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Optimizing Outcomes with Multifocal Intraocular Lenses

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Abstract

Current present-day cataract surgery evolves from a visual restoration to a refractive approach. Greater independence from glasses and improvement of the quality of life were provided after surgery with the appearance of multifocal intraocular lenses (MF-IOLs). Since its creation in the 1980s, MFIOLs has undergone various technical improvements, including trifocal implants and implants with extended depth of vision. Excellent results were achieved thorough preoperative check, including the visual needs of the patients and the inherent eye anatomy. This analysis offers a broad overview of the various types of Mf-IOLs and rules for optimizing results through full preoperative screening and treatment postoperatively complications.

Keywords: Diffraction Intraocular Lens; Intraocular Lens; Multifocal Intraocular Lens; Presbyopia Correcting Intraocular Lens

Introduction

Nowadays, cataract surgery is rapidly getting transformed into a refractive procedure with the transition from visual regaining to the normal refractive condition of the eye (Emmetropia) as a post-operative goal. Intraocular lenses have undergone various changes similarly with the improvement of equipments and methods of cataract surgery. Multifocal intraocular lens (MFIOL) implants afford a postoperative vision without glasses, both at a distance and near [1].

The review paper provides a full overview of several types of multifocal intraocular implants, preoperative evaluation and planning for improving surgical outcomes, present visual results, postoperative complications and handling of discontented patients [2].

Types of multifocal intraocular lenses

Accommodation, a property of the young lens, the ability of the eye to focus from distant to near objects. When a person is getting old or after a cataract surgery where the natural lens is replaced with a monofocal intraocular lens, the quality of accommodation is usually get lost. Intraocular lenses with presbyopia correction (IOL), including MFIOLs, provide independence for both near and far vision [3].

Three ongoing optical principles have been applied to ensure multi-focus in modern IOLs: multi-zone refractive, diffractive, and extended vision ranges (EROV) [4].

Concentric or annular ring-shaped zones with different diopters are used for refractive IOLs. The number of used zones changes, in dependent of the diameter of the pupil in the condition of the light and accommodation, to redistribute the proportion of light directed at the distance and close. Therefore, image quality and energy balance depend on the pupil [5].

Diffraction IOLs are designed with microscopic steps of a certain phase delay, usually at half the wavelength: the Huygens-Fresnel principle. At all pupil diameter, the light that falls on these steps is directed equally between the far and near focal points. Part of the light, about 18% of the energy, is directed to higher diffraction orders, and the rest is distributed equally over the far and near distance, i.e. 41% each [6].

The principle of Apodization was built on a greater need for remote vision in low-light conditions (when the pupils are large). Besides, a greater focus of light on the far focal point reduces the unfocused low beam with the subsequent visual phenomenon of glare and halos. This is achieved by gradually reducing the height of the diffraction pitch from the center to the periphery and then using a remote-dominant lens for large pupils [7].

Extended depth of focus (EDOF) IOL: Symfony IOL (Tecnis, Abbott Medical Optics Inc., Johnson and Johnson vision) unite a unique diffraction pattern with achromatic technology and a patented echelette design that supplys increased depth of focus [8].

To overcome the limitations associated with previous bifocal models, trifocal IOLs with three focal points were launced. Additional intermediate focus provides excellent vision quality for intermediate actions (Table 1).

	Type of optic	Optic diameter (mm)	IOL material	Add at lenticular plane (D)	Light distribution
ReZoom (AMO)	Refractive surface	6	UVblocking hydrophobic acrylic	+3.0 for near	Pupil dependent
ReSTOR (Alcon)	Anodized anterior diffractive surface plus refractive base	6	UV blocking hydrophobic acrylic	+3.0 D for near (SN6AD1) +2.5 D for near (SN6AD2)	Pupil dependent
Tecnis Multifocal (AMO)	Posterior nonapodized diffractive surface	6	Hydrophobic acrylic	+4.0 (ZMB00) +3.25(ZLB00) +2.75(ZKB00)	41% near 41% distance
AT LISA 809 (Carl Zeiss)	Posterior nonapodized diffractive surface	6	Hydrophilic acrylic (25%) with hydrophobic surface	+3.75 D for near	35% near 65% distance
Tecnis Symfony (Johnson and johnsons vision)	Anterior aspheric with posterior achromatic diffractive surface with echelette design	6	UV blocking hydrophobic acrylic	Extended depth of focus (ZXR00)	Pupil independent
AT LISA tri 839 (MP Zeiss)	Trifocal aspheric diffractive	6	Hydrophilic acrylic (25%) with hydrophobic surface	+3.33 D near add and +1.66 D Intermediate add	50% near, 20% intermediate, 30% near
Acrysof IQ Panoptix	Inner diffractive with outer refractive zone	6	UV filtering aspheric hydrophobic acrylic	+3.25 D near add and +2.17 D Intermediate add	
Acridiff (CARE group)	Apodized diffractive	6	UV blocking hydrophobic acrylic	+3.25 D near add	40% near, 60% distance
Infocus (Supraphob)	Anterior Refractive EDOF and micro diffractive optic with aspheric posterior surface	6	UV blocking hydrophobic acrylic	Extended depth of focus	Pupil independent

IOL: Intraocular Lens; UV: Ultraviolet; EDOF: Extended Depth of Focus

Table 1: Shows the characteristics of the most commonly used MFIOLs

Plan and Evaluation of pre-operation

Patient's lifestyle and expectations determine the choice of an intraocular lens. Patients who are overly critical or with unrealistic expectations are not ideal for MFIOL. The patient's visual activity and tolerance to dysphopsia at night-time ascertain the ideal choice of MF-IOL. It is really important to provide adequate advice on the possibility of loss of contrast and temporary dysphotopsia at night in exchange for a wider range of vision in the postoperative period. Furthermore, should be taken into account, the eye's inherent anatomy, physiology, and concomitant diseases that may affect visual results (should be excluded) [9].

- **Corneal astigmatism**

It was estimated that, in about 30% of eyes undergoing cataract surgery, corneal astigmatism of 1,25D or more is common. Preoperative keratometry using manual, automatic, or optical coherence interferometry can help determine the extent and location of the cylindrical forces. Repeatability of regular corneal astigmatism on various measuring devices would be an ideal case for implanting multifocal lenses. Corneal topography devices such as Pentacam (Oculus, Inc.) and intraoperative aberrometry (Ocular Response Analyzer, Wavetec Vision), can also assess astigmatism of the posterior part of the cornea [10].

Managing astigmatism is of greatest importance for obtaining ideal postoperative results with MF-IOLs. A significant decrease in visual quality is led by a postoperative astigmatic error exceeding three-quarters of the diopter. Astigmatism can be managed simultaneously by relaxing limb incisions or arched keratotomies, opposite clear corneal incisions, or toric IOL implantation, results with the former being less predictable and prone to regression over time [11].

To correct residual refractive errors, ablation procedures on the cornea have shown success. However, it is essential to attempt corrections after being ensured that adequate healing of the corneal incision and stabilization of the corneal topography. Since these patients make up an elderly population, the health of the eye surface must be confirmed, and systemic factors such as diabetes that can interfere with wound healing must be well controlled [12].

- **Cornea and external eye disease**

Improving visual results is obtained by a pre-operative evaluation and subsequent treatment of eye surface disorders such as dry eyes, blepharitis, and meibomian gland dysfunction. Although dry eyes can be considered as a post-surgery condition in patients who have not previously had symptoms, in most cases this is due to worsen of the previous condition due to a degradation of the corneal neuro-architecture and a decrease in corneal sensitivity. The most common cause of dissatisfaction in patients with multifocal implants is dry eyes, along with multifocal implants [13].

Aggressive pre-operative assessment of eye surface diseases and treatment in subclinical cases is obligatory. Medical scientists studied the results of a 3-month treatment regimen en (from 1 month before surgery to 2 months after surgery) with cyclosporine 0.05% on the visual results of patients implanted with MFOL. They declared significantly better uncorrected and corrected visual acuity compared to the control group (adding an artificial tear). In addition, contrast sensitivity, conjunctival staining, and tear film destruction time were notably increased [14].

Another corneal pathology, such as degeneration, scars and large pterygium can affect visual Results. Peripheral or visually insignificant corneal scars are not considered a contraindication for Mf-IOLs. The presence of pterygium and subsequent removal significantly affect corneal astigmatism, with larger pterygia having a greater effect. In such cases, a consistent removal procedure should be used before initating cataract surgery [15].

- **Previous refractive surgery or corneal aberrations**

The majority of candidates, who undergo prior refractive surgery, choose multifocal implants. They form a large proportion of candidates due to their big desire to get rid of glasses from the very beginning. However, a reduced contrast sensitivity is related to high aberrated corneas, as keratoconus or prior refractive surgery, which in turn will experience further impairment after a multifocal implant. Unbearable dysphotopsia has been reported after diffraction Mf-IOLs with an anterior corneal coma> 0.32 um [16].

Limited studies of MF-IOLs visual results in eyes with previous refractive surgery are available. Visual results were compared, by the scientist Alfonso and his colleagues, after implantation of hybrid refractive diffraction multifocal lenses with a spherical monofocal IOLs in 80 eyes with preliminary laser correction. The multifocal group showed lower better visual acuity correction

(BDVA) in photopic conditions with glare or low contrast, and mesopic (photopic and scotopic) conditions at all contrast levels. The authors concluded that the aspherical nature of the monofocal implant somewhat compensated for the increase in spherical aberrations after myopic Keratomileusis laser in situ (LASIK) [17].

Similar results were observed when comparing visual function in eyes implanted with Re-STOR SN60D3 IOL and in comparison with phakic eyes after hyperopic LASIK. Scientist Fernandez-Vega et al. issued their data showing the loss of one or more BDVA lines in 27.82% (6 eyes) in the multifocal group versus 3.84% (1 eye) in the a spherical monofocal group [18].

Calculating the power of the intraocular lens creates an additional problem in these eyes with less predictable results compared to normal eyes. In 2010, Scientist Muftuoglu et al. published results after implantation of MF-IOL (ReSTOR SA60D3 and ReSTOR SN60D3) in 49 eyes with the previous LASIK in myopia. No formula was used uniformly for all patients. After 1 month, 32 eyes (65%) and 41 eyes (84%) had a residual spherical equivalent within ± 0.50 D and ± 1.0 D of emmetropia, respectively. Twenty eyes underwent subsequent improvement, highlighting the degree of dissatisfaction after the initial results [19].

Profound research is needed to determine the results of MF-IOL with aspherical profiles. In addition, lacune data concerning patient satisfaction in the postoperative period, visual independence, and the degree of dysphopic symptoms must be addressed [20].

- **zonal weakness**

Variation of light distribution between the far and near foci because of decentralization or tilt of the intraocular lens, compromising the visual results of MF-IOLs. Scientists Soda and Yaguchi exhibited different effects of lens decentralisation on visual function using the transfer modulation function, but the results were overall clinically significant with decentralisation> 0.7 mm. Moreover, the effect of decentralisation and tilt on optical quality is more intoned in non-rotating symmetric IOLs compared to refractive diffraction IOLs.

Causes of IOL decentralization have been described as progressive zonal weakness, haptic deformity and asymmetric anterior capsular opening. Focal non-progressive zonal divergence, such as in the case of an injury, is not a contraindication for MF-IOL. Cases of progressive zonulopathies can serve as a basis for implanting a capsule tension ring (CTR) to stabilize the bag, reduce posterior capsular folds, and reduce late capsular contraction. Alio et al. who first evaluated CTR results with rotational-asymmetric MF-IOLs and revealed improved refractive indices and reduced postoperative aberrations. Mastropasqua noted similar results in a study comparing MF-IOL implantation results with or without CTR, with reduced third-order aberrations in the former group.

- **Kappa angle**

The Kappa angle is described as the angular distance between the pupil axis and the visual axis. The light rays from the object, if the angle is large, fall at a greater distance from the fovea, which leads to glare or halos. Karkhanova and her team studied the importance of the Kappa angle for centering MF-IOLs in a group of 52 eyes. The temporal decentralization of IOL caused a marked photic phenomenon, especially in cases with a large Kappa angle.

It was detected, according to similar results published in 2010, that the Kappa angle is one of the factors affecting the photic phenomenon in eyes with refractive multifocal implants, and recommends a thorough preoperative assessment to avoid this complication.

- **Retinal and optic nerve pathologies**

Abnormalities of the macular and optic nerves are associated with reduced contrast sensitivity. The evaluation of relevance of a multifocal implant in such cases is based on the expected progression of the disease and the effectiveness of the available therapy. Preoperative ocular coherence tomography of the macular and optic nerve head exclude the presence of subtle or hidden pathologies. Automatic perimetry and macular function checking are also useful additions. In cases of significant or progressive pathologies, MF-IOLs is contraindicated. In addition, impaired evaluation of the fundus during vitrectomy in eyes with multifocal implants has been documented. Moreover, the use of multifocal implantation as a means to enlarge eyes with age-related macular degeneration (ARMD) has been demonstrated.

In conclusion, careful preoperative evaluation and follow-up treatment help optimize postoperative results.

Visual results

- **Comparison of types of multifocal intraocular lenses**

Baumuller and his colleagues evaluated the results of bilateral implantation of apodized diffraction and multizonal refractive IOLs compared to standard monofocal implants. A total of 229 patients were included with a follow-up period of 6.6 ± 1.7 years with array and 4.3 ± 1.1 years with ReSTOR in this study. Between the two multifocal groups, visual independence was higher, and adverse visual symptoms were lower in patients with ReSTOR than in patients with array ($P<0.05$). Restore patients reported higher overall visual satisfaction than other groups ($P<0.001$) and assessed their vision at 8.8 ± 1.8.

According to meta-analysis comparing the results of refractive and diffractive IOL in 2013 showed a greater uncorrected far vision in the refractive MF-IOLs group. There was no significant difference between the two groups in uncorrected intermediate visual acuity. However, regarding near visual acuity, the diffraction group showed better results with greater reading speed and independence of glasses. In addition, glare and halo were lower.

Similar results were obtained when comparing the results of diffraction (ReSTOR, Tecnis ZM 900 and Acritec twinset), refractive (Array SA40N and ReZoom) and accommodation IOLs (Crystalens AT 45) in twenty studies. Diffractive IOLs reported a 1.75 times greater probability of independence from glasses, besides with the ReSTOR lens which exhibit twice as high an incidence of freedom from glasses compared to other multifocal implants.

In spite of successful results are outlined with bifocal IOLs regarding visual independence and improved quality of life, the estimated level of improvement in intermediate vision varies. Recent literature shows promising results with trifocal IOLs (at LISA trifocal IOL, FineVision trifocal IOL, and Panoptics). Comparative literature emphasizes the extended reading range provided by three separate focal points compared to earlier MF-IOL, with greater independence from spectacles for all distances. Contrarily, having two non-focused images will spontaneously increase the likelihood of halos. However, the results shown so far do not indicate an increasing incidence of photic phenomen.

- **Implantation of multifocal intraocular lenses in pediatric eyes**

In contrast to aging population, pediatric cataract have a full range of accommodation before surgery, which makes it difficult to make subsequent presbyopic decisions. Worsening of amblyopia and impaired binocular vision may follow after surgery. The implantation of a multifocal implant in such cases can allow rapid visual rehabilitation and reduced risk of amblyopia. However, visual dependence on glasses may return after a change in myopia because pediatric eyes are still growing. Although 90% of eye growth is completed within the first 2 years of life, a refractive change up to 4 diopters was demonstrated in the second decade of life.

Moreover, loss of contrast after multifocal implants can lead to amblyopia. Other important factors to consider are the displacement of the anterior iris-diaphragm of the lens due to higher pressure in the posterior vitreous and more aggressive capsular fibrosis with possible IOL decentration.

Initial results of MF-IOLs implantation (AMO array and SA 40N) in 35 pediatric eyes with a follow-up of 27.4 ± 12.7 months showed a BDVA of 20/40 or better in 70 % of eyes. In nine bilateral cases, Visual dependence was moderate, with only two children (22%) reported constant use of additional correction. The remaining children either used only distance correction (4 patients; 44%), or did not use glasses at all (3 patients; 33%). Stereopsis also improved significantly after MF-IOLs implantation (P= 0.01). Complications included pupil obscuration requiring surgery (16 eyes), permanent fibrous membrane (4 eyes), and IOL decentration requiring surgery (6 eyes).

A 9-year follow-up of three siblings implanted with MFIOLs (Array) for childhood cataracts aged 16-19 years, in another study, demonstrated a refractive bias of <0.5 D in four of the six eyes. None of the patients reported using glasses for daily far and near activities. Cristobal et al .published their data on MF-IOL implantation (Acrysof Restore) after unilateral cataract removal in five children aged 4 to 6 years. At the final observation, the average corrected distance and near visual acuity were 0.03 ± 0.06 log MAR and 0.10 ± 0.10 log MAR, respectively. There were no cases of IOL decentration. Stereoacuity was 120 s arc (angular second) in 2 patients, 240 arc seconds in one patient, 1980 arc seconds in one patient, and was absent in one patient. Four patients showed fusion on a 4-point test.

- **Femtosecond laser cataract surgery and multifocal intraocular lens**

Femtosecond laser in cataract surgery (FLACS) provides greater accuracy in critical stages, including anterior capsulotomy, theoretically leading to a more predictable effective lens position. In addition, arcuate keratotomy using the laser helps in the elimination of astigmatism of the cornea, thereby improving visual results. There is limited data on the results of femtosecond cataract surgery with multi-focal intraocular implants.

Lawless et al. compared the results of 61 consecutive eyes that underwent FLACS with ReSTOR (Alcon Laboratories Inc) SN6AD1, and 29 eyes that underwent standard phacoemulsification with the same IOL implantation. There was no significant difference in the mean uncorrected or BDVA after surgery between the two groups. However, internal aberrations and optical quality has not been studied. In addition, by excluding all eyes with refractive astigmatism> 1.0 D, an additional possible benefit of arched keratotomy with femtosecond support was not evaluated.

Michalz et al. published similar results without significant differences between uncorrected and corrected visual acuity at the distance between femtosecond and traditional phacoemulsification with monofocal implantation. However, in the femtosecond group was demonstrated significantly lower internal aberrations with the potential advantage of superior vision quality.

Therefore, comparing internal aberrations after standard and femtosecond cataract surgery with MF-IOL implantation is a path that still needs to be studied. More research is needed to determine whether technical advances such as the femtosecond laser can lead to superior optical and visual results.

Postoperative complications

Visual results may be limited in certain situations although many post-surgery studies have reported high levels of patient satisfaction after surgery. The most common causes of patient dissatisfaction are Defective vision associated with ametropia or posterior capsular opacity and dry eye.

- **Defective vision**

MF-IOL naturally split available light, resulting in greater sensitivity to loss of contrast, associated with a residual refractive anomaly and posterior capsular opacity. Residual refractive error can be caused by various factors, including inaccuracies in biometric analysis, limitations in calculating IOL power, and a defect in IOL positioning.

Rehabilitation options include glasses, contact lenses, or surgery in the form of LASIK, piggyback IOLs, or IOL exchange.

Alfonso et al. studied the results of femtosecond LASIK to correct the residual refractive error. About 96.2% of the eyes were within 0.50 D of the desired refraction, with enhanced BDVA lines in 10 eyes. Similar results were observed in other studies with apodized diffractive multifocal lenses.

Similar results were revealed in comparing Lasik comparison results for myopia, hypermetropia, and astigmatism after apodized diffraction - refractive and fully diffractive IOLs.

Since increased intraocular pressure during the laser procedure can lead to distortion of the recently made corneal incision to the entire thickness of cataract surgery, it is necessary to wait for the stability of the wound before the LASIK procedure. In addition, systemic conditions such as diabetes that may interfere with healing should be treated before superficial ablation.

Posterior capsular opacity (PCO) can lead to visual disturbances secondary to loss of contrast and glare. Patients with multifocal implants are more sensitive to early PCO compared to monofocal implants, which leads to more frequent Nd: YAG laser treatments capsulotomies. In addition, The PCO frequency is significantly higher when using hydrophilic materials.

- **Photic phenomenon**

Halos and glare are more often reported using MF-IOL than with a mono focal implant. Also, the refractive dysphotopsia more in refractive than in the diffractive patterns.

Careful preoperative guidance entails identifying the frequency of postoperative glare and halos and subsequent resolution after neuro adaptation. In addition, multi-focal implantation in night drivers and eyes with large scotopic pupils should be performed with extreme caution.

Conclusion

Over the past ten years MF-IOLs have undergone various changes. The appearance of trifocal and EDOF- IOLs can provide excellent intermediate visual acuity without photic phenomenon. In addition, lenses with an aspherical profile and a large number of Abbe offer excellent results, minimizing spherical and chromatic aberrations. Careful preoperative planning, along with advances in IOL technology, brings us one step closer to achieving ideal postoperative results that ensure independence and improved quality of life.

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