

Accommodating IOLs: Emerging Concepts and Designs

Steps toward providing excellent distance, intermediate, and near UCVA.

BY SAMUEL MASKET, MD

With respect to pseudophakia, accommodating IOLs are both the hope for and the wave of the future. Cataract surgeons' goal has long been to provide unaided, high-quality distance, intermediate, and near vision postoperatively. Although the concept of surgically emptying the capsular bag and refilling it with an accommodating polymer that matches the behavior of the juvenile lens has received consideration for many years, its actualization remains elusive today. Ophthalmologists' work toward that goal will involve many intermediate steps. Presently, the field is on the brink of a new era in accommodating IOL technology. This article considers the currently available lenses as well as those devices that are in varying stages of development. Because this is an ever expanding field, all present exam-

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ples cannot be addressed. Rather, present design concepts are considered in group styles. I make no attempt to include all products under development.

ACCOMMODATIVE FUNCTION AND EFFECT

I believe that an IOL's true accommodative function should be based upon the Helmholtz theory of accommodation. Accordingly, a truly accommodating IOL requires one or both of these transient and reversible

changes: (1) anterior movement of the optic and (2) increased optical power of the IOL. It follows, then, that accommodating IOLs must be dynamic. As a result, they are most likely to depend on the long-term flexibility of the capsular bag in order to function properly. For this reason, surgeons will likely need to modulate postoperative reactions of the lens epithelial cells in order to

(Courtesy of Advanced Medical Optics, Inc.)

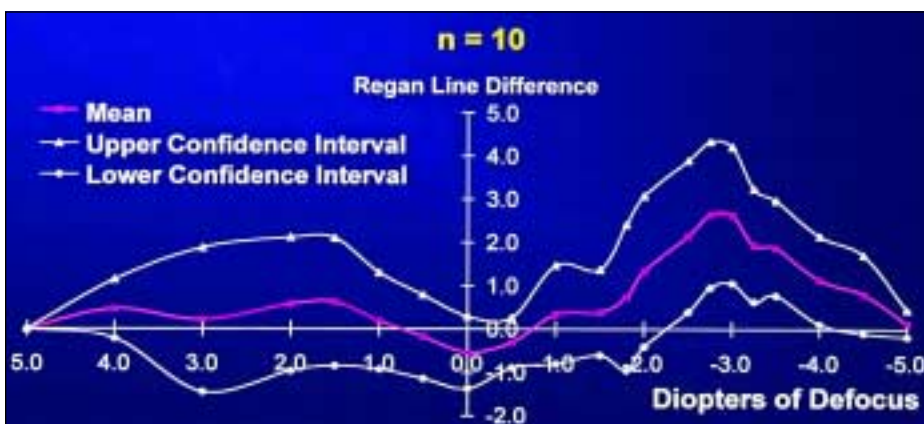
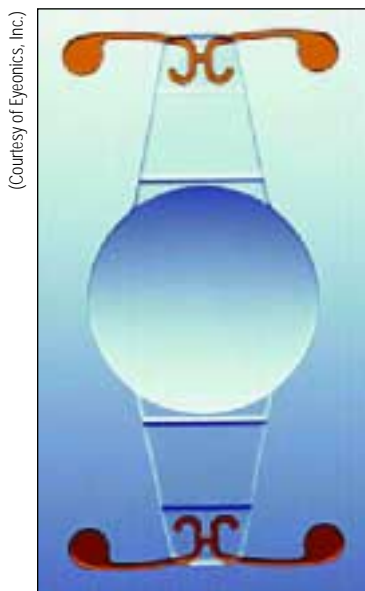


Figure 1. The defocus curve is used to determine the accommodative or pseudoaccommodative function of an IOL.

reduce the tendency for fibrometaplasia, typically observed for the anterior subcapsular lens epithelial cells after implant surgery. Additionally, it is important to recall that these postoperative changes vary with the nature of the implant material and its contact with the anterior capsule.

Another consideration is the methodology for measuring the accommodative effect of an IOL. Patients with monofocal IOLs demonstrate a small degree of accommodation that is probably related to artificial or pseudoaccommodative effects such as corneal asphericity, which produces a multifocal cornea. Alternatively, corneal astigmatism may also provide for degrees of pseudoaccommodation. It is generally accepted that patients with monofocal IOLs may generate between 0.50 and 1.50 D of pseudoaccommodation after surgery. Strictly measuring postoperative near visual acuity may therefore be misleading, because a degree of pseudoaccommodation exists in most patients. This caveat may be of particular importance in patients who have small or miotic pupils; similar to all optical systems, the eye with a small pupil has an increased depth of focus.

Researchers have employed several automated devices



(Courtesy of Eyeonics, Inc.)

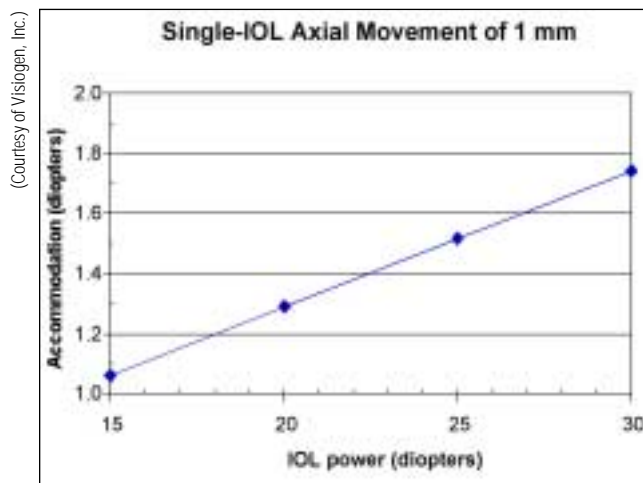
Figure 2. The Crystalens features a 4.5-mm, fixed-power optic with grooved plate haptics designed to allow flexibility and accommodation.

in their efforts to demonstrate either anterior movement of an IOL or a change in optical power on attempted accommodation—high-resolution anterior segment ultrasound biomicroscopy in the former case and a variety of new automated refractors and wavefront analyzers in the latter. Automated devices have yet to be standardized, however, and there appears to be no consensus as to the best objective means for determining true accommodative function. As a result, distance defocus curves have become an accepted tool for measuring the accommodative and pseudoaccommodative effects of IOLs. In fact, this system was employed for the FDA approval of the Array multifocal lens (Advanced Medical Optics, Inc., Santa Ana, CA). This method appears to be the most useful until such a time as objective tools are standardized and widely accepted (Figure 1).

DESIGN CONCEPTS FOR ACCOMMODATING IOLs

Single Fixed Optic, Flexible Haptic Support System

In accordance with the Helmholtz theory, one concept for an accommodating lens design (and the simplest) would be a fixed-power single optic with a dynamic, flexible haptic support system. The flexible hap-



(Courtesy of Visiogen, Inc.)

Figure 3. This chart reveals the degree of accommodation generated by anterior movement of the IOL. Note that higher dioptric powers induce greater accommodation than do lower-powered lenses of this design.



Figure 4. A SmartIOL filled the capsular bag of an autopsied human eye. After implantation through a 3-mm incision, the cornea was excised, revealing a 6-mm capsulorhexis and a well-centered implant.

(Courtesy of Visiogen, Inc.)

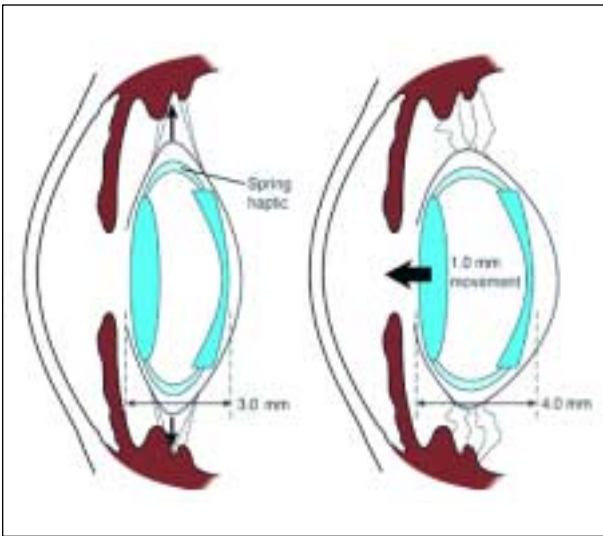


Figure 5. This concept for an accommodating IOL system uses dual optics in a truly telescopic design. During rest (left), the optics are close together, and the “springs” maintain potential energy. With accommodation (right), the springs exhibit kinetic energy, and the optics separate, thus increasing the optical power of the lens system.

tic would allow the optic to move anteriorly during the accommodative effort and thereby increase the effective power of the lens. Such a design system is currently employed in the Crystallens (Eyeonics, Inc., Aliso Viejo, CA), which the FDA recently approved for implantation. The lens is made of silicone with a 1.43 index of refraction, has a 4.5-mm optic, and features grooved

EXPECTATIONS

It is worth mentioning that matching the expectations of patients is difficult with any IOL but with pseudoaccommodating IOLs in particular. People’s demands of the early accommodating IOLs are likely to be unrealistic. Although sophisticated in their knowledge, patients often misunderstand the state of the art regarding IOLs. They have been influenced by the hyperbole surrounding LASIK correction, and they expect to fully eliminate their spectacle use after lens-related surgery. Ophthalmologists must be careful in dealing with unrealistic expectations regarding the optical outcomes of surgery, including spherical, toric, and accommodative visual function.

ACCOMMODATING IOLs IN DEVELOPMENT

Sarfrazi Twin-Optic Elliptical Accommodating IOL (Bausch & Lomb Surgical, Rochester, NY)

- Designed to mimic the optical changes of the crystalline lens during accommodation
- Dual-optic design features a positively powered anterior lens joined to a negatively powered posterior optic
- Foldable
- Human implantation has been scheduled

[A developmental accommodating IOL] (Quest Vision Technologies [Tiburon, CA], and Advanced Medical Optics, Inc. [Santa Ana, CA])

- Has been implanted in primate and cadaver eyes; no human implantations to date
- Has myopic configuration in the resting state and an anterior position in the accommodative state
- Being tested in both near and distance vision resting states
- Features a balloon-shaped haptic that is shaped like the capsular bag
- During disaccommodation, the zonules pull the capsule so that the lens flattens

Kellan Tetraflex IOL (Lenstec, St. Petersburg, FL)

- Made of hydroxyethylmethacrylate with a UV filter
- Haptic design facilitates movement of the optic
- Injectable through a 1.6-mm cartridge
- Features a 5.75-mm optic with square edges
- Currently being implanted throughout Europe and the Middle East
- CE Marked as a posterior chamber aphakic lens
- Available in + 5.00 to + 36.00 D

plate haptics. In the investigational FDA clinical trials, the Crystalens allowed approximately 70% of the subjects to remain free of spectacles (Figure 2).

Similar devices have been used in Europe. One is the Akkommodative 1CU lens (HumanOptics AG, Erlangen, Germany), which is made of a hydrophilic acrylic material. A number of similar lens designs are under consideration at this time.

One drawback to this design concept is that lenses of lower power will generate less accommodation with anteroflexion than will higher-powered IOLs. Figure 3 demonstrates a considerable difference in the achieved increase in IOL power with higher-dioptic lenses and 1 mm of anteroflexion. In addition, it has recently been suggested that lenses of this design characteristically move less than 1 mm anteriorly upon accommodative effort, as determined by ultrasound biomicroscopy.¹ Although simple in design, IOLs of this type are unlikely to be successful over a wide range of dioptric powers. In addition, the flexibility of the capsular bag remains an important aspect of performance for this lens design.

Dynamic Optic

Another accommodative IOL concept is a dynamic optic that increases power but maintains its position with accommodation. This design requires flexibility of the optic. One example, the SmartIOL (Medennium, Inc., Irvine, CA), consists only of a full-sized, 9.5-mm diameter by 3.5-mm optic made of a thermodynamic, hydrophobic acrylic material. This IOL is designed to fill the entire capsular bag (Figure 4). Accommodative forces are transmitted to the capsular bag from the ciliary body and, in turn, to the pliable IOL. With accommodative effort, the lens increases its anterior/posterior dimension, thus increasing optical power.

The SmartIOL requires continued flexibility of the capsu-



(Courtesy of Visiogen, Inc.)

Figure 6. The Visiogen Synchrony IOL.

lar bag. Considering the nature of the lens' hydrophobic acrylic material, its tacky surface, and the fact that it fills the capsular bag, however, it seems likely that the amount of posterior capsular opacification and capsular fibrosis will be limited. Another feature of this lens, given its flexibility and thermodynamic properties, is that it will be implantable through a 3-mm incision, although the IOL is equivalent to the size of the normal human lens.

A second dynamic optic lens, the Power Vision IOL (Power Vision, Santa Barbara, CA), does not change position within the eye during accommodation. Based upon the use of applied microfluidics, this lens—theoretical at this time—has a peripheral fluid reservoir. Upon accommodative stimulation, an actuator triggers microscopic pumps to move fluid from the periphery to the center of the lens, thereby increasing its anterior/posterior dimension and, hence, its optical power. As accommodation relaxes and the stimulus to near vision decreases, fluid is pumped back from the central to the peripheral aspect of the IOL, thus altering its optical power to the distance mode.

MULTIFOCAL IOLS

Until recently, the Array (Advanced Medical Optics, Inc., Santa Ana, CA) has been the only multifocal IOL available for use in the US. This pseudoaccommodative lens is considered to be a zonal progressive multifocal. Because light energy is divided between distance and near, the patient experiences a loss of contrast sensitivity and a reduction in vision quality resulting from halos and glare. For this reason, the IOL has not achieved a large market share, although it is available worldwide. A recent meta-analysis of the literature suggested that slightly fewer than 50% of patients implanted with this device are able to maintain spectacle-free vision for all ranges and that many experience some degradation of vision quality.¹ Although other pseudoaccommodating IOL designs are under FDA investigation at this time, the limits of this form of technology cannot be ignored, and lenses that provide a full range of accommodation and high-quality vision will likely supercede pseudoaccommodating IOLs.

1. Leyland M, Zinicola E. Multifocal versus monofocal intraocular lenses in cataract surgery: a systemic review. *Ophthalmology*. 2003;110:1789-1798.

Although lenses with a single, dynamic optic have yet to be implanted in humans, they are likely to achieve a greater degree of accommodative power than lenses with a fixed-power optic and flexible haptics.

Dual Optics

With a dual-optic, telescoping IOL, spring-like haptics separate a high-plus anterior lens from a posterior minus lens (Figure 5). The one-piece, dual-optic lens rests within the capsular bag. In the nonaccommodative phase, the tension of the capsular bag and zonules keeps the two optics in close proximity while the spring devices are collapsed and exhibit potential energy. With accommodative effort, the zonules relax, the capsular bag expands, and the springs express kinetic energy. This change allows the optics to separate as the anterior plus lens moves forward, thus producing a higher optical power that yields accommodation.

Visiogen, Inc. (Irvine, CA), has developed the Synchrony IOL, a dual-optic, single-piece, silicone device with an index of refraction of 1.43 (Figure 6). This lens has been implanted in approximately 60 eyes outside the US and appears to generate 2.50 D of accommodation, as measured by distance defocus curves.²

CONCLUSION

All ocular surgeons await the development of a surgical method for replacing the aging crystalline lens with a polymer that behaves exactly like the juvenile human lens without compromising the capsular bag's clarity and flexibility. While the creation of those polymers is underway, some of the IOL designs described in this article will move patients toward the goal of spectacle independence and establish lens-related procedures as the dominant form of refractive surgery. ■

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1. Rana A, Miller D, Magnante P. Understanding the accommodating intraocular lens. *J Cataract Refract Surg.* 2003;29:2284-2287.
2. Ossma IL. Measurement of accommodation after implantation of a dual-optic accommodating IOL. Paper presented at: The ASCRS/ASOA Symposium on Cataract, IOL and Refractive Surgery; May 4, 2004; San Diego, CA.