# Dual-optic Accommodating IOL—A Review

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## Abstract

This article reviews the design, development, objective accommodation data, and clinical results of the dual-optic accommodating IOL. The first-generation dual-optic accommodating IOL was designed to interact with the contraction and relaxation of the ciliary muscle to generate accommodation. The more recent aspheric version enhanced this technology to further improve the near benefit. The main advantage of the dual-optic accommodating IOL is the low incidence of problems with contrast, glare, and halos associated with multifocal IOLs. The main criticisms are the lower consistency of visual acuity at near distances and the lower refractive predictability. Newer IOL designs are bringing us closer to the ideal of providing patients with perfect high-quality vision at all distances. The dual-optic accommodating IOL has demonstrated to be a safe alternative to provide very good near and intermediate vision without sacrificing distance visual acuity or quality of vision.

## Keywords

Dual-optic accommodation IOL, cataract surgery, presbyopia, intraocular lens, quality of vision

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The benefits that patients expect from cataract surgery have increased with time. For many patients a better quality of life depends on higher spectacle independence. Ideally, we would provide them with perfect vision at all distances, in all lighting conditions, and without dysphotopsia or any impact on quality of vision. Even though we are getting closer to this ideal with newer designs, no lens is available today that can achieve all that.

The options available to increase depth of focus and provide distance and near vision following cataract surgery and intraocular lens (IOL) implantation include monovision, multifocal IOLs, and accommodating IOLs. Compared with monovision, the main advantage of implanting a multifocal or accommodating IOL is the potential for maintaining binocular function at all distances.

Multifocal IOLs were conceived to produce at least two focal points, separated axially, creating the functional equivalent of accommodation. These lenses can provide excellent distance and near visual acuities. The design challenge is to minimize loss of incident light to higher orders of diffraction, minimize optical aberration, and to balance the brightness of focused and defocused images.[1] The patient is forced to accept some compromise in vision quality due to the loss of contrast and the presence of glare and halos (up to 70 %).[2,3]

These limitations have led to the development of accommodating IOLs, expected to provide better image quality compared with multifocals, since intermediate and near vision is provided without multiple competing images on the retina.

In the phakic eye, accommodation is effected through contraction of the ciliary body and subsequent release of rest tension of the zonular fibers that suspend the crystalline lens, thereby resulting in an increased curvature of the lens.[4–6] Presbyopia is defined as the progressive loss of accommodating amplitude associated with the aging process, resulting in a compromised near visual function. Evidence suggests that ciliary body function persists even at an advanced age.[6] It is believed that presbyopia is the result of loss of elasticity of the lens and capsule, together with changes in geometry of the zonular annexes.[7] Replacement of the natural lens with an IOL capable of responding to contraction of the ciliary body and the resulting restitution of accommodative function is based on this principle.

Spectacle independence without compromising quality was pioneered by the original single-optic accommodating IOLs. While successful in many eyes, these lenses have somewhat limited amplitude of accommodation, and often provide inadequate or inconsistent near vision. Our research that measured movement of these accommodating IOLs with Scheimpflug photography, demonstrated axial movement of less than 0.5 D.[8] This excursion magnitude limits the accommodation interval inherent in the single optic design and therefore suggested the need for alternative strategies.

Visiogen, Inc. (Irvine, CA, US) developed a dual-optic accommodating IOL (Synchrony). It was a single piece silicone lens with two coaxial optics connected by a spring system. This allowed their relative distance to change with the accommodative effort. It came preloaded in a simple injector. This 3D design tries to mimic the natural lens' response to the contraction and relaxation of the ciliary muscle, which increases paraxial power and provides accommodation. This design maximizes accommodative amplitude with consistent results,[9] which is an advantage over single-optic IOLs. Furthermore, the design of this IOL had the theoretical potential to provide the distance and near focus typical of multifocal IOLs, with better intermediate vision and better image quality for all distances. The Synchrony IOL was implanted in more than 1,000 eyes throughout the world.

More recently, an aspheric version of the dual-optic IOL (Synchrony Vu, Abbott Medical Optics, Inc., St Ana, CA, US) was developed to further mimic the eye's optical changes during natural accommodation and to further improve the near benefit provided by the dual-optic IOL.

## Design and Development

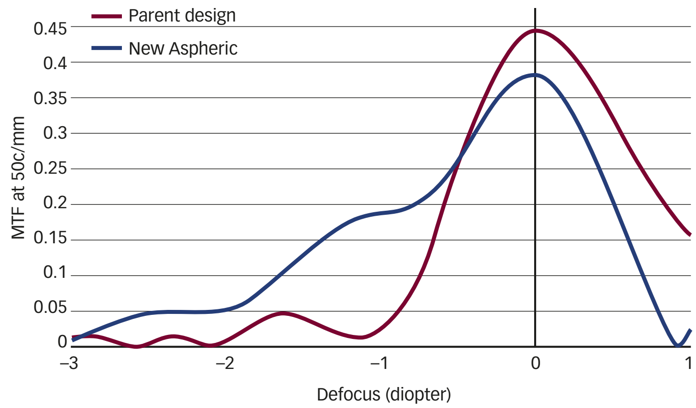
### Synchrony Dual-optic Accommodating IOL

The Synchrony dual-optic accommodating IOL (Visiogen, Inc., Irvine, CA, US) was specifically designed to fill the entire capsular bag and to maximally benefit from the accommodative capacity of the lens capsule during near vision.[9,10] The 3D, single-piece, foldable silicone lens has a 5.5 mm high-plus-powered moving optic attached to a variable 6.0 mm minus-powered optic using spring haptics. The clear optic zone for both optics is 5.0 mm in diameter. They are supported by 9.5 mm length haptic structures extending from opposite directions. Two posterior stabilizers extend laterally from the rear lens and are perpendicular to the direction of the haptic extension with an overall length of 9.8 mm. The lens is provided in a pre-loaded injector, which serves as the carrier and facilitates implantation through a small incision. The IOL was designed to provide single, clear focus over a wide range of viewing distances through active accommodation. When implanted within the capsular bag, the capsular tension exerts a compressive force and decreases the interoptic separation of the IOL to a minimum. This compressed state is the emmetropic state of the IOL. With accommodative action, the zonules relax and release the tension on the capsular bag, which results in a forward displacement of the anterior optic. The posterior element was designed with a wider surface area, which reduces the tendency for posterior excursion and provides stability in the center of the capsular bag.

### Synchrony Vu Aspheric Dual-optic Accommodating IOL

The next-generation, aspheric version of the dual-optic IOL (Synchrony Vu) further mimicked the optical changes in the eye during natural accommodation. The optical power of the crystalline lens increases as the negative spherical aberration increases.[11,12] The central region of the natural lens exhibits greater change in optical power than the more peripheral regions. The new-generation dual-optic IOL is designed to mimic the spatially variant characteristics of natural accommodation and to further improve the near benefit provided by the dual-optic IOL. It includes a central aspheric zone with negative spherical aberration (modeled as a conic surface with polynomial extension using Zemax software and the Le Grand El Hage schematic human eye) that blends into a peripheral spherical optic. This design was selected to utilize pupil constriction during near viewing to maximize the near benefit from the central aspheric zone without degrading optical image quality.[13] Extensive ocular modeling showed that a 2.5-mm central zone and 2.1 diopter (D) peak power provided the best balance between optical quality and depth of focus. This combination provides about 1 D greater depth of focus while still meeting ISO standards for optical quality of monofocal IOLs (see *Figure 1*). In summary, this design was chosen to achieve a selective increase in negative spherical aberration during near viewing associated with pupil constriction, while maintaining good optical quality during mesopic conditions with larger pupil diameter (about 5 mm). The intended result is an increase in near visual acuity while maintaining adequate contrast sensitivity and imaging quality, especially at mesopic conditions.

#### Figure 1: Modulation Transfer Function Curves of Synchrony Vu Dual-optic Aspheric IOL Compared with the Parent IOL (Synchrony)



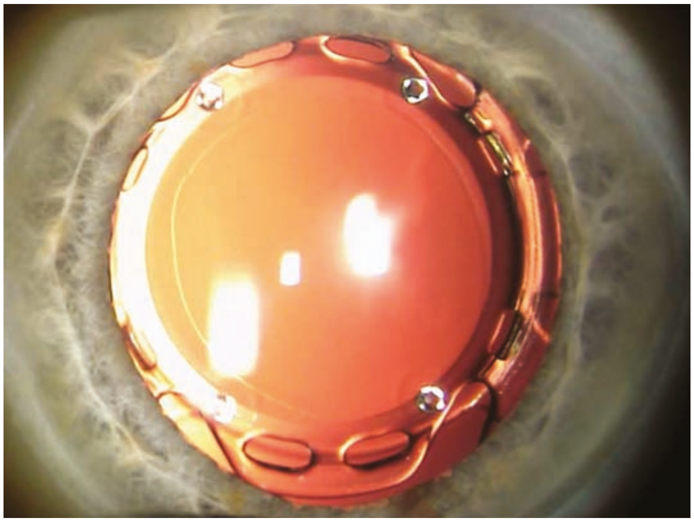

*The aspheric design provided 1D additional depth of focus. Marques EF, et al. Presented at XXX Congress of the European Society of Cataract and Refractive Surgeons (ESCRS), Milan, Italy.[13] MTF = modulation transfer function.*

## Accommodation Measurement Methodology

The performance of the dual-optic accommodating IOL has been discussed[14] and objectively demonstrated for up to 4 years postoperatively, both with dynamic high-resolution ultrasound biomicroscopy (UBM) and with iTrace aberrometry (Tracey Technologies).[15]

In a subsequent study,[16] continuous UBM was performed to demonstrate dynamic accommodative changes in Synchrony optic position during far and near viewing. Synchrony eyes (n=5), in which accommodation had originally been demonstrated by using the iTrace aberrometry and UBM during near and cyloplegic states, were tested again 4 years after surgery for dynamic objective accommodation and subjective push-down accommodation. For dynamic accommodation measurements, a mirror titled by 45 degrees and held at 40 cm from the supine subjects allowed simultaneous viewing of distance (6 m) and near (40 cm) targets. Continuous UBM measurements (Sonomed) were performed on the nonviewing eye while the subjects alternately focused at distance and near. Custom Matlab software was employed to dynamically analyze the static UBM images for IOL optic locations. The Matlab-based program successfully replicated Sonomed UBM measurements (r2 = 0.98), which allowed semi-automatic analysis of hundreds of images from each eye. The dynamic data demonstrated continuous changes in Synchrony optic separation during far and near viewing and fluctuations similar to the natural phakic accommodation. Furthermore, subjective push-down accommodation measured at 4 years

Figure 2: Maintenance of Capsule Transparency 2 Years after Implantation of the Synchrony Vu Dual-optic IOL



(mean ± standard deviation [SD]: 2.44 ± 0.37D) was not different from the 1 year tests (mean ± SD: 2.97 ± 0.17D). This case series demonstrated the accommodative capacity of both the capsular bag and ciliary muscle after cataract surgery and long-term restoration of accommodation with the Synchrony IOL.

## Clinical Results

The first clinical results with the dual-optic accommodating IOL were published by McLeod et al.[10] This initial clinical evaluation in 24 human eyes indicated mean 3.22 D of accommodation (range, 1 to 5 D) based on defocus curve measurement. Accommodative amplitude evaluation at 1- and 6-month follow-up in all eyes indicated that the accommodative range was maintained and that the lens was well tolerated.

Ossma et al. evaluated clinical outcomes with the accommodating dual-optic IOL in a prospective noncomparative case series with 21 patients (26 eyes) scheduled for phacoemulsification with implantation of the Synchrony dual-optic accommodating IOL and retrospective monofocal IOL control (10 patients).[14] The authors studied uncorrected and best corrected visual acuities (UCVAs/BCVAs) at distance and near in addition to accommodative range based on defocus curves. Uncorrected near visual acuity (UNVA) was 20/40 or better in all eyes. With distance correction, 23 eyes (96 %) had an acuity of 20/40 or better at near. Defocus curve analysis suggested a mean accommodative range of 3.22 D ± 0.88 (SD) (range 1.00 to 5.00 D) in the accommodating IOL group and 1.65 ± 0.58 D in the control group (range 1.00 to 2.50 D) ($p<0.05$). Visually significant posterior capsule opacification was evident in one eye (4.2 %) at the 6-month visit. The authors concluded that the Synchrony dual-optic IOL showed promise as an option to provide accommodative function in pseudophakic patients.

A study by Bohorquéz et al. evaluated reading ability in patients who had cataract surgery with binocular implantation of the dual-optic accommodating IOL over a 2-year period.[17] The study evaluated 15 patients with a CDVA of at least 0.1 logMAR and a mean age of 65.3 ± 8.5 years. Reading ability was assessed at 1 year and 2 years after bilateral implantation of the Synchrony IOL. Testing was performed with distance correction and without near addition (40 cm). Mixed-model analysis of variance with time (1 year and 2 years) and print size (1.0 to 0.0 logMAR; 11 levels) as factors showed statistically significantly better reading speed at 2 years, with significant differences at print sizes from 0.3 to 0.1 logMAR ($p<0.01$). Mean reading acuity (0.07 versus 0.15 logMAR) and critical print size (0.28 versus 0.48 logMAR) were also statistically significantly better at 2 years than at 1 year (both $p<0.01$, paired t test). Mild posterior and anterior capsule opacification was seen in four patients at the 1- and 2-year postoperative visits; none required a neodymium:YAG (Nd:YAG) capsulotomy. The authors concluded that the dual-optic accommodating IOL provided stable or improved reading ability over a 2-year period.

We recently performed a prospective, multicenter, nonrandomized study to assess visual outcomes with the new aspheric dual-optic accommodating IOL (Synchrony Vu).[18] The measured outcomes included visual acuity (monocular and binocular, uncorrected and distance corrected for far, intermediate, and near), contrast sensitivity, spectacle independence, and the incidence of glare and halos. Eighty patients (153 eyes), all requiring binocular implantation of IOLs following cataract surgery and without significant astigmatism, history of prior ocular surgery, or ocular pathology, were recruited at four sites. Preliminary data from 31 patients (61 eyes), 40 years of age or older (mean age, 70 ± 7.5 years) at 6 months postoperatively showed that all binocular patients had a distance BCVA of 20/25 or better. Binocular UCVAs of 20/25 or better for distance and intermediate distance were achieved by 94.4 % and 77.8 % of patients, respectively. Binocular near visual acuities of 20/32 or better (both uncorrected and distance corrected) were achieved by 72.2 % of the patients. Eighty percent reported not using visual correction for near. Mesopic contrast sensitivity was within a normal range,[19] both with and without glare. IOL optic decentration was noted in three eyes from one site, without impact on visual acuity but with complaints of glare symptoms.

More recently we described the case of a 69-year-old patient who presented with progressive loss of visual acuity and metamorphopsia in the left eye 18 months after cataract surgery with uneventful implantation of the dual-optic accommodating IOL (Synchrony).[20] The uncorrected distance visual acuity (UDVA) was 20/40, the uncorrected intermediate visual acuity (UIVA) 20/40, and the UNVA 20/50. The patient underwent pars plana vitrectomy (PPV) for epiretinal membrane removal and 12 months after PPV, the UDVA was 20/20, the UIVA 20/20, and the UNVA 20/32. Optical coherence tomography showed the epiretinal membrane (ERM) had been removed and the macular edema was reduced. This is the first report of an elective PPV in a patient previously implanted with a dual-optic accommodating IOL. During PPV, the visualization of the macula was perfect and post-operative visual outcome was excellent, with maintenance of accommodation and restoration of near visual acuity. The increased difficulty in retina visualization during PPV in eyes implanted with a multifocal IOL has been previously reported.[21–23] Therefore, accommodating IOLs have a distinct advantage compared with multifocal IOLs that should be considered when choosing a presbyopia-correcting IOL.

## Discussion

Accommodating intraocular lenses are dynamic devices designed to effect a change in optical power during near viewing by optimally interacting with the capsular bag and ciliary muscle.[24,25] The performance of an accommodating IOL depends both on its dynamic nature and on the equilibrium state between the IOL and the intraocular accommodative plant (i.e., capsular bag, zonular fibers, and the ciliary muscle). Any accommodating IOL will have to be carefully designed considering these factors and should be capable of fully utilizing the available accommodative forces after cataract surgery.

Dual-optic IOLs combine a high-plus anterior optic zone with a negatively powered posterior optic zone to produce a significant amount of accommodation. Essentially, the design uses the natural contraction and relaxation of the eye's ciliary body to generate accommodation when the patient focuses far and/or near. The most-recent generation of dual-optic IOLs has enhanced this technology by adding a central aspheric zone.

Dual-optic accommodating intraocular lenses offer some distinct advantages for postoperative cataract patients over their single-optic and/or multifocal IOL predecessors. They have at least partially addressed the contrast, glare, and halos problems[2,3] associated with multifocal IOLs. Accommodative amplitude is maximized[8,16] and may produce consistent results throughout a wide range of dioptric powers. Prevention of posterior capsule opacification (PCO) is another potential advantage. The rate of PCO with the dual-optic IOL is lower than with single optic lenses,[26] probably due to the maintenance of an open system, which allows circulation of aqueous in the capsular bag (see *Figure 2)*.

However, concerns remain regarding consistent and predictable visual acuity at near distances. One of the criticisms of existing accommodating IOLs is the lower refractive predictability compared with the multifocal version. Stability and final position of an accommodating IOL depend significantly on the size, shape, and contraction/fibrosis of the capsular bag, which interferes with the refractive result. Therefore, the design of accommodating IOLs should provide good stability and adaptation to the bag for more precise IOL power calculation. Another difficulty with the dual-optic accommodating IOLs has been the need for larger incisions to implant more complex devices. Small incisions induce less astigmatism, allow a quicker recovery, and increase safety.

We continue to implant a full range of presbyopia-correcting IOLs to meet patients' needs. Patients who want good spectacle independence at all distances and the highest possible quality of vision, or those who spend all day at the computer, may benefit from an accommodating IOL. As accommodating IOLs have monofocal optics, these lenses may also provide some security to surgeons or patients who are concerned about future macular or retinal developments. However, multifocal IOLs may be better indicated for the patient who is most concerned about excellent near vision and does not mind the potential for nighttime glare and halos.

## Conclusion

Our findings indicate that, without sacrificing distance visual acuity or quality of vision, dual-optic accommodating IOLs provide very good near and intermediate vision. We cannot promise our post-op cataract patients complete restoration of the crystalline lens of their youth. However, improving IOL technology continuously provides us with significant additions to the list of alternatives for these often-demanding patients. ■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