4 Multifocal Intraocular Lenses: Preoperative Considerations

Jorge L. Alió and Joseph Pikkel

As in every surgery, the surgeon and the patient should know and anticipate every aspect of the surgery and its results, as well as possible complications. In planning a cataract surgery with an implant of a multifocal intraocular lens, a wide spectrum of possible impacts can affect the final outcome, and hence the surgeon should be aware of them and take them into consideration. In this chapter, we will describe the various factors that should be known and understood prior to implanting a multifocal intraocular lens.

As in every surgery, the two "main players" are the patient and the surgeon, and hence there are factors that are patient-dependent and factors that are surgeon-dependent. In trying to simplify the process, we can narrow the preoperative considerations into three main questions or surgeon's considerations:

- Should I implant a multifocal intraocular lens?
- What kind of a multifocal intraocular lens should I use in this case?
- How should I calculate the multifocal intraocular lens power?

The use of multifocal intraocular lenses in special cases as well as the different qualities and specifications of existing multifocal intraocular lenses in the market today will be discussed in other chapters of this book; however, there are general considerations that apply in all cases.

Fig. 4.1 shows a schematic process of MF ILO preoperative considerations.

4.1 Patient's Factors

A major preliminary consideration is the patient's lifestyle and personality. Another important consideration is the patient's clinical ophthalmological situation. Inquiring about the patient's daily life as occupation, hobbies, daily activities, dysphotopsia and every other information is necessary in order to decide if the patient is a candidate to have a cataract surgery with a multifocal intraocular lens implant. Since the main cause of failure of multifocal intraocular lens implant and patient's disappointment is patient's inability to neuro-adapt to the multifocal intraocular lens, patient's personality is important in estimating the patient's ability

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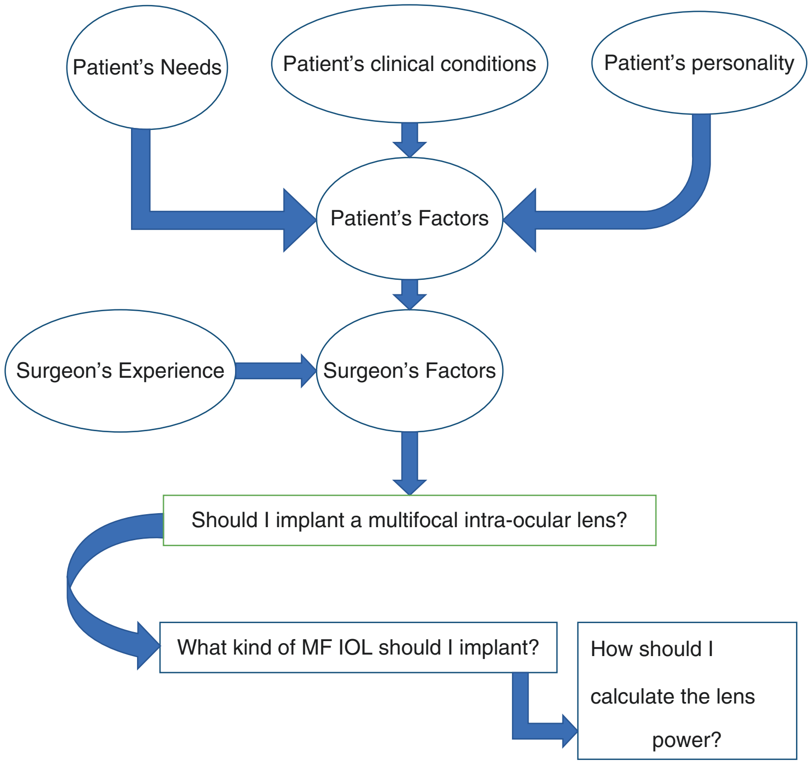

Fig. 4.1 Schematic process of MF ILO preoperative considerations

to neuro-adapt mainly in cases of post-operative dysphotopsia, glare and halos. Patients who complain about these phenomena prior to the surgery might be post-operative unhappy patients. Knowing your patient's personality and needs is a key factor of success in cases of multifocal intraocular lens implant. It might be wise, in some cases, to give up multifocal intraocular lens implant and compromise (in advice with the patient) implanting a mono-focal lens rather than having dissatisfaction and unhappy patient. Patients who have unrealistic expectations should be avoided from multifocal intraocular lens implant—they usually do not adapt and keep on complaining [1].

Patient's needs and preferences also play a role in choosing the right lens. A patient who reads a lot but does not use a computer or watches television, for example, may benefit more from good near vision than from good intermediate vision, and hence a multifocal intraocular lens that provides better near vision and less intermediate vision might be a good choice in this case. The combination of a proper patient selection and a proper lens selection results eventually in a satisfied patient.

A special care should be taken while treating patients who are mono-focal contact lens users for a long time. Multifocal intraocular lens implanted in these patients is a totally different solution for their refractive error than they are used to. These patients may have a greater difficulty in neuro-adapt to a multifocal intraocular lens.

4.2 Clinical Factors

The patient's clinical condition also plays a major role in deciding if to implant a multifocal intraocular lens. Postsurgically, vision degradation may result from surface dryness, blepharitis, basement membrane dystrophy, corneal scarring, corneal oedema, intraocular lens tilt, decentration of the lens, posterior capsular opacity, macular oedema, other retinal diseases and residual refractive error or astigmatism. Out of these variables, those that exist prior to operation must be diagnosed, and an effort should be made to predict the post-operative possible disturbances and try to avoid them—surface diseases and blepharitis should be treated prior to operation, and corneal scarring or diseases should be considered while planning the cataract operation. Among other things, the patient's ocular conditions in addition to its personality and lifestyle are factors that the surgeon should be aware of while choosing the specific multifocal intraocular lens that pits the best to the individual patient [2].

While the majority of patients, about 90%, will be satisfied with the final result of the operation, some patients will not benefit from multifocal intraocular lenses. Surgeons should avoid patients who have ocular pathology that precludes normal visual potential or a chance of satisfactory multifocality free of spectacles.

Patients who work at night, drive at night or have already contrast sensitivity problems might experience a further reduction in their contrast sensitivity and may have troubles in keeping their daily routine—mainly at night and in deem light conditions. These patients should be explained of the possible risk of contrast sensitivity reduction after a multifocal intraocular lens implant and adjust their expectations; in some cases it might be wise to advise these patients to avoid multifocal intraocular lens implant. In these cases, if a multifocal intraocular lens is implanted, the surgeon should use a multifocal intraocular lens that has the least contrast sensitivity reduction [3, 4].

4.3 Lens Considerations

The use of intraocular multifocal lenses becomes more common and technological innovations as well as new designs results in a constant improvement of these lenses. As a result, there is a large variety of multifocal intraocular lenses in the market, and surgeons may be confused as to what lens should they choose [5].

The value added by multifocal intraocular lenses, in comparison to mono-focal lenses, is the multifocal lens' optical function. A good multifocal intraocular lens design should give the surgeon the tool to adapt vision to the patient's lifestyle. To do that, one should understand the optical principals needed in an optimal multifocal intraocular lens.

Multifocal intraocular lenses optics are either rotationally symmetric or rotationally asymmetric. Some multifocal intraocular lenses modify the index of refraction so that it changes from the periphery to the centre of the lens, giving an adequate optical solution for different pupil's size. Some multifocal intraocular lenses are designed aspherically in order to remove chromatic aberrations, thus improving near and intermediate vision.

In order for a multifocal lens to be efficient, astigmatism must be completely eliminated, and therefore the ability to use multifocal toric intraocular lenses is of great importance. Since in most cases, multifocal intraocular lenses induce reduction of contrast sensitivity, this should be another concern when choosing a lens to implant. One should try to choose the multifocal intraocular lens that induces less reduction of contrast sensitivity. Multifocal intraocular lenses are contraindicated, because of the reduction of contrast sensitivity, in eyes of patients with aberrated corneas or in patients who already suffer from limited contrast sensitivity such as in cases of maculopathy, retinal dystrophy glaucoma or advanced senility [6].

In designing what kind of a multifocal intraocular lens one should implant, there are some important facts to guide our decisions towards a successful outcome.

Following many years of clinical experience implanting different multifocal IOLs appeared in the market and many clinical studies as well as our present understanding on the patient's needs, we postulate to follow these main principals as guidelines for the design and selection of a modern multifocal IOL:

- *The far focus should be dominant*. Humans are diurnal predators; therefore, our brain's dominant need is for distance vision. Another advantage of the dominance of far vision is the decrease of focus overlapping and reduction of glare and halos [7].

- *Adequate disparity between foci*. In order to produce an acceptable intermediate vision, some multifocal intraocular lenses are designed to have an overlap of the foci. However, while the intermediate vision is gained by this overlap, it produces also the disturbing phenomena of halos and glare. Therefore, the overlapping of foci should be minimized to decrease the incidence of halos and glare. In lenses where the near vision add is less than +3.00, the incidence of halos and glare will increase [8].
- *Aspheric design*. In our quest to achieve the best possible optical performance from the multifocal intraocular lens, one of our desires is that the lens should be free from aberrations. Aspheric lenses improve overall the optical performance of the lens. Asphericity is even more important considering that about 20% of patients do not have what is considered as a standard value of asphericity which is 0.27 microns. Lack of asphericity is even more common in patients who have previously undergone corneal refractive surgery [9].
- *Toricity available*. As mentioned before—for a multifocal intraocular lens to be efficient—astigmatism must be completely eliminated. If after the multifocal intraocular lens implant there is a residual astigmatism of more than 1.00 D, laser touch-up is required. About 4% of patients have more than 3.00 D of corneal astigmatism and 70% of patients have more than 1.00 D of corneal astigmatism; therefore, the availability to use toric multifocal intraocular lenses is of great importance [10].
- *Pupil independence/dependence*. Pupil size after cataract surgery is unpredictable, especially in cases in which the pupil was mechanically dilated. Pupil size is also affected by environmental conditions which are unpredictable as well. On the other hand, many of the multifocal intraocular lenses are designed so that the refractive power changes according to the distance from the lens centre and relays on a mean pupil size. Since the pupil size is unpredictable, the implanted lens should not depend on pupil size to obtain adequate performance for far and near vision [11]. For this reason, while in some cases pupil independency may be the best option, in cases with normal pupil reactivity pupil dependency may be a good alternative option.
- *Good optical performance at the optical bench and "in vivo"*. Lenses manufacturers are designing and testing intraocular multifocal lenses in order to produce the best available lenses; however, these efforts provide good performance at the optical bench in which conditions are not necessarily the same as inside the eye. Once a multifocal intraocular lens is implanted, intraocular conditions affect its optical performance and might decrease it as much as 50% compared to the optical performance on the optical bench. There is no way to predict the IOL performance in vivo when a new lens is introduced to the market; therefore, the optical quality as well as unpredictable aberrations should be carefully looked for by the surgeon and the first patients to be having the new lens implanted should be closely followed up and optical performance and aberrations should be measured at least 3 months after lens implantation in order to study the real quality and performance of new multifocal intraocular lenses designs [12].
- *Capsular bag stability.* The capsular stability is of great importance in achieving the best possible optical performance of the implanted lens. Instability of the capsular bag may cause tilt and decentration of the implanted lens, thus causing starbursts and preventing adequate focusing of light waves in different distances. A decentred or tilted lens may cause photic disturbances and a major inconvenience to the patient. Capsular stability is affected by the patient's zonular stability and by the implanted lens. While one cannot affect zonular stability, the implanted lens should be designed so that it does not reduce capsular stability and it is made by biomaterial that does not reduce this stability as well [13].
- *Low posterior capsular opacity rate*. There is no doubt that the capsular bag should be cleaned as possible during cataract surgery; however, there is major role in preventing posterior capsular opacity by the implanted lens

as well. Again, adequate lens design and biomaterial of the lens are major factors in preventing posterior capsular opacity. Light scattering and posterior capsular opacity significantly decrease the multifocal intraocular lens' performance and may lead to the need of ND:YAG capsulotomy. Though ND:YAG capsulotomy may resolve this problem, it may lead to difficulties in case of a necessary replacement of the implanted lens [14].

- *Compatibility to micro-incisional surgery.* As cataract surgeries move towards micro-incisional surgeries, the multifocal intraocular lens should be implantable through a sub 2 mm incision. The benefit of the practice of micro-incisional cataract surgeries is that it does not change the preoperative astigmatic or aberrometric corneal profile, while larger incisions do. The need for a multifocal intraocular lens implantable through a sub 2 mm incision is there for obvious. A lens implantable through a micro-incision helps the surgeon to control astigmatism and aberrations which are the two components necessary for optimal performance of these lenses [15].
- *Good far and adequate intermediate and near visual outcomes*. The quest for perfect vision in all distances is not achievable in current intraocular multifocal lenses. As mentioned before, the far focus should be dominant, hence, giving the patient a good far visual outcome. Nevertheless, the aim of intraocular multifocal lenses is to free the patient from the need to use spectacles or contact lenses; therefore, not only that the lens should provide excellent far vision, but it should also provide adequate intermediate function such as office and domestic tasks as well as adequate near functional vision for reading and other activities in which near vision is important for [16].

Now that we are aware of the patient's needs and personality as well as our knowledge of how to evaluate the performance of multifocal intraocular lenses, we can decide if a certain patient is a good candidate to a multifocal intraocular lens implant. If one have decided to implant a multifocal intraocular lens, there are still the preoperative measurements and lens power calculation.

4.4 Defocus Curves

Another way of comparing lenses' performance is using defocus curves. A defocus curve is a universally accepted measure of evaluating the subjective range of clear vision in presbyopia correction techniques such as accommodating and multifocal intraocular lenses.

A defocus curve provides an indication of the level of vision a patient can expect at various distances, simulated using minus and plus lenses in a phoropter to change the relative vergence of a distant eye chart. The first step in generating a defocus curve is measuring the patients' far vision refraction. Using the patient's distance refraction removes the variability due to residual refractive error. The next steps are changing the power of lens in half dioptre steps from slightly positive (+1.00 D or + 2.00 D) to about −4.00 D. In each refractive correction, vergence is measured. Defocus curves are graphs showing the relationship between lens vergence and distance focus. Usually, the main interest is in three important points: infinite optical distance vision, intermediate distance to 80 cm and a short-distance vision at 40 cm. These three points are actually representing the visual performance of the lens, as well as visual and optical quality of the patients in their daily lives.

If the patients' peak (best visual acuity) is at 0.00 diopters, it means that the intraocular lens provides good far vision. If the second peak is at around −2.50 diopters, it means that the lens provides good near vision sight (100/2.50 = 40 cm which is a comfortable reading distance). The height of the curve represents visual acuity in LogMAR, and the horizontal line is the additive lens power. Interpretation of defocus curve in brief is searching for the peaks and to what dioptre do they match and the flatness of the curve. Peaks should be at the diopters where we expect good vision for far (0.00D), intermediate (80 cm or − 1.25D) and near (40 cm or − 2.50D). Flatness of the curve means that the lenses' performance is similar in each correction. An ideal lens would produce a straight line at the height of LogMAR zero, but this is unachievable. In the following figure, a typical defocus curve is represented: (Fig. 4.2).

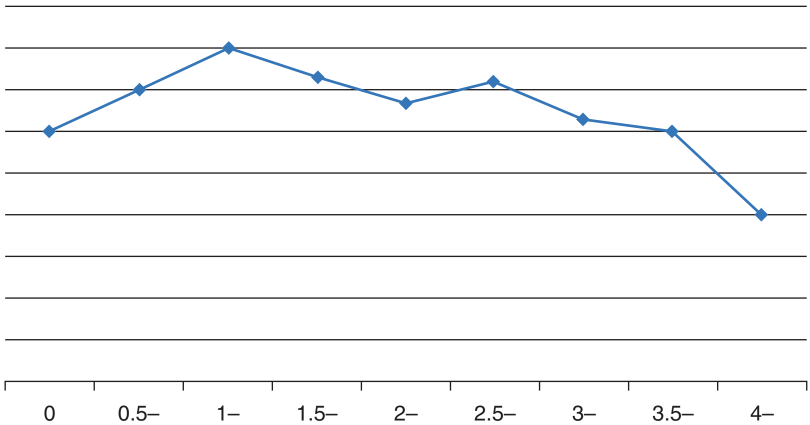

Fig. 4.2 A typical defocus curve

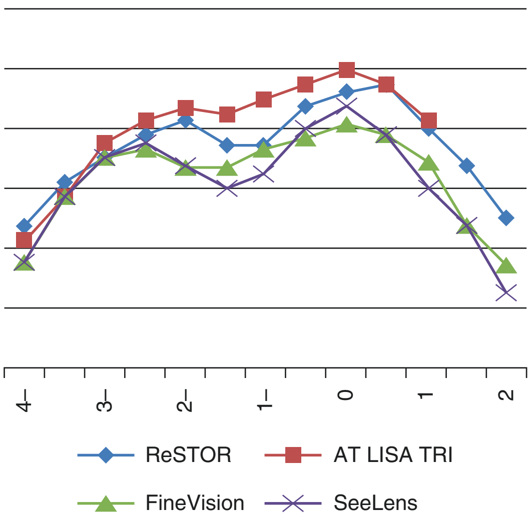

Fig. 4.3 Comparing different lenses' performance using defocus curves

In a study done at VISSUM in Alicante, Spain, three multifocal lenses' and two accommodative lenses' defocus curves were checked. The three multifocal lenses that were checked were the AT LISA tri 839MP; the Fine Vision trifocal, single-piece, foldable aspheric intraocular lens and the Bifocal AcrySoft Restor SN6AD1 (Alcon, Fort Worth, USA); and the Hanita SeeLens multifocal. The defocus curves of these lenses are in the following figure and represent typical defocus curves (Fig. 4.3).

As can be seen, the four lenses have a peak close to zero which means good far vision. Two of the lenses have a second peak near −2.50 diopters which means near vision good at 40 cm, while the other two have a better near vision by the distance of 50 cm. As a role, the flatter the curve is, the better is the performance of the lens. The flatter the curve is means that same vision is kept at different distances. However, the visual acuity is important too as the height of the curves' peak means the better visual acuity. In the figure, one curve is the highest, which means that visual acuity with all corrections was better.

Defocus curves are a useful method to evaluate the effectiveness and visual performance for specific IOL models using different levels of defocus (equivalent to different viewing distances). The problem with defocus curves is that there is no standardized methodology for measuring defocus curves; an assortment of different lens power has been used to evaluate IOLs; for multifocal IOLs, however, defocus curves can be useful for comparing lenses. In a current literature search that we have done, defocus curves of most of the lenses that exist in the market can be found. Different studies use different additive steps; however, comparing these studies does not show a significant difference in terms of the overall performance of lenses.

We recommend using defocusing curves as good tools to compare multifocal intraocular lenses' performance.

4.5 Multifocal Intraocular Lens Power Calculations

The aim of multifocal intraocular lenses is to free the post-operative patient from the use of spectacles or contact lenses. In order to achieve this goal, astigmatism should be eliminated and the refractive error should be ±0.25 D of plane.

Several measurements are required for determining the proper multifocal intraocular lens power [17–19]:

- Patient's age
- Central corneal refractive power (K readings)
- Axial length
- Horizontal cornea diameter ("white to white")
- Anterior chamber depth
- Lens thickness
- Corneal topography and corneal aberrometry
- Preoperative refraction
- Pupil size and pupil reactivity
- Ocular surface quality and dry eye
- Comorbidities

Though several formulas for intraocular lenses power calculations have been suggested by different investigators, there are no significant differences between them, and they vary in slight differences in assumptions of retinal thickness and corneal index of refraction. There are six variables that affect intraocular lens power calculations (K reading, axial length, lens power, effective lens position, desired refractive outcome and vertex distance). The only unpredictable variable is the effective lens position which is defined as the distance between the corneal anterior surface and the intraocular lens position. The term effective lens position is used because it is more accurate than anterior chamber depth. The effective lens position is affected by the intraocular lens design as well as positioning of the lens by the surgeon, but by assuming that the lens will be properly positioned, the effective lens position prediction is important for calculating the intraocular lens power. The common practice is using, for intraocular lens power calculations, in patients with axial length of 22–25 mm, third-generation formulas such as the Holladay [18], SRK/T [20] and Hoffer Q [21]. In cases outside this range, the Holladay 2 formula is considered to be more accurate.

Determining the desired multifocal intraocular lens power is slightly different than in intraocular mono-focal lenses where a slight post-operative myopia may be beneficial. In implanting multifocal intraocular lenses, the refractive target should be exactly plane or the nearest to zero hyperopic outcome (dependent on the available lenses). The near vision with multifocal intraocular lenses is usually good, and a slight myopia may cause an inconvenient near vision and reading vision [22].

As achieving the best available distance sight is the main goal, after measuring K readings, axial length and using the known a constant of the lens to be implanted, calculating the lens power for distant vision is possible using one of the formulas mentioned before. Near sight power should be calculated when considering among other things patient's needs and lifestyle.

Although the lens design and the other variables described earlier are the main factors influencing the desired refractive outcome, variations in surgery such as placement of the implanted lens, location and design of the incision and variations in calibrations and types of axiometers and keratometers may also be important. Each surgeon should personalize the lens constant by the outcomes of the first 20–40 cases of implanting a specific lens. This is the only way to achieve superior results with multifocal intraocular lenses and accuracy within ±0.25 D for 95% of patients [22].

In recent years, a few new formulas for calculating the multifocal intraocular lens power were developed as well as a few studies were made on comparing different biometers and the post-operative refractive results. These studies are part of a trend of using a "tailor-made" calculation that pits the specific patient as small eyes, myopic eyes, etc. [22–24]. This is a true advancement in lens power calculation that pits the modern approach of "personalized medicine".

Accurate K reading, axial length measurement, anterior chamber depth measurement, corneal diameter, lens thickness and preoperative refraction along with personalizing the lens constant and determining the correct refractive target are critical to ensure excellent results and patient's happiness with multifocal intraocular lenses.

4.6 Corneal Topography

There is an important role of corneal topography in preoperative cataract surgery considerations especially when implanting a multifocal intraocular lens. Since eliminating astigmatism is of great importance, corneal topography is important in planning the surgical incisions as well as in calculating the power of the implanted lens as described before. An accurate preoperative assessment of corneal shape provides understanding of pre-existing corneal aberrations that might affect the visual outcome. Since overall visual function depends on each of the optical components along the visual axis, corneal topographic characteristics can significantly affect the visual performance.

An accurate preoperative corneal surface assessment provides understanding of corneal aberrations that might affect the final visual outcome. Corneal topography is an important tool in planning the surgical incisions since small changes in corneal curvature can significantly influence the focus of light on the retina [25]. Surgical incision location is therefore of importance–surgical wound that is placed over the steep axis will reduce existing astigmatism [26]. Corneal topography is also important in estimating the amount of lenticular astigmatism and as this component will disappear after operation it should not be treated or affect the planning of the surgical incisions [27].

Corneal topography is even of more importance in patients who had prior corneal refractive surgery for accurate lens power calculation as well as for residual corneal astigmatism and aberrations assessment. Though still not the majority of patients who need cataract surgery, these patients are a group of patients that is rapidly growing [28].

4.7 Angle Kappa

One of the surgeons concerns should be preventing post-operative glare and halos. For that, knowing the patients' angle kappa is important. Angle kappa is the angular distance between the pupillary axis which is an imaginary perpendicular line from the centre of the cornea travelling into the eye via the centre of the pupil and the sight line which is the line representing the light ray that travels from the object to the fovea (Fig. 4.4).

If the angle kappa is large, the sight line, which is light ray from the object, falls in a distance from the fovea, causing halo or glare. There are several ways of evaluating the angle kappa; however, the

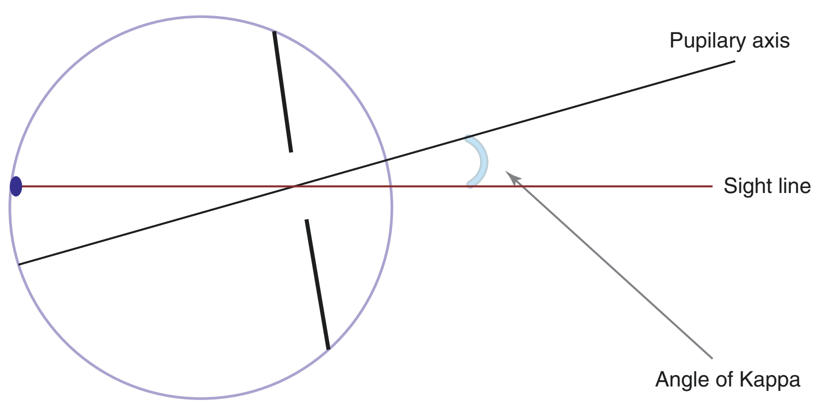

Fig. 4.4 The angle of kappa

simplest way to determine if angle kappa exists is by a simple examination of the corneal light reflex. The patient should be instructed to fixate on a light source held directly in front of the patient. If there is a decentred corneal light reflex from one or two eyes, a cover test should be done. If there is a shift of the eye manifest strabismus exists, and if no shift exists, angle kappa might exist. The next step is evaluating visual acuity and slit lamp examination of the pupil. Decentred corneal light reflex may be in cases of corectopia or coloboma or in cases in which visual acuity is abnormal due to macular pathology or eccentric fixation. If corneal light reflex is decentred and there is no pupillary abnormality, strabismus or abnormal visual acuity, angle kappa exists. If the decentration is nasal we call it positive angle kappa, and if the decentred reflex is temporal we call it negative angle kappa. Estimating the amount of decentration is by estimating the distance from the corneal centre to the corneal light reflex. Using instruments like Synoptophore and Orbscan was suggested too in order to measure angle kappa [29].

Recently, studies suggesting angle kappa as a cause for photic phenomenon after multifocal intraocular lenses implant were published, recommending evaluating angle kappa at the preoperative examination in order to avoid this disturbing outcome [30]. One of these studies suggested that patients with high angle kappa should be excluded from multifocal intraocular lenses implant because of the higher risk of postoperative photic phenomena [31].

As one can see, preoperative considerations are of most important especially in cataract surgeries with multifocal intraocular lenses. Though many factors influence the final outcome, none should be ignored or overlooked. Selecting a proper intraocular multifocal lens which pits patients' condition, needs and lifestyle is an essential part of a successful surgery. Planning ahead surgical incisions and strategy, according to clinical findings at the preoperative examination, helps to tackle possible problems during surgery and yet again to achieve the goal of patients' satisfaction.

Though we described here possible complications of multifocal intraocular lens implant, and a long list of preliminary considerations, overall, the value of multifocality for patients far exceeds the temporary discomfort of patients and surgeons and the short-term dysphotopsia that a few experience with multifocal intraocular lenses.

Compliance with Ethical Requirements Jorge L. Alió and Joseph Pikkel declare that they have no conflict of interest. No human or animal studies were carried out by the authors for this article.

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