Extended Wear Silicone Contact Lenses in the Correction of Aphakia

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Editor's Note

The following paper is one of several submitted to the CJO by Dr. M. Callender, School of Optometry, University of Waterloo. Written by students in one of his final-year classes, each represents a considerable amount of research and preparatory work in readying the paper for final submission. The editors of the CJO are pleased to present the first of what we hope will be regular submissions by graduating students and their instructors.

Introduction

The increasing number of elderly people in our population has been accompanied by a corresponding increase in the number of aphakic patients. Fortunately, the eye care field has seen a rapid increase in the options available for the visual correction of this group.

The purpose of this paper is to briefly review these options with particular emphasis on the use of extended wear contact lenses for the correction of aphakia. The major portion of this paper will concern itself with the use of silicone lenses on an extended wear basis.

Options Available For The Treatment of Aphakia

A variety of ophthalmic devices and surgical procedures exist for the visual correction of the aphakic patient. These include spectacle lenses of various designs, hard contact lenses with different amounts of oxygen transmissibility, soft contact lenses representing a variety of hydrogel polymers and water contents and several flexible silicone lenses. Surgical implantation of intraocular lenses is also an alternative. Naturally, all of these methods have both advantages and disadvantages.

Spectacles were the earliest form of correction, but their disadvantages are numerous. Lens thickness and magnification properties of the lens on the eye can be unsightly. Magnification may be increased 25 percent compared to the normal eye, resulting in spatial disorientation and distortions. In the unilaterally aphakic patient, image size differences between the two eyes eliminate the use of binocular vision. Field limitations such as reduced field of view are a problem with some lens designs. Prismatic effect produces the jack-in-the-box phenomenon and ring scotoma. Other disadvantages include aberrations (eg. pin cushion effect), fluctuating vision caused by changes in vertex distance, fusion problems, aniseikonia and anisophoria. Needless to say, adaptation to such changes can be difficult and frustrating.[1,4,10,18]

When compared to spectacles, contact lenses have several advantages. These include reduced magnification to levels of 5-10 percent, reduction or elimination of spatial distortion, visual fields that are nearly full, elimination of prismatic effects, good binocular vision and stereopsis and better single vision for the unilateral aphakic patient. Cosmesis and comfort (in terms of reduced weight) are greatly improved.[10,18] The disadvantages of daily wear contact lenses are primarily related to the type of patient who undergoes cataract surgery. Both the elderly and very young children are often unable to fulfill the requirements of lens handling, insertion, removal and daily maintenance. Other problems include frequent lens loss and damage, lens discoloration with hydrogel lenses and lens intolerance.[10,16,18]

Intraocular lens implants were initially thought to offer the ideal solution to the problem of aphakic correction. They seemed to possess all of the advantages of contact lenses, but required no handling or maintenance. There has been a marked increase in the number of ophthalmologists who are employing implant techniques with greater frequency. Boyd and Roper-Hall state that, during a two year period, 6000 surgeons implanted 260,000 lenses in 3000 U.S. hospitals.[5] However, good success with lens implants is directly related to good microsurgery techniques. Known complications include secondary infections, iritis and iris degeneration, eventual dislodging of the implant and corneal edema due to irreparable endothelial cell damage.[1,15] Although the utilization of intraocular lens implants will probably increase as techniques improve, this option is at present usually reserved for the elderly, for those patients

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unsuitable for contact lenses and for unilateral aphakics with no internal ocular pathology.[1]

For those patients with contraindications to intraocular lens implants who lack the ability to handle daily wear contact lenses, the extended wear contact lens may be the ideal solution.

Extended Wear Contact Lenses and Corneal Physiology

The minimum corneal oxygen need varies between 2-5 percent (equivalent atmospheric) depending upon the individual.[11] Current contact lens philosophy suggests that the cornea recovers during the evening from the stress of contact lens wear during the day. By comparison, extended wear contact lenses are thought to perform so well under open eye conditions that they allow the cornea to recover from the oxygen deprivation experienced while the lids are closed during sleep.[3] Corneal metabolism is affected during sleep by a drop in available oxygen from a PO2 of 155mmHg to 55mmHg, a decrease in tear osmolarity and an increase in tear acidity and corneal temperature.[3,12] The latter causes an increase in oxygen consumption. Reduced pH and tear osmolarity contribute to corneal edema.[3]

Thus, a lens which is suitable for extended wear must allow the passage of sufficient oxygen, especially when the lids are closed, to permit normal corneal physiology. The concept of prolonged lens wear was introduced in the early 1970's when John DeCarlé used an experimental hydrogel polymer to create the Permalens.[9] The oxygen permeability (DK value) of hydrogels is dependant on the water content of the material. The ability of a given lens to supply oxygen to the cornea is called its transmissibility (T) and is a function of both the permeability and the thickness (L) of the lens material (T=DK/L).[12] Since the design of a high plus lens requires a significant center thickness, a hydrophilic aphakic contact lens must rely on a high permeability (and thus a high water content) to provide an adequate corneal oxygen supply.[12]

Unfortunately, this high water content renders the hydrophilic lens very fragile and susceptible to deposits. Although longer lens life due to reduced handling is a theoretical advantage of extended wear lenses, high water content lenses are actually subject to loss, breakage, tearing and discoloration. Lens deposits are also a problem, the most common being lipid, calcium, protein and lysozyme.[3,7] Despite the high DK values exhibited by these lenses, the thickness required for adequate durability and ease of handling reduces their transmissibility to levels where anoxic syndrome can be present under extended wear conditions. This syndrome includes combinations of pain, photophobia, severe conjunctival injection, obvious edema, corneal striae and epithelial punctate staining. These problems which are associated with extended wear hydrogel lenses have encouraged the search for more suitable lens materials, one of which is silicone.

Advantages of the Silicone Lens

Silicone is physiologically inert and biologically and chemically neutral.[10] It has the highest permeability of all of the currently available contact lens materials (DK=600 x 10^{-11} (cm^2/sec) (m10/m1xmmHg)), and this permeability is not significantly affected by lens thickness.[2,8] Silicone transmits oxygen freely (16-18% equivalent 0_2 transmission for the Danker lens; 18.7% equivalent 0_2 transmission for the Dow Corning Silsoft) thus reducing corneal anoxia and edema.[2,8] This oxygen transmission is approximately 37 to 40 times greater than hydrophilic material of equivalent thickness and average hydration (40% H_20).[2] The difference is less when the hydrogel lens is very thin or of high water content but, as previously mentioned, such a lens then becomes more fragile and difficult to handle. When compared to hydrogel and non gas permeable hard lenses, silicone lenses have been found to produce a reduced corneal consumption of glycogen and a reduced corneal production of lactic acid.[1] Changes in corneal curvature and spectacle blur are rarely produced by this lens.[2,10]

Silicone has a higher tensile strength than hydrogel materials and thus provides the durability required in extended wear applications.[2] Silicone also has a high thermal conductivity. Compared to PMMA, silicone dissipates corneal surface heat more rapidly, thus reducing metabolic requirements for oxygen.[2,14]

Silicone is a material with near zero water content. For example, the polydimethyl siloxane used in the Danker lens has a percent of hydration less than 0.3.[10] Thus water and chemical substances are not absorbed into the lens. A wide variety of highly effective antibacterial and cleaning agents may be used and washed off the lens prior to insertion. Fluorescein may be used as a fitting aid.[2,10] Topical medication may be used without concern for excessive accumulation of the drug within the lens.[2,16]

Optical clarity is stable as compared to the fluctuations which may occur with a hydrogel lens.[2] Visual acuity is generally better since all manifest astigmatism in the aphakic is corneal and, if not too excessive, is thus nearly completely neutralized by the tear lens.[1,14]

In summary, the silicone elastomers provide the strength and durability of PMMA and thick low water content hydrogels and the oxygen permeability of ultra-thin or high water content hydrogels.

Disadvantages of the Silicone Lens

Silicone is not without its disadvantages. Pure silicone is hydrophobic, thus producing a lens which is uncomfortable and has a poor optical surface.[14] Two processes are available to render the lens hydrophilic. The first consists of a chemical modification of the surface which substitutes hydrophilic hydroxyl (OH) groups for some of the hydrophobic methyl (CH_3) groups.[6] However, this coating tends to break down in 12 to 72 weeks for the Danker lens and recoating does not give satisfactory results.[1,10] Molecular grafting with a hydrophilic substance such as vinyl has also produced a coat which eventually breaks down.[1,10] The second method involves copolymerization with other materials such as PMMA or CAB (eg. the Boston and Polycon lenses).[10] However, this defeats the purpose of extended wear since oxygen permeability is significantly reduced.

The mechanical properties of silicone make its manufacture difficult. Lens modification is not possible and exact duplication is not always satisfactory.[1,10]

Silicone is susceptible to protein, lipid and mucus deposits which reduce wettability, visual acuity, comfort and gas permeability.[1,7,8,13] However, these deposits are more easily eliminated than with hydrogel lenses and use of both a surfactant and an enzyme cleaner is recommended.[1]

Prior to adaptation, silicone lenses are less comfortable than HEMA but more comfortable than PMMA.[8,14] Adaptation is rapid however. Voerste (1978) reported that patients who changed from gel lenses to silicone lenses became the most enthusiastic wearers after overcoming their initial skepticism during the first week.[8]

Despite the fact that the silicone lens is extremely permeable to oxygen, lens movement is required for continual wetting of the cornea and the removal of metabolic by-products and cellular debris.[3,14] Loss of lens movement has been one of the major problems associated with this lens. It has been hypothesized that the elastic character of the silicone lens can produce a one-way valving system. Blinking compresses the lens against the cornea and tears are forced from beneath the lens. As the lid retracts, the pressure is removed from the lens surface, permitting the peripheral portion of the lens to exert its elastic character and close like a valve, thus obstructing the inflow of tears.[7,14] A proper fit and prompt follow-up visits are essential in order to ensure continual lens movement.

Fitting Philosophy

The examination and contact lens fitting of the aphakic patient is a specialized domain whose description is beyond the scope of this paper. A brief summary follows. Fitting is usually not attempted until at least 4 weeks after surgery in order to allow time for wound healing and to prevent the rupture of fine vessels around the iridectomy site and the posterior surface of the corneal section.[12] Generally, eyes that have undergone phakoemulsification heal faster and may be ready for contact lens fitting 4 to 6 weeks after surgery.[12] Intracapsular lens extraction may require up to 12 weeks for complete healing.[12] Fitting and power determination should not be attempted until the subjective refraction, the retinoscopic refraction and the keratometer readings have stabilized.[10,12]

In addition to the usual contraindications to contact lens wear, the aphakic must be evaluated for certain problems such as incomplete postoperative healing, structural abnormalities of the lids, poor patient hygiene or lack of cooperation for follow-up visits and the inability to remove the lenses in case of emergency.[12,14]

The special considerations involved in the fitting of silicone contact lenses are due to the previously mentioned problems with loss of lens movement on the cornea. Morgan states that the rule of thumb is to use the flattest base curve that produces reasonable centration and gives stable vision. He states that this is usually accomplished by fitting on low K.[14] Both Kaye and Bernstein suggest starting with a base curve at least 0.50 to 1.00 D. steeper than the flattest corneal meridian, depending upon the amount of corneal cylinder.[2,10] They both mention that a trial lens set is essential for the fitting procedure. An optimum fit allows a 0.5 to 1.0 mm excursion upon blinking.[2,10,14] The fluorescein pattern should show adequate tear flow centrally and under the peripheral curves. Perfect centration is rare due to lens weight and corneal topography, and a low riding position is normal.[2,10]

Conclusion

The silicone lens is a viable alternative when an extended wear contact lens has been judged to be the best solution for the aphakic patient. According to Hales, this is especially true in the pediatric aphakic group because most surgeons are reluctant to implant a lens in an infant or small child and because children have trouble handling contact lenses.[7]

The two major problems associated with the silicone lens are the occasional loss of lens movement on the cornea and the deterioration of the hydrophilic lens surface. The loss of lens movement can be prevented by a proper fit and conscientious follow-up care. As for the breakdown of the lens surface, further research and development will hopefully solve this problem.

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