Accommodating IOL Designs

What elements are needed in accommodating IOL designs to make them successful?

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CRST Europe asked an international panel of leading surgeons the following question: What elements are needed in accommodating IOL designs to make them successful? Their answers are below.

EDUARDO F. MARQUES, MD

Based on my experience, there are five essential elements in successful accommodating IOL designs, as outlined below.

No. 1: Allow spectacle independence for all distances. A successful accommodating IOL should provide enough pseudophakic accommodation to allow spectacle independence for all distances. This can be achieved using one or a combination of the two physiologic changes that also occur in the natural lens with contraction of the ciliary muscle:

- *Increase in paraxial power of the IOL.* This is the mechanism used in the Synchrony dual-optic accommodating IOL (Abbott Medical Optics), which changes the relative distance between the IOL's two optics with ciliary muscle contraction, thus increasing paraxial power and providing intermediate and near focus. This mechanism has been demonstrated objectively in patients up to 4 years after implantation of the IOL. It was also one of the mechanisms of action suggested for the Crystalens accommodating IOL (Bausch + Lomb), which is believed to move anteriorly with contraction of the ciliary body, although this is controversial.
- *Increase in anterior curvature of the IOL.* Some believe this is the mechanism of action of the Crystalens, which may change shape due to its flexible material. Additionally, the second generation of the dual-optic accommodating IOL (Synchrony Vu) includes a central area of negative spherical aberration on the surface of the anterior optic to try to mimic the changes occurring in the natural lens during ciliary body contraction. In theory, this change allows a gain of 1.00 D depth of focus for near.

No. 2: Guarantee the same optical quality as a monofocal IOL. The main advantage of accommodating IOLs is the lower incidence of the dysphotopsia and loss of contrast sensitivity that are typical of multifocal IOLs. This is due to the use of monofocal optics, a trait that all available accommodating IOLs have in common.

No. 3: Afford excellent refractive predictability. One of the criticisms regarding existing accommodating IOLs is their lower refractive predictability compared with multifocal IOLs. Stability and final position of an accommodating IOL depends largely on the size and shape of the patient's capsular bag, as well as contraction and fibrosis of the bag, which interfere with the refractive result. The design of accommodating IOLs should provide good stability and adaptation to the bag, allowing precise IOL power calculation.

No. 4: Allow easy, safe implantation through a small incision. Small incisions induce less astigmatism, allow quicker recovery, and provide increased safety compared with larger incisions. One of the difficulties with accommodating IOLs has been the need for larger incisions to implant these more complex devices.

No. 5: Prevent posterior capsular opacification (PCO). Prevention of PCO is an essential characteristic of a successful IOL. The rate of PCO is lower with dual-optic IOLs than with single-optic, probably due to the maintenance of an open system, allowing circulation of aqueous in the capsular bag. Other strategies include the more common use of a square optic edge.

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PETER MOJZIS, MD

The development of accommodating IOLs to restore the dynamic dioptric range in presbyopic and cataract patients has been a challenge for many years. Accomodation in phakic patients is achieved by one or a combination of some of the following mechanisms: ciliary muscle movement, change of lens shape, and increased vitreous pressure. Unfortunately, artificial reproduction of the process of accommodation is a complex issue.

Different techniques have been used to develop accommodating IOLs, such as anterior movement and steepening of the anterior surface of the IOL as a result of ciliary muscle contraction (NuLens [NuLens]; FluidVision lens [PowerVision]) or anterior vaulting and axial movement of the IOL (Crystalens; Tetraflex [Lenstec]).

Another interesting concept is the replacement of the crystalline lens with a polymer material that, theoretically, acquires the lens shape after polymerization (SmartLens; Medennium). The main concerns with this approach are leakage of the polymer and the development of PCO.

I am convinced that the IOL design of the Light Adjustable Lens (Calhoun Vision) may be adequate to achieve an accommodative effect. This lens consists of a photosensitive silicone material that can be adjusted to the desired refractive power using ultraviolet (UV) light.

In my opinion, considering the mechanism of accommodation using only one concept to achieve artificial accommodation is insufficient. A promising new project is a lens that combines several mechanisms, the WIOL-CF (Medicem). The WIOL-CF is a polyfocal accommodating lens made of a special hydrogel material with properties comparable to those of the natural lens. The lens is flexible and soft and has a diameter of 8.9 mm, similar to the size of the crystalline lens. Its material enables the IOL position and shape to change during contraction or relaxation of the ciliary muscle.

The smooth surface and size of the WIOL-CF help to ensure perfect centration and stability and to prevent PCO formation. Another important feature is the polyfocality of this IOL, which is created by its hyperbolic curvature. Further, the additive effect of pseudoaccomodation facilitates near vision. This combination of three mechanisms of action—accommodation, pseudoaccomodation, and polyfocality—may be an approach that leads to a functional level of visual acuity at different distances. For this reason, I prefer the WIOL-CF.

The ideal accommodating IOL should provide emmetropia for distance, produce a sufficient amount of accommodative range with minimal aberrations during deformation, and be capable of injection through a microincision. The polymerization process should be safe and stable, without any adverse events. The ability to adjust IOL power and customize the lens postoperatively is desirable. The main benefit of this premium IOL should be its ability to generate a variable focus at any time depending on the patient's need.

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EWA MRUKWA-KOMINEK, MD, PhD

To determine the elements of successful accommodating IOL designs, we must first understand the mechanism of accommodation, which has been studied at least since the time of Helmholtz. During cataract surgery, the natural crystalline lens is replaced with a prosthetic IOL with a fixed power to produce emmetropia. Because the natural lens changes power at different distances of focus, accommodating IOLs should also have the ability to change lens power. They should be designed to change the eye's power or focal length with the patient's natural efforts to accommodate.

The aim of accommodating lens development has been to mirror the properties of the natural crystalline lens as closely as possible. These elements can be divided into material, design, and function. The material of an accommodating IOL should enable it to change refractive power. The IOL should have a size close to that of the natural lens (10 mm), hydration close to 62% water content, and a refractive index close to 1.43. The lens should also have a smooth, highly hydrated surface; be resistant to protein adsorption and cell attachment; and have glare-free optics with an antireflective surface, a negative charge, and a material that absorbs UV light.

Currently, the accommodating IOL that is most similar to the natural lens is the WIOL-CF bioanalogic accommodating polyfocal lens. It has large, glare-free continuous hyperbolic aspheric optics and a full-disc plano-convex lens up to 9 mm. The full-disc configuration results in self-centration, excellent stability, resistance to dislocation, and optics with no zones, thus providing excellent contrast sensitivity. A continuous transition between the optics and rim yield no edge effects, improving night vision and minimizing glare.

The WIOL-CF's sharp-edged continuous rim and smooth, convex hyperbolic surface closely adhere to the posterior capsule and do not allow penetration of cells behind the lens, making the lens resistant to PCO. The aspheric hyperboloid optics improve its depth of focus. Water content of the WIOL-CF material is 42%, and the refractive index is 1.43, similar to that of the natural lens. Its low refractive index results in minimal surface reflection and glare at night. The lens is made of a highly biocompatible material and has a smooth, negative-charged surface, which influences its resistance to proteins, cell attachment, and PCO and does not cause adhesion to tissue. Another important feature is the lens' ability to be injected through a small incision.

Pseudophakic accommodation may be a result of several different mechanisms. Near focus could primarily be due to lens deformation—a result of ciliary muscle contraction and vitreous body back-stop support—and far focus could be a result of lens polyfocality, anterior-to-posterior movement, and shape relaxation. Accommodating lens designs that take into account this combination of mechanisms may improve patients' overall visual results.

The WIOL-CF achieves its results through its unique design and material developed to resemble the properties of the natural crystalline lens. Implantation of the WIOL-CF restores many of the characteristics of the young natural crystalline lens in terms of its optics, function, and position in the eye. It provides the retina and brain with comprehensive and understandable visual information. Therefore, the WIOL-CF represents a leading technology for the treatment of cataract and presbyopia in patients who demand more than good visual acuity at selected, predefined distances.

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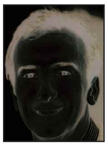

DOMINIQUE PIETRINI, MD

Truly accommodating IOLs are our greatest challenge in regard to presbyopia correction following cataract surgery. The accommodative effect of these IOLs depends on many factors, chiefly the lens and optic designs.

First, researchers and manufacturers must consider the variability of the size of the capsular bag, which can range from 9 to 12 mm, according to Mana Therani, MD.[1] Most recently designed accommodating IOLs try to mimic the natural crystalline lens shape, and the relationship between the IOL and the capsular bag equator is the basis of reliable transmission of the forces applied to the bag by ciliary muscle action. This condition is crucial for all types of accommodating IOLs, based on displacement of the optic to obtain the maximum and optimal repeatable effect on optic movement. The IOL should have the ability to stay in contact with the equator in bags of all sizes or to be customized based on preoperative evaluation of capsular bag size. The ideal volume of the lens should also be integrated into the design, especially for lens-refilling techniques.

Most accommodating IOLs based on optic displacement (single- and dual-optic lenses) are naturally unstable. The IOL design should consider postoperative changes in the conditions of the capsular bag, such as shrinkage and variable changes in the capsular response depending of the presence of residual lens epithelial cells (LECs). The presence of LECs leads to anterior capsular fibrosis, which may affect the accommodative response due to changes in capsular elasticity. The fibrous metaplasia of anterior LECs may improve lens fixation, but it may also lead to decentration of unstable optics. On the other hand, thorough cleaning of anterior LECs could lead to IOL instability and capsular thinning, as recently suggested by David J. Spalton, MD.[2]

Control of postoperative capsular opacification and fibrosis will improve the predictability and repeatability of the effect and open the field to lens-refilling techniques, including Phaco-Ersatz[3] and the SmartLens. Large optics and small incisions are mandatory to achieve optimal results and good quality of vision.

The optic component also plays a major role in pseudoaccommodation. For single-optic IOLs including the Crystalens, 1CU (HumanOptics), and Tetraflex, the anterior displacement of the optic will never be sufficient to provide full accommodation; this mode also depends on the power of the lens, favoring higher lens powers. The optic must be improved for better effect, through inclusion of an aspheric component or the ability to change the central power with ciliary muscle action.

For dual-optic IOLs, this effect is theoretically more important, and evolution of the design, with better transmission of ciliary forces to the anterior optic, should improve performance.

Overall, restoration of accommodation is a field of ophthalmology in which research and investigation will bring improvements in our understanding of the accommodative process, and these will result in better-performing accommodating IOLs with new designs and concepts.

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DIMITRA M. PORTALIOU, MD

The demand for a permanent and satisfactory solution for the management of presbyopia has resulted in the growth and development of numerous types of accommodating IOLs. The unique designs and properties of accommodating IOLs are targeted toward overcoming accommodative decline and offering patients spectacle-free near vision after cataract surgery.

There are several elements essential to successful and functional accommodating IOL design. First, the lens should be made of a highly biocompatible material that guarantees the long-term function of the lens (ie, no glistenings, low PCO rate, no calcification, and no deposits). It must be emphasized that PCO should be understood not only as a barrier preventing light from reaching the retina (that can be solved by Nd:YAG laser), but in broader perspective as a marker of capsular fibrosis that can undermine the accommodative properties of any IOL design relying on shape change or anteroposterior movement.

A successful accommodating IOL should be implanted with a standard implantation method and through a reasonably small incision (preferably smaller than 2.5 mm); the procedure should be uncomplicated and provide a reliable, repeatable result. The availability of toric correction is also a must, as is high contrast sensitivity in both photopic and mesopic light conditions to avoid the compromises and safety issues of current multifocal technologies.

Although it may be attractive to strive for the accommodative range of a young natural crystalline lens (5.00 to 10.00 D), it is important to realize that a lower target (2.00 to 3.00 D, corresponding to the vision of 40-year-olds) may be more achievable and enable a simple, reliable surgery with good long-term outcomes, compared with some experimental concepts aspiring for a higher range. Last, the IOL should be associated with a low level of glare and other undesirable optical phenomena.

One of the currently available accommodating IOLs that seems to combine most the aforementioned qualities is the WIOL-CF, mostly because of its design that mimics the properties of the crystalline lens; in our experience, high rates of patient satisfaction and spectacle independence have been seen with this lens.

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MAGDA RAU, MD

Generally, current accommodating IOL designs can be divided into three categories: vaulting single-optic, vaulting dual-optic, and optic-reshaping. Vaulting optic models use the eye's natural accommodative mechanisms to attain power change through anterior and posterior movement (or vaulting) of the optic; optic-reshaping models employ those same mechanisms to reshape the optic.

The limitation of vaulting single-optic models has been their restricted range of accommodative power. In my experience, these lenses provide 0.50 to 1.00 D of added power for near vision. I have implanted approximately 300 of these IOLs; to improve near visual acuity, I calculated a slightly myopic refractive result (-0.50 to -1.00 D) for the nondominant eye.

From what I have learned during the past 10 years of using accommodating lenses, a successful design should take into account several critically important elements to achieve safe, predictable, and effective results. First, the accommodation-driving concept of the IOL must be reliable and not influenced by characteristics of the capsular bag or by capsular bag stretching and must yield at least 2.00 to 3.00 D of variable focus. Over time, with any IOL, capsular fibrosis will occur around the haptics of the lens. With conventional IOLs, this fibrosis helps to stabilize the IOL in the capsular bag; with accommodating IOLs, however, the phenomenon may also minimize or negate the IOL's accommodative effect. Therefore, second, the effect of capsular fibrosis should not influence the long-term mechanism of accommodation. Third, an accommodating IOL should achieve its accommodative amplitude through more than one mechanism. For example, the Akkolens (Akkolens International) uses a different mechanism of shifting optics, and the lens is placed in the sulcus.

PCO occurs in many cases over a period of 5 years, depending on lens material and optic design. Therefore, fourth, the design should provide a means of performing Nd:YAG capsulotomy safely and effectively without loss of accommodation.

Although most accommodating IOLs do not cause the optical aberrations seen with multifocal IOLs, accommodating designs with small optics can cause such problems in patients with large pupil sizes. Finally, the ability to target the postoperative refraction reliably and predictably is of paramount importance. ■

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