11 Multifocal Intraocular Lenses: Neuroadaptation Failure Corrected by Exchanging with a Different Multifocal Intraocular Lens

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11.1 Introduction

The correction of a visual disability such as cataract surgery and refractive lens exchange with intraocular lens (IOL) implantation is one of the most successful procedures in medicine. As patients seek spectacle independence for all distances, multifocal (MF) IOLs have been widely used as a solution for presbyopia and cataracts [1–8]. Moreover, depending on the patient's daily activity, work, and preference, MF IOLs can be chosen to favor far, intermediate, or near vision [9–12] However, in some cases the implantation of MF IOLs can be followed by visual symptoms such as dysphotopsias, glare, halos, or by reduced contrast sensitivity and decreased visual acuity [13–15]. Nevertheless, some patients after MF IOL implantation end up dissatisfied despite having an excellent vision.

Few authors studied the reasons behind patients' dissatisfaction following the implantation of MF IOLs. Some reported unsatisfactory visual acuity as the main reason of dissatisfaction [16]. Others reported that blurred vision and photic phenomena associated in some cases to posterior capsule opacification (PCO), dry eye syndrome and ametropia are behind patients' dissatisfaction [17, 18]. It is much simpler when it comes to PCO or residual refractive errors that can be easily managed with YAG-capsulotomy, spectacles and keratorefractive surgery. However, when dealing with dysphotopsias, we lack effective treatments for these subjective complaints. New reports proved that cortical neural areas are responsible for the long-term adaptation to such visual symptoms, suggesting that the persistence of these dysphotopsias is a neuroadaptation failure [19, 20]. Eventually, the only solution in such cases would be the explantation of the MF IOL.

After an extensive search of the literature, several articles that reported MF IOL explantation were found [21–28]. However, these articles studied the outcomes after the exchange of the MF IOLs to monofocal ones. In an ongoing study (manuscript submitted for publication) [29], we are reporting successful outcomes where we exchange a MF IOL to another MF IOL technology due to neuroadaptation failure. This exchange could work owing to the hypothesis that there may be different neuroadaptation processes for the different optical profiles of refractive and diffractive IOLs in different patients. Some patients may adapt faster or slower to photic phenomena, decreased contrast sensitivity, and distortion associated with the MF IOLs we have nowadays in the market. This exchange of one MF IOL to another MF IOL may be the right solution in dissatisfied patients with visual

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complaints but that want to preserve the benefits of multifocality improving patients' satisfaction.

11.2 Causes of MF IOL Explantation

Patients' demands are growing continuously; they seek good quality vision in all distances. That is why, we see an increased number of MF IOLs being implanted. However, not all the time patients end up happy after this surgery. Subsequently, the infrequent procedure of IOL explantation is gaining more popularity among patients with MF IOLs.

A number of authors presented their case series where MF IOLs were explanted. Let us go through them one by one:

- Kim et al. included a case series of 35 eyes. Under photic phenomena they classified glare, halos, both positive and negative dysphotopsia. The surgical indications for the explantation were blurred vision in 60% of all the eyes, photic phenomena in 57%, photophobia in 9%, loss of contrast sensitivity in 3%, and 29% of the eyes had multiple complains [21].
- The etiology of MF IOL explantation in a series of 50 eyes by Kamiya et al. was as follows: decreased contrast sensitivity in 36% of the eyes, photic phenomena in 34%, incorrect IOL power in 20%, IOL dislocation/decentration in 4%, anisometropia in 4%, 14% had preoperative excessive expectations, and 32% were of unknown origin including neuroadaptation [23].
- In a case series of 30 eyes, Tassignon et al. demonstrated the different complaints patients were facing that led eventually to the explantation of the MF IOLs such as blurred vision, diplopia, uncomfortable binocular vision, halos, glare, photophobia, and loss of contrast sensitivity. In 15 out of the 30 eyes, they measured the centration of the MF IOL optic and found out that 14 out of the 15 eyes had a slight decentration. However, they suggested that this decentration alone does not explain all these cases of unsatisfied patients, and that IOL tilt and Stiles Crawford effect also play a role [24].
- Two cases were described with glistenings in the bulk of the MF IOLs' optic, that were eventually explanted as the patients presented with glare, halos, and blurry vision. Thus, van der Mooren et al. concluded that glistenings in combination with multifocal optics may result in clinically significant visual symptoms due to straylight [30].
- Galor et al. reported the subjective visual symptoms of ten patients (12 eyes) that led to refractive MF IOL explantation. The most common complaints were halos and glare, blurry vision, and decreased contrast sensitivity [25].

Few papers talk about patients' dissatisfaction after the implantation of MF IOLs that eventually leads to the explantation of these lenses in some cases:

- Woodward et al. classified the causes of patients' dissatisfaction in their series of 43 eyes into blurred vision and photic phenomena. The blurred vision was associated with ametropia, dry eye syndrome, PCO, and unexplained etiology, while the causes of photic phenomena included IOL decentration, retained lens fragment, PCO, dry eye syndrome, and unexplained etiology. Conservative treatment was applied to improve the symptoms of these patients such as keratorefractive surgery, laser capsulotomy, and dry eye syndrome management. However, 7% of the eyes did not improve and required IOL explantation [17].
- The same classification was followed by de Vries et al. where in their series of 76 eyes the etiologies of blurred vision and photic phenomena were residual ametropia and astigmatism, PCO, and large pupil. The patients were treated conservatively but 4% of the eyes did not improve and eventually had an IOL exchange [16].
- In the case series (74 eyes) reported by Gibbons et al. patients complained mostly of foggy or blurry vision for both far and near

distances, followed by photic phenomena and multiple images. The causes behind these visual symptoms were mainly refractive residual error and dry eye. Seven percent of the eyes had MF IOL explantation after the failed attempts of conservative treatment [18].

Other authors combine in their articles the explantation of both monofocal and MF IOLs. In these cases, most of the causes of the exchange of monofocal IOLs can fit the MF IOLs as well. Thus, it is important to know not only visual symptoms but also some anatomical reasons behind the explantation of IOLs that can be faced by any surgeon.

- The dislocation of an in-the-bag posterior chamber IOL was the most frequent indication for IOL exchange in the case series of 109 eyes studied by Davies et al., followed by the MF IOL intolerance that was observed in 18.3% of the eyes. Other indications for the IOL exchange included uveitis-glaucoma-hyphema (UGH) syndrome, residual refractive error, refractive surprise, positive dysphotopsia, pseudophakic bullous keratopathy, IOL opacification, monocular diplopia, and others [27].
- An observational multicentric retrospective study was conducted in Spain. Fernandez-Buenaga et al. studied the causes behind the explantation of a total of 257 pseudophakic IOLs. The principal cause was IOL decentration/dislocation, followed by incorrect lens power, IOL opacification, neuroadaptation failure, pseudophakic bullous keratopathy, endophthalmitis, and others [22].
- Jones et al. in their series of 57 eyes reported as the most common indications of IOL exchange the following: IOL dislocation, incorrect IOL power, patient dissatisfaction, and optic opacification [26].
- In the tenth annual survey of complications of foldable IOLs requiring explantation, Mamalis et al. reported that the second most frequent explanted IOL was the multifocal hydrophobic acrylic IOL mostly because of glare/optical aberration and incorrect IOL power [28].

Our group is currently conducting a new clinical study where we investigate the possibility of exchanging one MF IOL to another MF IOL [29]. Therefore, our study includes 26 eyes where MF IOLs were explanted due to neuroadaptation failure followed by the implantation of a MF IOL of another technology. Into neuroadaptation failure we included all the subjective visual symptoms of the patients that did not have any clear anatomical cause such as photic phenomena, blurred vision, insufficient vision, and monocular diplopia.

So, for example, in the case series of explanted MF IOLs by Tassignon et al. [24], we agree with the authors that the decentration they found does not explain the visual complaints and patients' dissatisfaction, and we may suggest here neuroadaptation failure as the main reason behind these visual symptoms. In addition, in the case series by Davies et al. [27], the intolerance to MF IOLs reported as a cause of MF IOL explantation is in our opinion because of neuroadaptation failure.

11.3 Neuroadaptation in MF IOLs

In our modern world, MF IOLs are continuously chosen by the patients and are implanted by several surgeons, but some of the patients complain of visual symptoms and are dissatisfied despite having an excellent visual acuity. Additionally, no other cause is found for the deteriorated optical quality even after excluding other probable reasons leading to the dissatisfaction like posterior capsule opacification, retinal problems or dry eye disease. According to various studies, the most common causes for MF IOL explantation are photic phenomena and glare [16–18, 21, 23–25]. Commonly used optical examinations do not demonstrate any differences among the patients experiencing and not experiencing dysphotic symptoms as they have similar visual acuities, light scatters, high-order aberrations, and pupil diameter [31, 32]. Therefore, this proposes the presence of other mechanisms, maybe neural, that stand behind these visual manifestations and patient's dissatisfaction.

Rosa et al. in their recent papers investigated neuroplasticity after MF IOL implantation using functional magnetic resonance imaging that is noninvasive and allows the in vivo study of the brain activity [19, 20]. The ability of the brain to reorganize its function and structure in response to changes in the environment is known as neuroplasticity. In their first paper, the authors compared the neural responses between two groups, patients with recent MF IOL implantation and a control group of healthy phakic individuals [19]. Using a "Blood Oxygen Level Dependent Signal Characterization in the Primary Visual Cortex," they showed that patients were more affected by a light source than were controls. During a whole-brain analysis, the subjects were asked to discriminate a low-contrast stimulus under glare in comparison with higher-contrast stimuli without glare. The patients with MF IOLs under glare had a significant activation of the attention network that involved the frontal, middle frontal, parietal frontal and post-central gyrus, as well as the activation of the anterior cingulate gyrus, unlike the controls that had only deactivation of the occipital lobe and middle occipital gyrus (visual areas). In addition, patients that were more bothered by the visual symptoms had higher activities in the attention network and in the cortical areas responsible for solving complicated tasks. Apparently, the increased activity of the cortical areas devoted to learning and cognitive control, to attention and to task planning and solving, reflects the initiation of the neuroadaptation process. This process refers to the capacity of the brain to reorganize its connections in answer to the changing patterns of inputs received from the surrounding, for example, the implantation of a MF IOL after cataract surgery [19].

In a similar study, the authors compared the visual and cortical activities between the early postoperative period of 3 weeks and the 6-month visit in the same patients with implanted MF IOLs mentioned above [20]. When patients viewed threshold contrast stimuli, they were less affected by glare at the second visit, meaning an improvement of disability glare at the visual cortical level. As to the attention network, it was significantly activated under glare in patients with MF IOLs in the first visit compared to the relative activation of only the middle frontal gyrus 6 months postoperatively, while there was no significant difference in attention, effort, or learning cortical areas of engagement between the two visits in the control group. This implies that less effort-related areas had to be activated for stimuli discrimination in patients with MF IOLs 6 months after the surgery. In addition, a significant enhancement in the quality of visual symptoms in accordance with the functional MRI findings was reported in the second visit of the operated patients, and no significant changes between the visits in the controls. The visual acuities both far and near as well as the reading performance improved significantly at the 6-month visit in patients with no significant changes in controls. The authors concluded that in the initial postoperative period, the neuroadaptation to MF IOLs occurs through a process of attentional network, subcortical caudate, and cingulate recruitment. Afterward a form of long-term adaptation occurs and regulates the brain activity toward a non-effort neural activation pattern; therefore fewer brain regions are required to perform the tasks [20].

Despite the possible variation of neuroadaptation to multifocality among patients [4], we already have the evidence that it exists according to the studies mentioned above. Therefore, more attention should be paid to it with further investigations, especially in finding out the difference in neuroadaptation depending on the implanted MF IOL, whether it is diffractive, refractive or extended depth of focus. This is important as these IOLs have different optical and visual functions and different implications on the patients.

11.4 MF IOL Explantation: Techniques and Outcomes

As discussed previously, the issue of neuroadaptation is of an extreme importance when it comes to MF IOLs. When neuroadaptation failure happens and does not improve with time, the only way to solve the problem is by an IOL exchange. However, when patients are very demanding and do not want to give up on spectacle independency for all distances, the idea of exchanging the MF IOL by a monofocal one is not the ideal option anymore. That is where the application of another MF IOL technology is encouraged.

Most of the times it is difficult for the patient to understand the concessions to be made like decreased contrast sensitivity or some photic phenomena in exchange for having good visual acuity on all distances. That is why it is critical to take the time and explain to the patient, the surgery, the consequences, the neuroadaptation process, and the possible complications and their possible solutions. And one of these possible solutions is IOL exchange. Although this option should be referred to only after previous addressing of other treatment options in order to improve the prevailing situation. For instance, residual ametropia in some cases can be corrected by spectacles, contact lenses or laser refractive surgery. Moreover, dry eye syndrome, IOL decentration with the pupil, residual ametropia, and posterior capsule opacification must be ruled out before proceeding to IOL exchange.

11.4.1 Techniques

All explantation techniques of an in-the-bag foldable IOL begin with the same steps. Corneal incisions are made (Fig. 11.1a), after which viscoelastic is used to dissect the IOL from the capsular bag (Fig. 11.1b). Afterward, depending on each case, the most appropriate technique

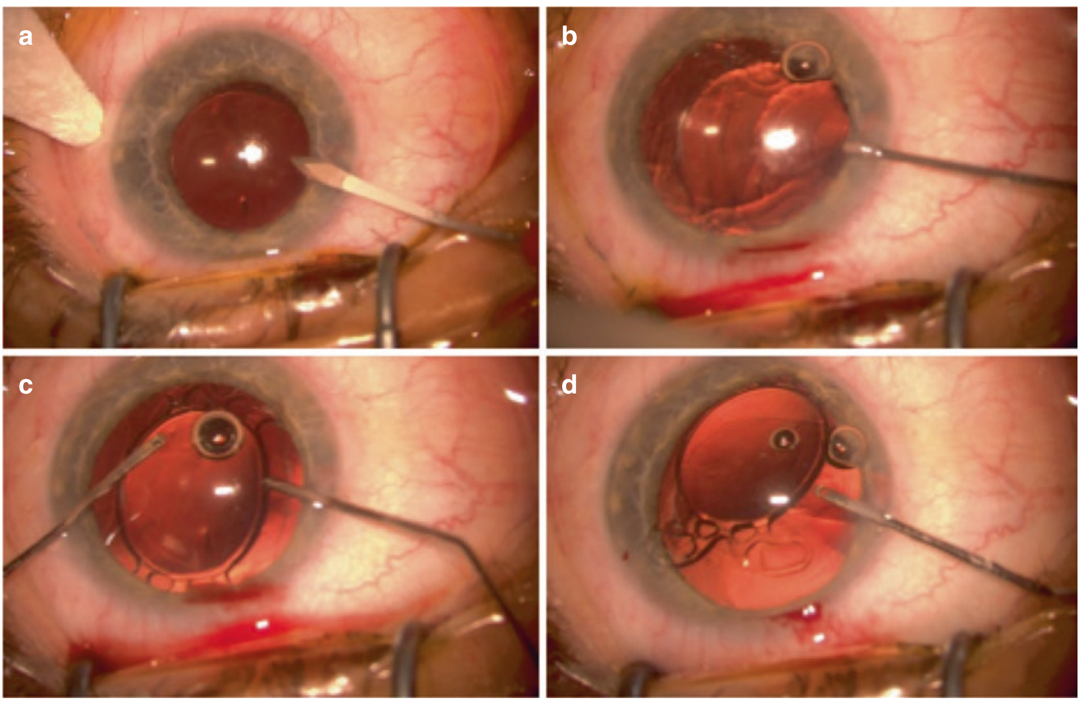

Fig. 11.1 Intraocular lens (IOL) optic cut explantation technique: (**a**) corneal incisions; (**b**) dissection of the IOL from the capsular bag using viscoelastics; (**c**) loosening the IOL from the capsular bag; (**d, e**) overlapping the IOL onto the anterior capsular rim; (**f, g**) a radial cut of the optic is performed to the center of the IOL; (**h, i**) extraction of the IOL through the main incision using two forceps; (**j**) the IOL is eliminated from the anterior chamber

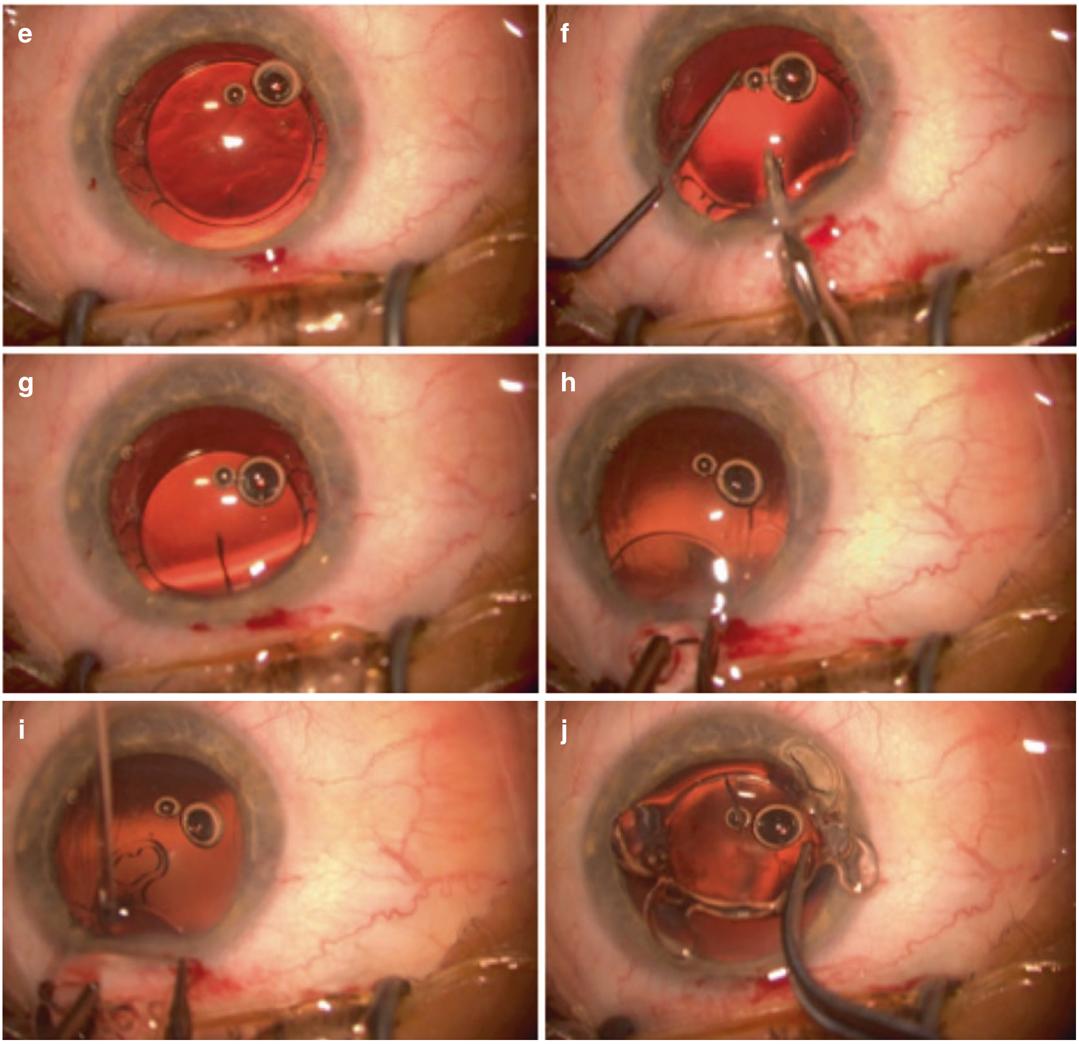

Fig. 11.1 (continued)

is chosen. Although a lot of explantation techniques exist, we are going to list the ones mostly utilized:

- Optic cut technique [33]: Using a Sinskey hook and a Lester hook (Katena, USA), the IOL is loosened from the capsular bag (Fig. 11.1c) and overlapped onto the anterior capsular rim (Fig. 11.1d, e). Subsequently, a cut of the optic is performed radially to the center of the IOL (Fig. 11.1f, g), followed by its extraction through the main incision using two forceps that are alternated in grasping the IOL (Fig. 11.1h, i) while eliminating it from the anterior chamber (Fig. 11.1j).
- Haptics cut technique: In the case of a tight adherence between the haptics and the capsular bag because of a fibrotic reaction, the haptics of the IOL are cut and left in the bag. Otherwise, the attempts to remove them may lead to zonular dehiscence. Afterward, the optic is removed.
- Eguchi's technique and its variation: Two radial incisions of the optic are made and are separated from a range of 35 to 90°. Eventually, a triangle or a quarter of the lens optic is

obtained and removed from the anterior chamber through a small corneal incision followed by the rest of the IOL.

- Folding technique: After elaborating the IOL from the capsular bag, it is folded onto itself in the anterior chamber and explanted through a corneal incision.
- Removing the whole IOL: Mostly this technique is applied to unfoldable IOLs; however, in some cases, it may be the most comfortable technique to choose. After evacuating the IOL from the capsular bag to the anterior chamber, a bigger corneal or scleral incision is opened and the IOL is removed in one piece from the eye.

However, our favorite is the cutting technique described above [33]. In our opinion, it holds minimal risk for more complications and is easier and faster than others. The folding technique has a potential risk for endothelial damage and removing the whole IOL needs a larger corneal incision that increases the risk of postoperative astigmatism or a scleral incision that prolongs the surgery time.

11.4.2 Outcomes

Nowadays, quite a few studies discussed the explantation of multifocal IOLs due to different reasons. In most of these studies MF IOLs were exchanged by monofocal ones, and only in few sporadic patients MF IOLs were exchanged by another MF IOLs. Moreover, no paper until now except ours (manuscript submitted for publication) talks about the possibility of explanting a MF IOLs and re-implantation of another MF IOL of different technology.

For instance, in the study reported by Kamiya et al. 5 eyes of the 50 had a MF IOL exchanged by another MF IOL due to the incorrect IOL power calculation for the primary surgery [23]. Two eyes in the study by Tassignon et al. had the MF IOLs explanted followed by the implantation of monofocal IOLs in combination with sulcular additional MF IOLs as piggy-back. Though because of unsatisfactory vision one of these lenses had to be removed 6 months after the exchange [24]. In both case series reported by Woodward et al. and de Vries et al., 3 eyes had MF IOL explantations where 1 eye in each study was exchanged by another MF IOL, one because of incorrect IOL power [16] and the cause of the other exchange is unclear in the paper [17]. Therefore, no systematic study was conducted on such cases of MF IOL exchange by another MF IOL.

All other reports about MF IOL explantation had in their series MF IOLs exchanged by monofocal ones. The outcomes they demonstrated were good, with good postoperative refractive outcomes, with decreasing or disappearing of the visual complaints in most of the cases, with low rate of complications [21, 23, 25] and the feasibility of the exchange as late as 18 years after the primary surgery [24]. However, these studies do not mention the patients' spectacle dependency after the exchange. Studying the satisfaction of the patient is one of the most essential tests to be done in such cases. To do that, it is important to use the right tools which are the validated questionnaires. In all the previously mentioned reports where MF IOL explantation was studied, no validated questionnaires were used.

No relevant investigation was carried out where MF IOLs were exchanged by another MF IOL technologies. And this is the subject of our recent study. All the patients in our series had their MF IOLs explanted due to neuroadaptation failure [29]. The only solution we could offer them is to exchange the lens. After studying each case and a mutual agreement between the doctor's indications and the patients' desire, all MF IOLs were exchanged by another MF technology in the patients enrolled in the mentioned study. We made sure to use the VL-14 quality of life and the quality of vision questionnaires to asses patients' satisfaction and its improvement after the exchange.

We had excellent outcomes where uncorrected and best corrected distance visual acuities increased significantly with no significant change in the refraction. Best corrected near visual acuity increased insignificantly and the percentage of spectacle independency increased. Patients reported improvement of their quality of life and quality of vision, decrease in their visual symptoms, and an increase in their overall satisfaction of vision in all distances after the exchange.

11.5 Conclusion

Although intraocular lenses have been explanted for decades, the explantation of MF IOLs has been a recent phenomenon that we hear about more often. Few authors reported the causes and results of exchanging MF IOLs to monofocal ones. Further, our group is studying the exchange of MF IOLs to another MF IOL of different technologies. The results of this study showed that this is a promising procedure that may be the ideal solution in some patients that suffered neuroadaptation failure after the implantation of a specific type of MF IOL. Besides, this procedure showed to be feasible and successful in most of the cases and able to enhance the patient's dissatisfaction and keep the advantages of MF IOLs in the benefit of the patient. It seems that neuroadaptation process happens differently for different MF IOLs in different patients; however, this should be confirmed by an independent clinical study.

11.6 The Best of This Method

1. It gives a chance to treat neuroadaptation failure with MF IOLs.
2. This evidence supports the idea that different neuroadaptation processes are involved in different MF IOLs with different outcomes.
3. It provides a chance to keep spectacle independency to already failed cases.

11.7 The Pitfalls of the Method

1. The surgical technique can be difficult due to the encapsulation of the IOL and complications related to late manipulation of the capsular bag.
2. It requires good surgical skills and planification in the hands of an experienced surgeon.

Compliance with Ethical Requirements

Conflict of Interest Olena Al-Shymali and Jorge Alió declare that they have no conflict of interest.

Informed Consent All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study.

Animal Studies No animal studies were carried out by the authors for this article.

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