A search for the phrase "myopia surgery" yields more than 120,000 results, mostly about LASIK. A search for "presbyopia surgery" returns more than 72,000 results, ranging from monovision cataract surgery to sheer quackery. At present, a surgical procedure capable of restoring youthful accommodation to the crystalline lens of a presbyope does not exist. Both corneal and lens-based approaches have been attempted, but none has emerged as a clear solution to presbyopia. Current techniques for presbyopia correction can be divided into four categories based on mechanism of action: (1) monovision, or the creation of myopia in one eye through surgery or with a contact lens; (2) procedures that attempt to restore physiologic accommodation of the crystalline lens; (3) corneal and pseudophakic procedures that try to create new accommodative mechanisms; and (4) procedures that use optics to provide a pinhole effect or multifocality in one eye.

MONOVISION
Monovision is a strategy used to compensate for presbyopia by correcting one eye for distance vision and the other for reading with contact lenses or as an adjunct to cataract or refractive surgery. It is the most common and perhaps the least controversial technique for presbyopia correction. Monovision can result in near-normal visual function at both distance and near. However, not all patients tolerate monovision. Distance vision is decreased in the monovision eye, and there is some loss of binocular visual function, which can cause a slight decrease in depth perception. Because the monovision eye is made myopic, patients may experience problems with driving, particularly at night. Others may find that it does not provide adequate near vision.

Contrary to popular belief, the dominant eye is not necessarily the one that should be used for distance vision. Rather, the patient’s dominant activity determines where to set the focus of the dominant eye. For example, because I spend most of my day at a computer, I wear my monovision lens in my dominant eye.

RESTORATION OF ACCOMMODATION
To date, restoration of physiologic accommodation has not met with much success. Two general approaches have been tried: (1) increasing the volume of the anterior segment and (2) softening the lens to allow it to flex better.

The first approach is based on the theory promoted by Ronald Schachar, MD, PhD, stating that decreased accommodation is due in part to the increased size of the crystalline lens occurring with aging. A series of procedures have been attempted using lasers and scleral bands to provide more room for the lens to accommodate. Some successes have been reported; however, complications have precluded these procedures from receiving widespread acceptance.

Softening the crystalline lens with the femtosecond laser has also been tried. Early donor-eye studies suggest that this laser can be used to soften the lens, which may delay onset of presbyopia. Human studies are in the early stages, but this technique may be redirected toward laser-assisted cataract surgery rather than presbyopia correction.

This approach is based on the Helmholtz theory of accommodation, which was accepted nearly without challenge until recent times. In the 1860s, Hermann von Helmholtz, MD, described accommodation as the result of an increase in the curvature of the anterior crystalline lens surface that occurs through the release of zonular tension when the ciliary body contracts, causing an increase in the refractive power of the lens. Dr. Schachar challenged Helmholtz’s theory, claiming that as lens size increases with age, anterior segment crowding affects accommodation. Results from some scleral expansion procedures suggest

**TAKE-HOME MESSAGE**
- Presbyopia correction techniques fall into one of four categories based on mechanism of action.
- Spectacles remain the most common method of presbyopic correction.
- A definitive solution for presbyopia remains elusive.
that this theory may have some merit.1

Recent imaging methods such as high-resolution anterior segment ultrasonography, optical coherence tomography, and Scheimpflug imaging show that accommodation also involves anterior movement of the crystalline lens and a shift in the refractive power of the eye. The forward movement likely results from increased vitreous pressure caused by ciliary body contraction. This mechanism has been well documented, particularly in phakic IOL studies where IOL-lens touch is a concern.4

An integration of these theories summarizes our current understanding of physiologic accommodation of the crystalline lens. All of these mechanisms likely play a role and may give rise to surgical techniques for presbyopia correction.

NEW ACCOMMODATIVE MECHANISMS

There have been efforts to create new accommodative mechanisms on the cornea and the lens. Several publications have described changes in corneal shape occurring with accommodation.5 These reports are contradictory, and some suggest that the corneal changes that occur work against improving near vision.

Lens-based procedures include a variety of designs for accommodating lenses. To date, the CrystaLens (Bausch & Lomb, Rochester, New York) is the only IOL that has received US Food and Drug Administration (FDA) approval with labeling for accommodation. The CrystaLens design is based on forward movement of the lens due to increased vitreous pressure during accommodation. The lens has the advantage of being a monofocal optic, thus avoiding the side effects of multifocal lenses. However, the accommodative range was limited to approximately 1.50 D in the FDA trial.6 The Tetraflex IOL (Lenstec, Inc., St. Petersburg, Florida) is being evaluated in clinical trials for FDA approval and is approved for use in Europe, the Middle East, and other markets. Early reports suggest that this lens also has a limited accommodative range.7

Other IOLs with clever designs that attempt to effect a power change are currently being evaluated, such as the NuLens8 (Nulens, Ltd, Herzliya Pituah, Israel), which uses a soft shell and hard exterior to simulate accommodation; the Synchrony dual-optic lens9 (Visiogen, Inc, Irvine, California), which uses two lenses with telescope-like optics; and the LiquiLens (Vision Solution Technologies, Rockville, Maryland), which has a liquid core of two substances with different refractive indices and relies on gravity to shift the power of the lens with downward gaze.

Clearly the race is on in the accommodating IOL arena. Whether any of these IOLs will be indicated for the primary treatment of presbyopia with refractive lens exchange or will be marketed primarily as a premium IOL for patients undergoing cataract surgery remains to be seen.

Lenses substitute and intracapsular IOLs, whereby the crystalline lens capsule is filled with a polymer, silicone IOL, or other material after the lens substance is removed, have also been tried. The SmartIOL (Medennium, Irvine, California), a hydrophobic acrylic IOL with the same dimensions as the human lens, can be inserted through a 3-mm incision. To date, limited peer-reviewed reports have been published regarding this lens. Reports indicate that success using polymer and liquid materials has been limited by leakage and poor refractive predictability.10

OPTICAL SOLUTIONS

Various optical solutions for presbyopia have been attempted, both on the cornea and with IOLs.

The AcuFocus corneal inlay (AcuFocus, Inc., Irvine, California), designed to create a pinhole effect, is inserted within the cornea under a LASIK flap. Early clinical results were complicated by melts, haze, and limited patient satisfaction,11 but clinical trials are ongoing and this lens shows promise, particularly as an adjunct to LASIK surgery.

Corneal procedures have generally attempted to create a steeper central cornea (i.e., positive corneal asphericity resulting in negative optical spherical aberration) using tissue shrinking procedures or special excimer laser profiles. Collagen-shrinking procedures such as thermal and conductive keratoplasty have been hindered by regression and poor predictability.12 Laser procedures have been challenged by limited effectiveness, reliance on pupil size for effect, regression of effect, and irreversibility. Many shapes, sizes, patterns and optical approaches to performing corneal laser presbyopia surgery have been tried, and to date none have achieved widespread acceptance.13 However, enthusiasm for these procedures remains high—perhaps a triumph of hope over experience.

Multifocal IOLs are commonly used to treat presbyopia in patients undergoing cataract surgery. These lenses are divided into two broad categories, refractive and diffractive, depending on their designs. Examples of diffractive IOL are the AcrySof Restor multifocal IOL (Alcon Laboratories, Inc., Fort Worth, Texas) and the Tecnis Multifocal IOL (Abbott Medical Optics, Inc., Santa Ana, California); these IOLs use diffractive optics to divide incoming light for distance and near foci. Refractive multifocal IOLs, such as the ReZoom (Abbott Medical Optics Inc.) have zones of different refractive powers to focus incoming light at various focal points.

The CrystaLens HD is not a multifocal IOL, but rather combines a pseudoaccommodative mechanism with a central spherical optic. It can be anticipated that future technologies will make use of combined mechanisms of action in an effort to increase their effectiveness.

All multifocal procedures, whether based on the cornea or using an IOL, necessarily result in decreased image brightness and reduced contrast sensitivity, and all have the potential to cause glare, halos, rings, and other unwanted
side effects. Although multifocal IOLs are in widespread clinical use, careful patient selection is crucial to achieving satisfactory results. Multifocal procedures of any sort are not recommended for patients who desire good vision in mesopic conditions, such as night driving.

The diverse range of approaches to presbyopia reflects the innovation and ingenuity that characterize ophthalmology. However, for now, spectacles are still the most common method of treatment for presbyopia. For the presbyopic patient with clear crystalline lenses, monovision with contact lenses works well in those who can tolerate it. For patients undergoing cataract surgery, accommodating or multifocal lenses are gaining in popularity; however, these lenses rely on good refractive outcomes to deliver their full benefit, something cataract surgery alone cannot always accomplish.

A definitive treatment for presbyopia remains elusive. We will know the answer when the clinical results are in. Patients will know a viable solution is available when Google searches for presbyopia surgery become less confusing. In the meantime, I will stick with my monovision contact lens.

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