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Beyond monofocal optics, below extended depth of focus IOLs – new standard in cataract surgery with monofocal plus?

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HIGHLIGHTS

Monofocal plus and extended depth of focus/field lenses are a safe solution for surgeons who are used to monofocal lenses. Enhanced monovision is an easy and effective technique.

ABSTRACT

Recently, due to higher demand for presbyopia correction, we are seeing an increase in the variety of premium intraocular lenses, which are used during cataract surgery. Premium intraocular lenses include multifocal lenses, lenses with extended depth of focus/field, and recently developed enhanced monofocal or monofocal plus lenses. In the article, we discuss the characteristics of monofocal plus lenses and lenses with extended depth of focus/field, the basics of enhanced monovision technique, and general rules of patient's qualification for these types of lenses.

Key words: intraocular lens, cataract surgery, EDOF lenses, enhanced monofocal lenses, presbyopia, monovision

INTRODUCTION

Most recently due to the changes in lifestyle, longer life expectancy, and new work conditions including more screen-based use, the patient demand for presbyopia correction has grown. In response to these demands, we have currently seen an increase in the variety of intraocular lenses that can be used to correct presbyopia. This growth has created apprehension among eye care providers who must choose the best option for their patients. The success to select a lens for a particular case depends on a thorough understanding of the patient's needs and intraocular lens (IOL) characteristics including its disadvantages and advantages. Recently it is impossible to create a lens that gives a perfect image of targets at varying distances with no increase in aberrations and no loss of light [1].

Premium IOL technology refers to biomaterial of the IOL, aspheric design, and most importantly – modified optical properties. The term *premium IOL* reflects not only greater visual comfort for the patient after the surgery, but also (in most of the cases) the higher cost of the lens. The purpose of using premium lenses is to improve uncorrected visual acuity to correct long, near, and intermediate distances and by that to achieve independence from glasses. Most premium lenses are also produced in toric versions to correct corneal astigmatism.

Premium IOLs include multifocal lenses and lenses with extended depth of focus/field (EDOF) [2]. In multifocal IOLs, additional foci are obtained by creating diffraction rings on the surface of the lens (they are classified as diffraction lenses) or optical zones with different refractive index (refractive lenses) [3]. EDOF IOLs have been regulated by the Food and Drug Administration (FDA) separately from monofocals and other multifocals since 2016 and this category of IOLs was growing rapidly in the last few years [1]. In June 2014 the first EDOF IOL (Symfony, Johnson and Johnson Vision, Jacksonville, FL) was introduced into the European market and the Symfony was the first EDOF-labeled IOL approved in the United States in the 2016 year [4]. The paradox of this registration is that Symfony has diffractive, multifocal optics. The FDA definition says that "EDOF IOLs are those lenses that provide Snellen visual acuity to within 1 letter of that provided by a monofocal IOL, and a depth of field that is at least 0.50 D greater than a monofocal". The American National Standards Institute definition of EDOF IOLs is similar – it defines them as "implants that provide increased depth of focus compared to a monofocal IOL, with statistical superiority for photopic intermediate vision and noninferiority for distance vision" [5]. The basic optical principle used in the construction of the EDOF IOLs is to create a single-elongated focal point to enhance the depth of focus, on the contrary to the monofocal IOLs (in which light is focused on one single point) or multifocal (MF) IOLs (having 2 or 3 discrete points) [6]. EDOF IOLs are associated with theoretically less troublesome dysphotopsias due the different technology – the smoother transition between foci is achieved by introducing a small degree of optical aberrations. This improves vision at short distances, however, it is associated with a slight decrease in image quality [2]. Both multifocal and EDOF lenses have been shown to increase levels of spectacle independence. Unfortunately, both lens types may be the cause of unwanted photic phenomena such as glare and halos but to a much lesser extent with EDOF lenses [7]. The dysphotopsias are more visible in low light conditions (especially at dusk), making for example driving difficult. These unwanted visual symptoms following multifocal IOL surgery are common, one research has found between 30% and 65% of patients report visual aberrations [8]. However, EDOF lenses provide excellent intermediate vision, the quality of vision for near distance maybe inadequate [9]. Patient with myopia, who is used to good near vision may be dissatisfied – in this case EDOF mini-monovision with setting target refraction for one eye at -0,5 D can be useful. What causes confusion is that recently developed enhanced monofocal or monofocal plus lenses do not quite qualify as EDOF IOLs according to the definition set forth by the American National Standards Institute [10]. Monofocal plus lenses combine features of different types of lenses: they provide the same distance visual acuity as standard monofocal IOLs but with better intermediate visual acuity and without the photic phenomena like EDOF and multifocal IOLs [11]. The new IOLs include the TECNIS® Eyhance ICB00 (Johnson & Johnson), the xact™ Mono-EDoF™ IOL (Santen), the ISOPURE® (PhysIOL/BVI), and the RayOne EMV (Rayner).

RayOne EMV was introduced for the first time in October 2020 in countries accepting the CE mark and was developed in collaboration with Professor Graham D. Barrett as a new non-diffractive extended range IOL designed to enhance the outcomes through monovision. In the case of monovision, a plano target is maintained in the dominant eye, and a power-offset is applied in the non-dominant eye. This lens is considered not exactly multifocal or monofocal, but somewhere in between the two. The RayOne EMV increases the depth of focus by inducing a small amount of extra positive spherical aberration. It can provide approximately 2.5 D depth of focus when used in a modest monovision setting with approximately a -0.75 to -1.50 D offset between the dominant and nondominant eye [11]. When compared to standard monofocal IOLs, RayOne EMV promotes superior intermediate vision. The lens is suitable for patients who are not candidates for diffractive trifocals and are looking for some spectacle independence and reduced dysphotopsia. To gain the greatest benefit of binocular distance vision in the case of RayOne EMV it is recommended that the closest plus to zero is targeted in the dominant

eye with approximately 1.0 D of offset in the non-dominant eye [12].

ENHANCED MONOVISION PERFORMANCE

Monovision is an affordable method that allows to achieve greater depth of field with less amount of dysphotopias in comparison to multifocal IOLs. It is a surgical option in which traditional monofocal lenses are used to correct distant vision in the dominant eye and the non-dominant eye focuses intentionally for near to mid-range vision [13].

Full monovision is defined as the reading eye exhibits a residual refractive error of -2.50 D or more. Modified monovision or mini-monovision requires a smaller interocular dioptric power difference between eyes than traditional monovision, typically between -0.75 and -1.75 D of myopia [13]. Mini-monovision is a quite cheap and efficacious option for the management of presbyopia and has fewer side effects than multifocal IOLs especially if it comes to photic phenomena [14]. A few studies showed that it is a good choice to lessen patient dependence on spectacles for near, midrange, and distance functions after cataract surgery [15].

Some researchers used questionnaires to estimate the functionality of patients postoperatively, the rate of spectacle use, and general satisfaction. Overall, patients after pseudophakic monovision achieved high scores of contentment [14, 16–18]. In the case of monovision, patients indicated greater satisfaction related to lower costs of the procedure, the possibility of recommending this technique to their relatives, as well as a generally high level of satisfaction with the procedure, without significant difference compared to patients undergoing the surgery with multifocal lenses. In a trial by Wilkins et al. outcomes of bilateral cataract surgery with multifocal intraocular lenses were compared to results with monovision. The general conclusion was that patients randomized to bilateral implantation with the diffractive multifocal lenses were more likely to report being spectacle-independent. They were also more likely to undergo IOL exchange than those randomized to receive monofocal implants with the powers adjusted to give low monovision. The authors of this trial showed also that patients of monovision group had significantly better contrast sensitivity than patients who received multifocal lenses after the surgery [14].

PATIENT QUALIFICATION

To choose the perfect option for the patient the preoperative visit should include a thorough interview regarding the patient's working conditions, an assessment of the distance needed to perform the most common activities, and estimation of the expected postoperative effects [19]. A wider range of functional vision then can be achieved thanks to the process of neuroadaptation in which the brain can use the distance image (from the dominant eye) combined with the near image (from the non-dominant eye) [20]. The best postoperative outcomes with the greatest patient satisfaction can be achieved only when the knowledge about advantages and compromises inherent in each IOL is combined with a deep understanding of the patient's needs [1].

The literature shows that patients qualified for implantation of lenses with an extended focal length should be calm, balanced, and optimistic about life. In case the of multifocal IOLs, it was established that the subjective satisfaction or dissatisfaction of patients is related to certain personality characteristics. In the study by Rudalevicius et al. it was established that patients with neuroticism as the dominant personality trait were least happy with the postoperative outcomes and in contrary, those with conscientiousness and agreeableness as dominant personality traits demonstrated the highest satisfaction with the postoperative outcomes [21]. The patient should be informed about possible side effects that may occur after implantation of any type of lens, such as the phenomenon of dysphotopsia (halo, glare) and weakening of contrast sensitivity [19]. Before choosing the lens type it is necessary to perform topography and tomography of the cornea to exclude irregular astigmatism and astigmatism of the posterior surface of the cornea because it can cause the formation of higher-order aberrations (such as coma or trefoil).

Those types of astigmatism are contraindications for EDOF lens implantation. Acceptable regular preoperative astigmatism is 1.0 D [22]. A history of laser eye surgery is not an absolute contraindication to a multifocal implant, but care should be taken in the eyes after the correction of large refractive errors. In those cases, optical corneal aberrations of a higher order occur and it is safer to suggest an EDOF or monofocal lens [23]. Any abnormalities of the lens ligament apparatus that may contribute to lens displacement and decentration, such as Pseudoexfoliation syndrome (PEX) and Marfan syndrome are a contraindication to the implantation of EDOF lenses [19].

A pupil diameter of less than 3 mm in photopic conditions and more than 6 mm in mesopic conditions and irregularity of the pupil shape should be a warning sign against the implantation of EDOF lenses. In the case of diffractive lens implantation the diameter of the pupil less than 3 mm worsens the sensitivity to contrast [24]. On the other hand, a wide mesopic pupil (a width more than 6 mm) increases the number of higher-order aberrations in the optical system and consequently, the perception of dysphotopsia is greater. Therefore, neither a low-reactive, too narrow pupil in photopic conditions, nor too wide pupil in mesopic conditions is beneficial for the proper functioning of multifocal lenses [19]. To give patients increased depth of focus with-

out compromising their quality of vision in RayOne EMV the aspheric optic was applied and that induces a small amount of extra positive spherical aberration [12]. Patients must be aware that spectacle correction may be required for reading small print.

CONCLUSIONS

To conclude, careful IOL selection before cataract surgery is crucial to achieve good satisfactory outcomes. This process requires careful patient assessment, including the quality and quantity of corneal astigmatism, the health of the ocular surface, and other ocular comorbidities. That information should be combined with data from a thorough interview with the patient. The surgeon should know patients' visual goals, lifestyle characteristics as well as their personality type. Finally, all those factors combined assist specialists in personalizing the IOL choice for cataract surgery. Patients who want absolute independence from glasses, who are keen readers leading more in-door lifestyle, and also those who are more likely to accept optical side effects (halo, glare, starbust) will benefit from choosing multifocal lens. On the other hand, people leading more outdoor lifestyle with a strong need for optimal vision during the night (for example while driving) and highly demanding individuals, relatively intolerant to dysphotopsias will be more satisfied with EDOF IOL than with multifocal one. Enhanced monofocal IOLs and EDOF lenses are a safe solution for surgeons who are used to monofocal IOLs. EDOF IOLs are much more expensive than monofocal lenses. As shown in the article surgeons do not have to be afraid of monovision because it is a very safe and effective technique.

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