfortable from the start, and, because the user does not need to build up tolerance to them, they can be useful for occasional wear. On the debit side they are costly: they tend to be relatively expensive to buy, and they usually require more money to be spent on solutions to care for them than do other lenses. They are far less durable than rigid lenses and require much more frequent replacement. A good life for a soft lens in daily use and disinfected by chemical means might be 12 to 18 months. Lenses that are disinfected by heat may last as little as six months.

Unlike a rigid lens, which can nullify some degree of corneal astigmatism by presenting a spherical surface to the atmosphere, a soft lens wraps on to the cornea and conforms to its curvature. Ordinary soft lenses are therefore unable to correct more than a little corneal astigmatism. Soft lenses with toric anterior surfaces can be fitted to people with astigmatism (fig 4) but they are expensive and may not always provide stable vision because of their tendency to rotate on the eye. To stabilise them they may have to be ballasted, and this can produce a thick inferior edge. The lower part of the cornea can then become starved of oxygen with consequent vascularisation. Very thick lenses, which do not follow fine irregularities of the corneal surface well, can be used to correct the irregular astigmatism of keratoconus and scarring, but they induce substantial

FIG 4—Toric hydrogel lens on eye, truncated at inferior edge to prevent excessive rotation

metabolic stresses and consequently enhance the hazards of long term wear.

Because they are permeable to oxygen, soft lenses can be made much larger than rigid Perspex ones: typically 12.5 mm or more in diameter. A large lens gives better vision than a small one as it centres well and can have a large optical zone. The larger lens is also more comfortable because it is less mobile and its edges are behind the lid margins and so do not impact on them during blinking. Unfortunately, the long circumference tends to irritate the tarsal conjunctiva and the high surface area maximises the deposition of potentially antigenic deposits.

GAS PERMEABLE LENSES

The problems of correcting astigmatism with soft lenses led manufacturers to seek other gas permeable materials that would combine the advantages of both Perspex and polyhydroxyethylmethacrylate; both the mechanical rigidity of the hard lens and the gas permeability of the soft one were important. The first hard gas permeable material used was cellulose acetate butyrate in 1937. Unfortunately, the optical quality was poor and the material fell into disuse until the 1970s, when incentive and improved manufacturing techniques produced a renewed surge of interest. Cellulose acetate butyrate has a maximum water content of only 2.2%, and, like other hard gas permeable materials, it therefore depends on its chemical structure to pass oxygen across its molecular lattice-work. More modern materials, which incorporate substances such as silicone and fluorine into their structure, now easily outperform soft lenses in their ability to transmit oxygen, and gas permeable devices (fig 5) are therefore less apt to induce metabolic stresses than are hydrogels.

FIG 5—Rigid gas permeable lens on eye. Lens is engraved R to help wearer distinguish it from left one

As the surface area is smaller than for a soft lens and the tendency of most hard gas permeable materials to attract deposits is less than that of hydrogels the risk of deposit related problems is reduced. Because it is gas permeable a larger lens can be tolerated than if the lens was made of Perspex. The movement of the lens and its impact velocity on the lid edge is therefore less than for a small hard lens, making the gas permeable lens more comfortable.

Although they are not as rigid as Perspex lenses, hard gas permeable lenses are sufficiently inflexible to correct similar degrees of corneal astigmatism. These modern lenses still require expensive solutions to maintain them but cost less to run than soft lenses. Gas permeable lenses are softer and therefore more easily damaged than Perspex ones, but they can still give up to two years of service before microscopic structural changes occur because of mechanical and chemical degradation.

In a comparison of instantaneous comfort the soft

lens wins and may be tolerated for a full day's wear from the start. In contrast, to reach a continuous wear time of 10 hours with a Perspex lens may take several weeks of gradually increasing the number of hours during which the lens is worn each day. With a highly gas permeable lens the same wear time can often be achieved in five days.

Another lens material, which lies between the hard and soft groups, is silicone rubber. This has a high gas permeability, and its optical properties are excellent. Being soft yet containing no water, it may be suitable for fitting to relatively tear deficient eyes. Its surface is hydrophobic, however, and the lenses have a tendency to collect deposits badly despite attempts to reduce this by surface coating; this has limited their use to special applications in hospital contact lens units.

Care of contact lenses

Lenses worn only during the waking hours are cleaned and disinfected after removal every day. The cleaning process removes the environment derived and tear related deposits and breaks down the microbial biofilm, which collect during wear. Both surfaces are treated with a special fluid, which is usually specific to each type of lens material (fig 6). The cleaning solution

FIG 6—Selection of contact lens care solutions

should then be rinsed off before the lenses are soaked overnight in fresh disinfecting solution. This is because the cleaning solution can reduce the effectiveness of the disinfectant. The lenses may be rinsed again before being reinserted. Users of rigid lenses may prefer to apply a viscous cushioning solution (known as a wetting solution) to their lenses immediately before placing them on their eyes. Only sterile isotonic saline sold in pressurised canisters must be used to rinse soft lenses. (Sterile isotonic saline is also available in unit dose sachets, but these are less convenient and economical.)

It is probably expedient to rinse cleaning fluid off rigid lenses with rising main tap water (depending on its quality) as they will subsequently be placed in a disinfecting solution, but plain tap water must not be applied to the lenses after they have been disinfected. If tap water is used between the cleaning and disinfecting processes it may be wise to rinse this off with a brief application of sterile saline or freshly boiled and cooled tap water. Soft lenses may be disinfected by heat, which saves on solutions but shortens the life of the lens and tends to make protein deposits more difficult to remove.

Among the alternative cold chemical solutions, 3% hydrogen peroxide is probably the most effective. Contrary to some manufacturers' current recommendations, however, it is still necessary to clean the lenses before disinfection. Also, although a 10 minute disinfection cycle may be specified in the instructions, a soaking time of at least two hours is now known to

be necessary to effectively eliminate *acanthamoeba* trophozoites and cysts (R E Silvany *et al*, Contact Lens Association of Ophthalmologists and International Society of Refractive Keratoplasty annual meeting, New Orleans, 1989) and overnight soaking is recommended. Only hydrogen peroxide solutions that are specifically formulated for contact lenses must be used, and solutions must be neutralised with the additional unit dose unpreserved solutions provided before the lenses are reworn. The system that uses a platinum disc to catalyse the degradation of the peroxide during the disinfection process cannot be recommended because it has inadequate antiacanthamoebal activity.

Almost all soft lens wearers, and some wearers of gas permeable lenses, will need to treat their lenses with proteolytic enzymes every few weeks. Protein removal is carried out as an extra stage after cleaning the lenses and before disinfecting them. The enzyme tablets are dissolved in sterile isotonic saline, and the lenses are soaked for a period which varies according to the type of lens and the particular enzymatic product. It is best to clean and rinse the lenses again afterwards, before disinfecting them, as the enzymes may only loosen the deposits and a mechanical action is desirable to complete their removal.

Every lens case must be cleaned weekly with hot water and a small brush, such as a toothbrush intended for children. Soap and detergents should not be used. After rinsing with rising main tap water the case should be shaken to remove surplus water, its outside blotted with a tissue, and then left to air dry before its next use. Cases should be discarded and replaced as soon as they have become discoloured or deposited, or whenever the lenses are renewed. Because of the nature and sources of contact lens related keratitis, ornate and expensive permanent lens cases should not be used unless they have a replaceable inner component. No regimen for the extended wear (see glossary) of lenses can yet be said to be satisfactory.

Risks of lenses

Contact lenses are foreign bodies on the eye and may induce changes that can be sight threatening. Many studies have examined the complications associated with specific lens types and some have compared the risks of wearing different sorts of lenses. Few attempts have been made to determine the size of the problem of contact lens associated eye disease in a community, however, although a long term prospective study of people who wear cosmetic lenses is currently under way at Moorfields Eye Hospital.

Daily wear rigid lenses have been found to be the safest type and extended wear soft ones the most dangerous.^{3,6} Schein *et al* showed that people who wear extended wear soft lenses day and night have as much as a 15 times higher risk of suppurative keratitis than do people who wear daily wear soft lenses only during the waking hours.⁴ Furthermore, they also found that, for users of extended wear lenses, the risk of suppuration was incrementally related to the number of nights over which the lenses were worn. This indicates that the predisposing factors to suppuration are cumulative. If physiological stress is involved it would seem that the eye is being progressively compromised without the opportunity for recovery. Extended wear of soft lenses seems to carry a 21 times greater risk of microbial keratitis compared with the daily wear of gas permeable rigid lenses.⁷

Although the exact amount of oxygen that the cornea requires to prevent measurable changes in its characteristics⁸ (the critical oxygen requirement) is still debated,⁹ clearly no hydrogel lens can meet these metabolic needs. Though some gas permeable materials

show greater promise in this respect, the extended wear of contact lenses is presently dangerous, and its practice for cosmetic use cannot be condoned.

Perhaps we will one day have sufficient understanding of the adverse mechanisms and the technology appropriate for overcoming them, for the risks of extended wear to be reduced to those of daily wear. Until then overnight wear of soft lenses can be justified only in three instances. The first is for people who have a medical need for contact lenses but are unable to handle them. These include infants and some elderly people with aphakia and people with some specific disabilities. The second is for people who require therapeutic lenses for corneal disorders; but the danger of supplementing their disorder with an even more devastating one must be carefully considered. The third is for people in hostile environments where it is deemed that removing the lenses for cleaning and disinfection is likely to be more hazardous than leaving them in place. Such people will usually need to wear their lenses for only a few nights before returning to daily wear. Only the last group is likely to present to high street optometric practices; the others should always be treated in hospital. All other patients should wear lenses only during waking hours.

Disposable soft contact lenses have recently been introduced. They are priced to be competitive for extended wear for periods of one to two weeks. Although they are claimed to promote eye health by eliminating the complications associated with lens deposition and reactions to lens care solutions, they are unlikely to be superior to reusable lenses in any other respect.¹⁰ Alarming numbers of cases of suppurative keratitis are now being reported in association with disposable lenses, and practitioners should be aware that their use cannot be assumed to be beneficial until the results of proper epidemiological studies are available.

Overall, those who wish to wear their lenses for many hours on most days of the week should be fitted in a gas permeable rigid material, if possible. Daily wear soft lenses should be reserved for people who have only an occasional need for their lenses, who prove to be intolerant of rigid ones, or who have needs which cannot be met by rigid lenses.

Successful contact lens wear requires scrupulous attention to detail. The users must understand that it is vital that they conform to the recommended maintenance and wear regimens for the types of lens that they have. Complications are common, but it is unusual for serious disease to arise when lenses are used responsibly.

Most complications of contact lenses are self limiting if the lens is removed at the first hint of trouble. All wearers must be counselled to remove their lenses immediately and seek professional advice if they experience ocular pain, red eye, or visual loss. Topical drug treatment must not be instituted without removal of the lens, and topical steroids must not be used except in specialist centres.

Contact lens practitioners should routinely give thorough instructions to patients on the proper handling and care of their lenses and should back this advice up with written information. Routine progress checks are important to detect the more covert problems at an early stage. Twice yearly examinations are recommended for full time wearers of soft lenses and annual examinations for those with rigid lenses.

Glossary

Ametropia—A condition in which there is some error of refraction in consequence of which parallel rays, with the eyes' accommodation at rest, are not focused on the retina. May refer to myopia (short sight) or to hyperopia (long sight).

Anisometropia—A difference in the power of refraction of the two eyes.

Aniseikonia—A relative difference in the size or shape of the images in the two eyes. Small differences can be tolerated by cerebral adaptation, but an image size difference of more than 10% will almost certainly result in double vision.

Aphakia—Absence of the crystalline lens, or a lens implant, after surgery for cataract. (If an implant lens is inserted the eye is said to be pseudophakic.)

Astigmatism—A condition of unequal curvatures along the different meridians at one or more of the refractive surfaces of the eye (here, that of the anterior cornea), in consequence of which the rays from a luminous point are not focused at a single point on the retina but are spread out as a line in one or another direction. Thus, if the person were viewing a cross the image of only one of the two arms could be focused on the retina at a time; the other would be focused in front or behind it, and would therefore appear blurred.

Regular astigmatism—The curvatures in each meridian are of different radii but follow the normal topography of the surface.

Irregular astigmatism—The radii of curvatures vary randomly because the surface is uneven.

Daily wear—The lenses are worn only during the waking hours and are removed before sleep.

Extended wear—The continuous wear of contact lenses throughout the waking and sleeping hours, without interruption.

Toric—Relating to, or having the curvature of, a torus (see below).

Torus—A geometrical figure formed by the revolution of a circle round the base of any of its arcs. The result is a smoothly contoured surface that has different radii of curvature in different meridians. In the case of a refractive surface such as the anterior surface of the cornea, the refractive power will be greatest for light incident perpendicular to the meridian of greatest curvature (smallest radius of curvature), and least for light falling perpendicular to the meridian of least curvature (largest radius of curvature).

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Update box for *Oxford Handbook of Clinical Medicine* (2nd ed), p 346

Breath activated inhalers¹

Terbutaline is now available in a breath activated inhaler device (Turbohaler). Such devices are easier to use than ordinary inhalers as coordination of inspiration with device activation is not required. Each inhalation of terbutaline through the Turbohaler gives a dose of 500 µg. There are no propellants, lubricants, preservatives, or other additives. The cost at £17.88 per 200 doses is about twice that of a traditional refill canister of terbutaline. However, this apparent price differential may be substantially mitigated because Turbohalers contain no fluorocarbons to deplete the ozone layer.

The steroid budesonide is now also available in a Turbohaler. — J M LONGMORE

Principal source

1 Corticosteroids in asthma. *Drug Ther Bull* 1990;28:45-6.

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