Presbyopia and Accommodative Intraocular Lenses—the Next Frontier in Refractive Surgery?

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While refractive surgery now addresses the vision needs of approximately one-third of the Western population—those afflicted with myopia, hyperopia, astigmatism, and aphakia—successful means of correcting presbyopia would aid 100% of the population, since virtually everyone develops presbyopia during the fifth decade of life. Studies to identify the causes of presbyopia might form the basis for its successful treatment, which is now limited to the addition of plus power to optical correction, or the use of monovision in myopes. Loss of accommodation is also a consequence of cataract or clear lens extraction—even when a multi-focal intraocular lens is implanted. The search for an accommodative intraocular lens has practical implications for these patients.

ARVO SYMPOSIUM ON PRESBYOPIA

At the Association for Research in Vision and Ophthalmology (ARVO) meeting in Sarasota, Fla, a special symposium on Presbyopia: Causes and Treatment was held on May 3, 1992.

Harry J. Wyatt, PhD, of the SUNY College of Optometry in New York reviewed the historical development of theories of presbyopia and listed nine possible causes:
1. The substance of the lens becomes stiffer.
2. The lens capsule loses elasticity.
3. The zonules lose elasticity.
4. There is a change in the lens-zonule geometry.
5. There is an alteration in the optical properties of the lens.
6. The choroid becomes stiffer.
7. There is a decrease in active muscle tension with atrophy of the ciliary muscle.
8. There is a decrease in the muscular innervation.
9. There is a change in the neuromuscular junction.

He described a mathematical model of accommodation based on published mechanical indices, which assumed that the scleral spur is the fixed fulcrum for the ciliary muscle, that Bruch's membrane of the choroid is elastic and is pulled forward when the muscle constricted, and that the lens is elastic and increases its anterior radius of curvature during accommodation.

Johannes W. Rohen, MD, of the University of Erlangen, Germany, described the structure of the accommodative apparatus and its role in presbyopia. He emphasized that the ciliary muscle is not directly connected to the zonules, but rather links the choroid and scleral spur. Bruch's membrane of the choroid is elastic, and accommodation is accomplished by constriction of the ciliary muscle which pulls the choroid forward and produces a passive relaxation of the zonules with a passive increase in the radius of curvature of the anterior surface of the lens.

With increasing age, two major anatomic changes occur in the ciliary muscle. The first is a loss of elastic fibrils with an accumulation of randomly oriented collagen fibrils at the junction of the muscle and Bruch's membrane. The second change is an anterior movement of the body of the ciliary muscle toward the scleral spur. Both of these changes decrease the ability of the muscle to contract.

Jane Koretz, PhD, of the Rensselaer Polytechnic Institute in Troy, NY, described the elastic and geometric contributions of the lens and zonular system to presbyopia. She emphasized that during accommodation, the anterior lens increases its radius of curvature and its refractive power, and that the posterior surface of the lens remains virtually stable. With increasing age, the lens becomes thicker, slightly denser, with flattening of its anterior curvature. The thickening is due to an increase in cortical mass, since the nucleus retains its same basic size and shape throughout life. This increase in lens thickness and mass requires more force to change its shape during accommodation.
Paul Kaufman, MD, of the University of Wisconsin in Madison, described the role of the ciliary muscle in presbyopia based on his studies in monkeys. With increasing age, the ciliary muscle maintains an overall normal anatomic appearance, retains the ability to respond to direct stimulation of the Edinger Westphal nucleus, demonstrates a normal complement of enzymes that form the basis for neuromuscular behavior, and contracts normally when removed from the eye. Thus, a major cause of presbyopia seems to be the loss of elasticity of Bruch's membrane and the degeneration of the posterior tendinous attachment of the ciliary muscle to Bruch's membrane, and not degeneration of the ciliary muscle.

Jay Enoch, PhD, of the University of California at Berkeley, described the increasing number of options for optical correction of presbyopia. He emphasized the psychophysical principle of sharing the visual field, as is done in a heads-up display on jet aircraft, where two images are presented to the retina at the same time. This can be done with multifocal lenses where the two images are shared; it can be done with monovision where the images from the two eyes are shared; or it can be done with changeable lenses such as liquid crystal displays where the sharing of images is done at different times. He reviewed the basic types of variable focus lenses, thin wafer lenses that can be easily used to modify a presbyopic correction, bifocal and multifocal contact lenses and intraocular lenses, and liquid crystal lenses that are in their experimental phase.

Jean-Marie Parel, Ing, ETS-G, of the Bascom Palmer Eye Institute in Miami, Fla, described surgical techniques for remedying presbyopia. Parel has fostered the establishment of a research study group known as The Accommodation Club, whose purpose is the exchange of information concerning techniques of accommodative intraocular lenses.

**ACCOMMODATION CLUB FORUM**

On September 7, 1990, in Barcelona, Spain, the Accommodation Club held its second international meeting at the Instituto Barraquer. The Club was founded in 1989 to foster research on cataract surgery designed to preserve and restore accommodation. Its major emphasis is on techniques of removing cataracts with the preservation of the capsule in such a way that it can be refilled with some material and preserve accommodation.

Jean-Marie Parel, ETS-Ing (Miami, Fla) directed the workshop, structuring the meeting around four major topics.

In the session on instrumentation and technology, the participants discussed not only the anatomy underlying accommodation and its physiology and measurements, but also the instruments used in cataract surgery, specifically those designed to make very small openings in the lens capsule and to fragment or dissolve the nucleus and cortex and remove it with minimum disruption to the integrity of the capsule bag, including sophisticated methods such as endoscopic evaluation of the structures and fluorometric determination of the presence of residual lens epithelium.

A session on surgical techniques addressed methods for maintaining the integrity of the lens capsule and included a vigorous and prolonged discussion on the uses of lasers to remove the cataract, including both ultraviolet and infrared wavelengths. One millimeter diameter phacoemulsification tips, new mechanical lens fragmenters, methods of enzymatic digestion and others were presented, most of them in preliminary forms. A major topic discussed was the necessity for complete refilling of the capsular bag, so that accommodation would function in the same time frame as normal. This turns out to be an enormous challenge.

The session on proliferation of the lens epithelium causing postoperative clouding of the capsule explored methods to remove the lens epithelium or prevent its proliferation, emphasizing the difference between the terminal epithelium in the lateral fornix of the capsular bag and the anterior subcapsular endothelium. The growth of lens epithelium in tissue culture and the use of animal models was described, as well as the following methods of inactivating the epithelium: cryotherapy, mechanical scraping, ultrasonic disruption, cytotoxic agents, hypomotonic fluids, photosensitizers, monoclonal and polyclonal antibodies attached to cytotoxic agents, and drugs that block or modify the cell cycle.

The session on polymeric materials and optical modelling engaged in a vigorous discussion of the physical properties of the material that could fill the capsular bag and preserve accommodation. Numerous materials were discussed, including silicones, polyHEMA, hydrogels, polysiloxane compounds, photocrosslinkable collagen gels, accommodative intraocular lenses, and small bags filled with substance.

It was clear from the vigorous interchange at the conference and the reports of research at multiple centers around the world that ophthalmology had entered a third phase in the modern development of cataract surgery: first, the intraocular lens; second, small-incision surgery; and third, the search for preservation of accommodation.

On November 13, 1992, the Accommodation Club held its third meeting, this time at the Bascom Palmer Eye Institute in Miami, Fla. The meeting was hosted and moderated by Jean Marie Parel. It featured speakers with whom Parel had collaborated in his superb biophysics laboratory. The papers provided updates on instrumentation surgical techniques, synthetic materials, and multiple methods to preserve clarity of the lens capsule.
IOLs FOR CORRECTION OF MYOPIA

There are two methods to use IOLs to correct myopia:

1) Removal of the clear crystalline lens and replacement with an intraocular lens of appropriate power, or 2) insertion of an intraocular lens with retention of the crystalline lens; the former technique eliminates accommodation, the latter preserves it.

Removal of the crystalline lens with replacement by a low power intraocular lens in myopes is being carried out in patients with cataracts by the IOLAB Corporation, which currently has 2-year follow up on 65 eyes. IOLAB will wait for at least 3 years before analyzing the results of this study, according to Warren Heller, MD, the study's medical monitor. In this issue of Refractive and Corneal Surgery, TheodoreWerblin opines positively on clear lens extraction for myopia (see p. 480).

Currently, there are four intraocular lens styles being investigated for the correction of myopia in phakic eyes: the multiflex style anterior chamber intraocular lens by Domilens, which caused endothelial damage when the anterior vault is high, and is now being investigated with a model of lower anterior vault; the Worst lobster claw lens, manufactured by Ophtec B.V. (Holland) and Chiron-IntraOptics in the USA that adheres to the peripheral iris and has been implanted in a large number of eyes; the angle-fixated, glass optic, Spider lens with four flexible loops, being investigated by Momose in Japan; and a silicone disk lens that lies on the surface of the crystalline lens in the posterior chamber, being investigated by Fyodorov and colleagues in Moscow, and by Fechner in Germany.

Clearly, the intersecting themes of refractive surgery, accommodation, and intraocular lens implantation combine to create new frontiers for the surgical correction of refractive errors.

REFERENCES