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MULTIFOCAL INTRAOCULAR LENSES

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When faced with a patient with bilateral cataract, many surgeons would leave him or her emmetropic in both eyes, thus making most patients dependent on spectacles for near visual tasks. Although satisfaction may be high for many of these patients, an increasing percentage would prefer to be less dependent on spectacles.

One technique available to surgeons to reduce spectacle dependence is the use of multifocal intraocular lenses (IOLs). However, there are some side effects of this technology, and a variable number of patients complain about problems, such as glare and halos, especially under mesopic conditions.

DESIGNS OF MULTIFOCAL INTRAOCULAR LENSES

Refractive Designs

Different zonal areas of these IOLs have different refractive powers. These zones are typically annular in shape around the center of the IOL. Refractive multifocal IOLs typically use a series of zones with near and distance foci, thus being multifocal with 2 main

foci (Figure 18-1). These IOLs are pupil-size dependent and, therefore, will perform differently under different light conditions. A typical side effect of refractive multifocal IOLs is halos, especially at low-level light conditions.

Diffraction Designs

Diffraction multifocals follow the Huygens-Fresnel principle. According to this principle, each point on an advancing wavefront is the center of a fresh disturbance and, therefore, the source of new waves (known as secondary waves). Furthermore, the overall advancing wave may be regarded as the sum of all these secondary waves arising from points in the medium already traversed. Diffraction multifocal IOLs generate an interference pattern using multiple diffraction rings with a gradient starting from the center of the IOL to the periphery. The result is that there is constructive interference of the transmitted light at both the near and far focus. An unwanted side effect is that approximately one-fifth of the light is lost to higher-order foci and aberrations, with the losses being greater at the extremes of the spectrum. Typically, these IOLs are truly bifocal.

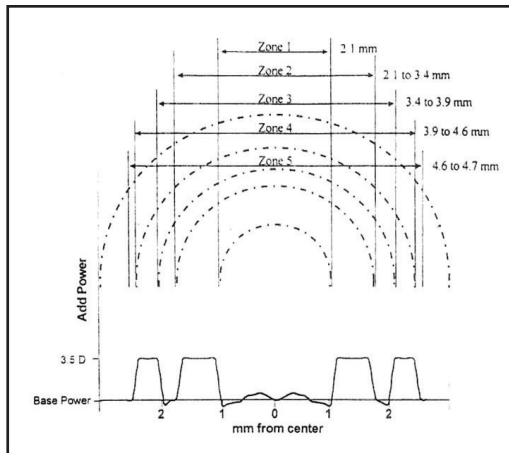


Figure 18-1. Schematic representation of the zonal-progressive multifocal lens design of the Allergan Medical Optics Array multifocal intraocular lens. (Reprinted from *Ophthalmology*, vol 111(1), Montés-Micó R, Espanã E, Bueno I, Charman WN, Menezes JL, Visual performance with multifocal intraocular lenses, pp 85-96, Copyright 2004, with permission from Elsevier.)

Which Multifocal Intraocular Lens Design Fits the Patient's Needs Best—Or Should We Mix and Match?

The advantages of refractive-designed multifocal IOLs are good distance vision and relatively good intermediate vision, whereas the results for near vision tend to be worse than with diffractive designs. Another advantage of refractive IOLs is that 100% of the light that comes into the eye is used, whereas only 80% of the light is usefully utilized in diffractive IOLs, the rest being lost to higher-order diffraction. A disadvantage of diffractive IOLs is lower intermediate visual acuity compared with refractive IOLs.

The multifocal IOL design to be used is dependent on the patient's needs. Refractive designs may be more suitable if patients want distance and intermediate vision, whereas diffractive designs may be better for patients who want good reading performance. An alternative option is to “mix and match” with a diffractive multifocal IOL used in one eye and a refractive multifocal IOL in the patient's other eye. Although patients may benefit from the advantages of both designs, it should be kept in mind that the dysphotopsia experienced may be different in each

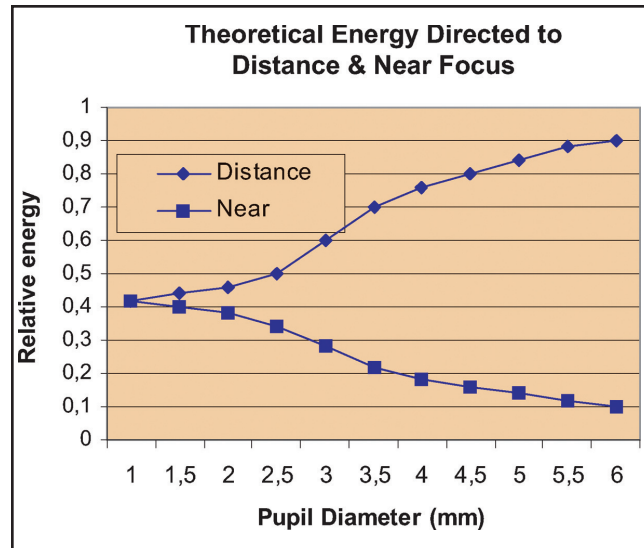


Figure 18-2. Distribution of light to the distance and near focus as a function of pupil diameter with the Alcon SA60D3 multifocal IOL with diffractive apodized optics. (Reprinted from Bellucci R. Multifocal intraocular lenses. *Curr Opin Ophthalmol.* 2005;16:33-37, with permission from Wolters Kluwer Health.)

eye and that this may be more disturbing than having the same design of IOL in both eyes. To date, the peer-reviewed literature on this concept is not sufficient to make any recommendations.

Apodized Designs

In principle, multifocal IOL implantation leads to reduced contrast sensitivity compared with monofocal IOLs because, at either distance or near focus, the light from the out-of-focus image is superimposed on the in-focus light. One attempt to reduce this side effect is the use of a so-called apodized design. “Apodistánoi” is the greek term for “to separate.”¹ For diffractive apodized multifocal IOLs, the step height of the diffractive elements is reduced from the center to the periphery (Figure 18-2). Consequently, with a small pupil, the IOL has a similar light distribution for far and near, thus resulting in good near vision. Typically, we read under good lighting conditions, and the near reflex also causes miosis. In dim light conditions, with a larger pupil size, the IOL becomes distance dominant, which may be useful for activities such as driving at night. However, it should be noted that dysphotopsia, including halos and glare, is still observed with apodized multifocal IOLs.

Toric Multifocal Intraocular Lenses

Residual astigmatism after cataract surgery and multifocal IOL implantation influences the postoperative outcome and may lead to poor performance with these lenses. This effect of decreased visual function appears to be more pronounced for multifocal IOLs compared with monofocal IOLs. Hence, it is important to correct astigmatism during cataract surgery when using multifocal IOLs. The available options to correct astigmatism are either to implant a multifocal toric IOL or to use corneal incisional techniques, such as limbal relaxing incisions or opposite clear corneal incisions, in combination with the multifocal IOL.

Aspheric Multifocal Intraocular Lenses

Aspheric IOL designs were introduced to decrease higher-order aberrations by compensating for the spherical aberration of the cornea. The aspheric IOL design results in a better visual outcome, especially for contrast sensitivity and visual quality under mesopic conditions. Many current multifocal IOLs also have an aspheric optic design to optimize visual function.

COMPARISON BETWEEN MULTIFOCAL AND MONOFOCAL INTRAOCULAR LENSES

Regarding safety, it is mandatory to compare results for multifocal technology with those achieved with the pre-existing, standard, monofocal IOLs. This is best done by a meta-analysis of randomized controlled trials. Leyland and Pringle² have performed such a meta-analysis of trials with a direct comparison of multifocal and monofocal IOLs.

Distance and Near Visual Acuity

Concerning unaided distance visual acuity, no significant difference was observed between different multifocal IOL designs and monofocal IOL designs.

As expected, there was improved near vision in patients with multifocal implants (on average, Jaeger 3).

Contrast Sensitivity

A clear trend has been seen for multifocal IOLs, especially diffractive IOLs, to result in reduced contrast sensitivity compared with monofocal IOLs. However, different methods of contrast sensitivity testing were used across trials so that a meta-analysis of the data was not possible.

Dysphotopsia

The use of monofocal IOLs demonstrated better results compared with multifocal IOLs when subjective glare testing was performed or when patients were questioned about the presence of glare or halos.

Spectacle Dependence

Leyland and Pringle² found that the majority of multifocal IOL-implanted patients still used spectacles for some tasks, usually small print. However, the number of multifocal IOL patients who were completely independent from spectacles ranged from 26% to 47% across trials compared with the much lower proportion of 1% to 11% when monofocal IOLs were implanted.

Complications

As expected, there were no differences concerning complications during cataract surgery when multifocal IOLs or monofocal IOLs were implanted. However, it should be mentioned that decentration, or tilt, of multifocal IOLs may result in more pronounced dysphotopsia and a decrease in visual quality.

Patient Motivation

Leydolt et al³ observed a long-lasting decrease in spectacle dependence when they motivated patients implanted with standard monofocal IOLs to read without spectacles in the first months after surgery. Patients with standard cataract surgery were randomly assigned to a “motivated” or “not motivated” group. In the motivated group, patients were asked not to use reading spectacles to “train” their near vision. In both groups, best-corrected distance visual acuity (VA); distance-corrected near VA; best-corrected near VA; the defocus curve; reading speed; as well as pilocarpine-, cyclopentolate-, and near-point-induced IOL shift assessed with partial coherence interferometry were measured and shown to be the same for both

groups. In addition, a questionnaire concerning postoperative satisfaction, independence of using reading spectacles, and daily-life performance without spectacles was given to the patients. Although visual performance and IOL shift was similar in both groups, 40% of the motivated patients and only 11% of the unmotivated patients were completely independent of spectacle use. The fact that motivated patients seem to adapt strategies that allow them to read without spectacles for a significant proportion of time should be taken into account when results of multifocal IOL studies without a control group are evaluated.

PSEUDOACCOMMODATION AND PUPIL SIZE

Pseudoaccommodation

Some patients who have undergone cataract surgery and have received monofocal IOLs have good distance and near vision and do not need spectacles for either distance. The patients attain this through a large DOF of the eye or pseudoaccommodation (see Chapter 17). This is influenced by various factors, such as small pupil size, myopic astigmatism, corneal multifocality, and the higher-order aberrations of the eye. In addition, macular and cortical function, related to perception, are known to play a role in extracting information from a defocused image, such as deciphering optotypes from a reading chart. Therefore, visual perception also contributes to psychophysically assessed pseudoaccommodation. These effects can sometimes result in good uncorrected distance and near vision with standard monofocal IOLs.

Pupil Size

To measure the influence of pupil size on visual quality using different multifocal IOLs, Choi and Schwiegerling⁴ fabricated an artificial eye that had the average spherical and chromatic aberration levels found in the human eye. Different multifocal IOLs were inserted into a saline-filled wet cell. Two different pupil sizes (3 and 6 mm) were preset before the measurements were started using refractive, diffractive, and apodized multifocal IOLs. Outcome parameters of this study were the modulation transfer function (MTF) and simulated nighttime driving performance using a portable device to photograph nighttime

driving scenes through the IOLs. Using the 3-mm pupil size, the apodized and full-aperture diffractive IOLs produced similar MTFs for near and distance vision, whereas the zonal refractive IOL performed poorly for near vision. When the 6-mm pupil was used, the apodized diffractive IOL shifted optimal performance from near vision to distance vision, whereas the full-aperture diffractive IOLs continued to balance performance between distance and near. The night-driving photographs showed more stray light artifacts for the zonal refractive than the full aperture and apodized diffractive IOLs.

Ortiz et al⁵ showed that refractive multifocal IOLs result in higher intraocular aberrations, whereas hybrid refractive-diffractive multifocal IOLs were least affected by pupil diameter in terms of aberrations. Refractive-diffractive multifocal IOLs showed significantly less increase in optical aberrations when the pupil was enlarged (Figure 18-3).

MULTIFOCAL INTRAOCULAR LENSES—A GOOD SOLUTION FOR EVERYBODY?

Patient Selection

Haring et al⁶ compared the incidence and severity of photic phenomena after the implantation of a refractive multifocal IOL and a monofocal IOL. Patients were randomly selected from groups of patients who were implanted with multifocal and monofocal IOLs and were asked whether they experienced light sensations postoperatively (light streaks, halos, flare, flashes, or glare) that they had not noticed preoperatively. In the multifocal group, more than 40% of patients reported dysphotopsia, whereas only 9% of patients in the monofocal IOL group reported these effects. In detail, patients in the multifocal group mentioned significantly more halos and flare compared with the monofocal group. In total, 18% of patients in the multifocal group were bothered by these phenomena, compared with only 4% in the monofocal group.

Patient selection for multifocal IOL implantation has to be performed carefully. For example, implantation of multifocal IOLs is not recommended in patients who drive at night for a living, such as taxi drivers.

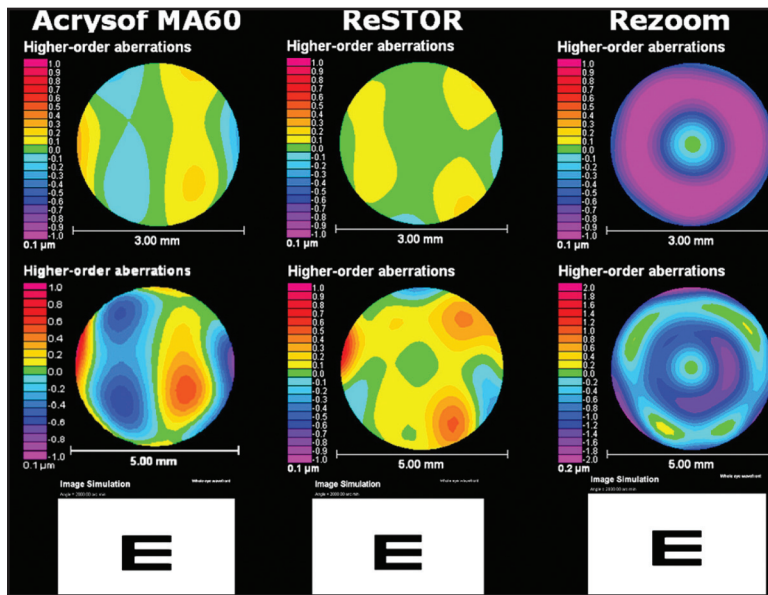


Figure 18-3. Comparative maps of the in vivo intraocular wavefront of 3 IOLs (*monofocal*: AcrySof MA60 IOL, Alcon Laboratories, Fort Worth, TX; *diffractive*: AcrySof ReSTOR, Alcon Laboratories; *refractive*: ReZoom, Advanced Medical Optics [AMO], Santa Ana, CA) with a 3.0-mm pupil (top row) and 5.0-mm pupil (center row). Bottom row: E-Snellen simulation considering the total ocular aberrations with a 5.0-mm pupil. (Reprinted from *J Cataract Refract Surg*, vol 34(5), Ortiz D, Alio JL, Bernabeu G, Pongo V, Optical performance of monofocal and multifocal intraocular lenses in the human eye, pp 755-762, Copyright 2008, with permission from Elsevier.)

Multifocal Intraocular Lenses for Patients With Concomitant Eye Diseases

Due to the fact that most of the relevant eye diseases increase with age, such as age-related macular degeneration, diabetic macular edema, or glaucoma lead to a decrease in contrast sensitivity, there is debate over whether multifocal IOLs should be implanted in patients at risk for such disease. To date, however, there are few clinical data for these scenarios. Kamath et al⁷ showed no disadvantages for glaucoma patients receiving multifocal IOLs, but the sample size was very small, with only 11 glaucoma patients included.

Teichman and Ahmed⁸ suggested the following patient groups to be potential candidates for multifocal IOL implantation: glaucoma suspects and ocular hypertensive patients with no disc or visual field damage who have been stable; glaucoma patients with early or mild visual field damage that has been controlled and stable; and patients with a level of glaucoma in the fellow eye that is similar and not severe, advanced, or progressive.

It appears to be unwise to implant multifocal IOLs in patients at risk of developing retinal disease or glaucoma, which could then potentially result in very poor contrast sensitivity and poor visual function. These patients are typically not good candidates for IOL exchange either, which may become necessary to restore some useful visual function. A conservative approach to using multifocal IOLs in patients at risk of concomitant disease appears sensible.

Multifocal Intraocular Lenses for Children

In contrast to most cataract patients, children have the capability to accommodate. Therefore, multifocal IOLs may play a role. However, safety and effectiveness in the pediatric population needs to be demonstrated.⁹

One of the main problems concerning multifocal IOL implantation in children is the refractive shift that occurs with the growth of axial eye length. Another aspect is potential aggravation of amblyopia secondary to the loss of contrast sensitivity associated with multifocal IOLs.

The question of what age multifocal IOLs could be implanted is controversial. Due to the fact that 80% to 90% of the eye growth occurs within the first 2 years of life, some surgeons argue that multifocal IOLs could be used in young children, whereas many surgeons suggest that multifocal IOL implantation should be carried out only in children above the age of 10.⁹ Wilson et al¹⁰ observed an average change in axial eye length of 0.5 mm in the second decade of life, with a large variation between patients. These data may suggest that multifocal IOLs should not be used in the first 2 decades of life.

In addition, it should be mentioned that emmetropia, or slight hyperopia, should be achieved for adult and pediatric patients when the power of a multifocal IOL is calculated because myopic patients with multifocal IOLs may be more spectacle-dependent postoperatively compared with patients who received monofocal IOLs.¹¹

A relatively high rate of complications was observed after implanting multifocal IOLs in children.¹² In total, 67% of patients were spectacle-dependent after implantation of multifocal IOLs, and nearly 50% of the patients developed posterior synechiae, one-third developed severe fibrin reactions, and 17% of the patients had to be reoperated due to decentration of the IOL. Although these complications could be expected in similar numbers after implantation of monofocal IOLs in pediatric patients, it should be taken into account that tilt and decentration of the IOL, due to fibrosis and posterior capsule opacification, influence the visual outcome more when multifocal IOLs are implanted.

SUMMARY

There is good evidence that the use of multifocal IOLs improves near vision, with only little adverse effect on distance acuity. Especially for patients who want to be less spectacle-dependent, implantation of multifocal IOLs may be a useful option. Although some patients who receive monofocal IOLs do not need spectacles for reading or for distance due to pseudoaccommodation, spectacle independence is more likely to occur with multifocal IOLs. The drawbacks of multifocal IOLs are decreased contrast sensitivity and dysphotopsia, such as glare or halos. This needs to be taken into account for the informed consent process, and careful patient selection is key to success with multifocal IOL technology.

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