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Potential Concerns and Contraindications for IOL Monovision

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Abstract

Pseudophakic or intraocular implant (IOL) monovision has been widely used in surgical cataract practice for more than 3 decades. More and more premium IOLs compete presbyopia management, but IOL monovision still remains the most commonly used modality with good spectacle independence and high patient satisfaction. Little attention, however, has been paid to its contraindications and concerns in the ophthalmology literature considering the widely used scope of this modality. Due to the length limitation, those well-known contraindications for IOL monovision will be just briefly mentioned, but those not easily recognizable ones are fully discussed. To author's knowledge, this is the first attempted review to address this important issue.

Introduction

Monovision as a method of prescribing optical aids was proposed in 1958 by West smith for presbyopic contact lens wearers [1-3]. In his paper [1], he revealed the fact that he had a contact lens of +1. 50 D for his own left eye for reading while he did not need any correction for his distance vision with a vision of 20/20 in each eye. The first clinical report was from Fonda with 13 cases of monovision corrected by spectacles and contact lenses in 1966 [4]. Dr. Fonda also used different power for his readings add in his glasses as monoviison [4]. Pseudophakic, or intraocular lens (IOL), monovision was first published by Boerner and Thrasher [5] in 1984 and is now the most common surgical management of presbyopia for cataract patients[A,B]. For the past decade, refractive cataract surgery has become a very widely used modality among more and more cataract surgeons in USA as well as in the world. IOL monovision belongs to refractive cataract surgery, but there have not been many studies on this topic in literature, considering how widely it is used in our profession.

The high success rate in terms of patient satisfaction and spectacle independence for pseudophakic monovision is well documented in the literature. It has been shown to work with or without a contact lens simulation trial prior to cataract surgery, step by step monovision mimic tolerance test [6], a single +1. 0 lens test [7] or no plus lens test [3,8]. It worked whether the anisometropia level at <1. 0 D [9], or just a little above 1. 0 D [7,10] or around 2. 0 D [6,11] or even at 2. 75 D level [3]. It worked whether conventional IOL monovision was used or crossed IOL monovision was used [8,10].

IOL Monovision is probably not assimple as it seems. Not much attention has been paid to its contraindications and concerns in the ophthalmology literature considering the widely used scope of this modality. It is probably beneficial to raise these issues for discussion to stimulate future case reports as well as formal studies.

The major problem associated with monovision relates to the potential compromise inbinocular visual function. IOL and laser induced monovision are surgically induced, and therefore these issues are of more concern compared to spectacle and contact lens monovision. Monovision aims to set one eye for distance and one eye for near. The fundamental purpose is to increase the depth of focus whilst maintaining acceptable stereovision. Binocular depth of focus refers to the summation of the monocular range of clear vision for each eye, spanning from the near focal point of the near vision eye to the far focal point of the far vision eye. The main trade off is the compromise in stereopsis. If severe enough, it can lead to problems with fusion and even diplopia. The literature contains varying reports regarding the impact of monovision on stereopsis. Most studies demonstrate only a mild compromise in stereo acuity in the majority of IOL monovision patients. Overwhelmingly most IOL monovision patients do not experience depth perception problems in their daily activities. Compromised fusion and induced diplopia, however, remain the main problems for cataract surgeons to avoid when they offer pseudophakic monovision.

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Even within the 120-degree binocular field of view shared with both eyes [12] the difference in image size of the same object with the left and right eyes are potential sourcefor confusion with monovision if the disparity in image size is too large. One of three outcomes will happen: Fusion with increased depth focus without any major issue beside a minor compromise in fine stereopsis as occurs in the majority of patients with IOL monovision; one image can be suppressed, so that only the other is seen, as in amblyopia; If fusion and/or suppression do not occur, two images of a single object are seen with symptomatic diplopia. Theoretically, any external ocular muscle abnormality can compromise binocular function in Panum's fusional area. Anisometropia and aniseikonia are an additional demand on the fusional capacity for patients with monovision.

We probably do not need to spend much time with detailed discussion about some well accepted facts: IOL monovision should not be offered to those patients who have history of external ocular muscle (EOM) surgery, diplopia, prism usage; those who have signs of tropia, significant phoria of > 8 prism diopters, or EOM restriction. (Some studies have shown a unique function for extreme monovision to correct symptomatic diplopia, [2,13-15] that will not be discussed in this article). It is important to know that those patients are not good candidates for IOL monovision in most clinical situations.

Some ocular conditions, however, are not that easy to recognize as potential contraindications for IOL monovision. This will be the main topic to discuss for this paper. To author's knowledge, this is the first attempted review to address this important issue.

Long-standing unilateral traumatic cataract

Patients with long-standing unilateral dense cataract, especially traumatic cataract, may already have compromised fusion function. If preoperative strabismus is noted at examination, even if the trauma happened during adulthood, there is a good chance that that patient will have diplopia after cataract surgery [16-18] due to disruption of fusion. Pratt-Johnson [16] reported 24 cases of unilateral long-standing traumatic cataract from 1984 to 1988. All 24 cases had unilateral traumatic cataract and developed intractable diplopia after their vision was restored with IOL or contact lenses to 20/40 or better. None of the 24 cases had a known history of interrupted binocular function prior to their trauma and the average age when trauma occurred was 18 years. There was no central nervous system trauma associated with the ocular trauma and the study noted that risk of diplopia increased if the interval of cataract formation prior to vision restoration reached 2.5 years or longer. The authors also noted that these patients typically had secondary strabismus in the injured eye one year or longer after the injury. It can be difficult or sometimes impossible to accurately evaluate ocular alignment if the vision is very poor and if the strabismus is very small or if it is in the transitional process of becoming deviated. For those patients, warning of the possibility of postoperative diplopia is warranted even if the eyes appear straight. It may worsen the risk if crossed monovision is planned. In this circumstance, therefore, it is reasonable to correct the affected eye aiming for slightly more myopia than the fellow normal eye. After the first eye surgery is done, if postoperative Worth-4-Dot test at that time shows intact fusion with 4 dots at 6 meters, or if 4-diopter base out test does not suggest small central scotoma, or if the patient has good stereo acuity, then it is probably safe to consider IOL monovision option with the fellow eye aiming at plano, if the patient requests spectacle independence. The Worth-4-Dot test, 4D-BO prism testand Titmus stereopsis test prior to the first eye surgery in the presence of long-standing dense cataractis typically not possible in the presence of poor vision.

Fixation switch diplopia

Fixation switch diplopia has been described as an acquired diplopia in adults who have a history of strabismus or amblyopia since childhood [19,20]. With a history of childhood strabismus or amblyopia, the patient may not have diplopia if the affected eye is not the fixation eye. Diplopia can happen if the amblyopic eye starts to be the fixation eye when refractive status changes, such changes can happen as the original fixation eye becomes more myopic (as happens as cataract forms), intentional or unintentional monovision modality introduced, or if an inaccurate refraction prescription is provided.

Kushner [19] reported 16 adult patients with fixation switch diplopia. All 16 had a history of strabismus since childhood. Six of the 16 developed diplopia owing to their monovision correction. In all 16 patients, symptoms were completely eliminated when proper optical correction was instituted to encourage fixation with the dominant eye at all viewing distance.

Boyd et al. [20] reported a group of 24 patients as "Fixation Switch Diplopia" who had spontaneous intermittent unilateral diplopia. All 24 patients had the following features: When they were asked to demonstrate the production of diplopia, each patient fixed with the non-preferred eye and no suppression was present in the preferred eye; when fixing with the preferred eye, suppression could be demonstrated in the non-preferred eye and the diplopia disappeared. They were all able to alternate fixation, but not able to alternate suppress. There is no alternate suppression present in this entity of patients. Each of the 24 patients also had strabismus onset before age 7 years old and the preferred eye had better vision than the non-preferred eye. The vision of the preferred eye in all cases was 20/20 or better. The severity in the non-preferred eye can be quite variable. In some of the mild cases, the symptom was trivial and 5/24 was even not able to tell the duration of their intermittent diplopia. Vision was only mildly affected at 20/40 to 20/20 level in 17 out of 24 cases. 5 out of 24 had good stereovision with 80 to 40 arcs of seconds. The EOM deviation could be minimal to less than 10 prism diopters. This finding had some similarity with what Parks had noted in his 100 cases of monofixation syndrome[21Parks]. This study also noted that intermittent fixation switch diplopia happened more if the non-preferred eye vision had good visual acuity. For that reason, the authors intentionally treated some cases by decreasing the vision with glasses in the non-preferred eye.

These studies raised an important concern when we do IOL monovision. If we happen to choose the non-preferred eye as distant fixating eye, it may cause fixation switch diplopia. From this perspective, the pretty common practice pattern of routinely choosing the worse eye or denser cataract eye aiming plano and the follow eye for near regardless of dominant eye test may be a concern if we also missed the history. It is important to ask every single prospective patient of IOL monovision: "Do you have a history of an eye turned in or out?" "Can you recall any double vision in your whole life?", "Do you always have one eye weaker than the other eye?". For this entity group, crossed IOL monovision is contraindicated, and conventional IOL monovision should be avoided too so we do not add anisometropia as an extra burden to an already compromised binocular function.

Case 1

A sixty nine year old gentleman was seen in August of 2008 with

a history of traumatic cataract in his left eye at age 10. No history of EOM surgery or diplopia. General health was unremarkable. Vision left eye CF at 4 feet without correction, 20/200 with -4D. Right eye was the dominant eye, also -4D refraction. Pre op examination also revealed mild cataract in right eye with an epiretinal membrane. The decision was made to do cataract surgery in the left eye. Surgery was uneventful on 8/11/2008 with a 15. 50 diopter SN60WF, and post op vision was 20/20 without correction for the left eye. The patient also wanted to do the right eye cataract surgery. Given the fact that the pre op was -4 myopic, decision was made to target monovision with the right eye aiming at -1. 50 D. Surgery went well on 8/18/2008 with a SN60WF 14. 50 D in the bag. Post operatively the patient was unhappy despite achieving the desired target of 20/20 plano in the left eye and 20/25 in the right eye with -1.5 D. He was not willing to wear glasses or contact lens, so a piggyback IOL was performed for the right eye. A Starr AQ -2D sulcus piggyback IOL on 6/1/2009 resulted in 20/25 plano, but pigment dispersion plus steroid response caused ocular hypertension and secondary glaucoma. The Piggyback IOL was removed and an IOL exchange was performed on 7/29/2009 with a MN60AC 11. 50D in the sulcus with optic capture and a final result of plano. Unfortunately he developed CME and ERM with metamorphopsia. Retina PPV and member peeling was performed on 1/5/2010 with a result of 20/20. After that, it was first noticed to have 1-2 prism diopter of LHT, but the patient declined wearing a pair of glasses and is doing pretty well and fairly happy since then.

Why was that patient not happy after successful surgery result of 20/20 plano left eye and 20/25 with -1. 5D right eye? It is likely that he had a strong dominant right eye considering the fact that he had traumatic cataract in his left eye at age 10 and the left eye had been suppressed with poor vision since then. Now, the left eye corrected to be 20/20 plano functioning as dominant eye and 20/25 with -1. 5D for the right eye as the near vision eye. Binocular system may not be able to function harmoniously if a long suppressed eye suddenly becomes the dominant fixing eye. It is probably advisable to avoid choosing a long term-suppressed eye or amblyopic eye for the distant vision eye if mono vision is to be considered. One argument could be his 1-2 prism diopter of LHT, first noticed after all the surgeries were over, but still that patient seemed to be able to tolerate that misalignment well without any prism correction. This special case does suggest the potential risk of fixation switch issue in long-standing unilateral traumatic cataract with crossed monovision.

Monofixation syndrome

Monofixation syndrome is the loss of bifixation or foveal fusion resulting in the manifestation of a facultative absolute scotoma in the fovea of the non fixating eye [21-23]. To avoid selecting a patient with monofixation syndrome as a candidate IOL monovision can be challenging. The absence of foveal fusion that characterizes monofixation syndrome can occur in strabismic as well as orthotropic eyes [21-23]. The presence of a unilateral macular lesion can also cause monofixation syndrome. If eccentric fixation is present in one eye, the cover and uncover test may not reveal any shift. Due to the fact that some monofixation patients (~ 30%) appear orthophoric, especially those primary monofixation syndrome, the commonly accepted criteria of avoiding any tropia and >8-10 diopter phoria as the recommendation for IOL monovision may not be enough. What is more, the largest deviation found in monofixation patients with cover and uncover testing is 8 prism diopters horizontally and 2 to 3 prism diopter vertically [21]. They retain good peripheral fusion and they may still have normal retinal non response (NRC) because the deviation is small. Preoperative examination with 4-diopter prism base out test (4ΔBO) and/or Worth 4-dot fusion at distance 6 meters might be helpful to make the diagnosis, although it may not be reliable if the cataract is dense and vision is poor. One helpful question is to ask: "Are you aware if one eye has always been weaker than the other? If the answer is yes, then we should be careful about the decision to offer IOL monovision. Being weaker is different from being non-dominant; the former refers to visual acuity while the later refers to preference. Two thirds of monofixation syndrome was noted to have amblyopia whilst one third were not amblyopic but did have alternate fixation, simultaneously transferring the macular scotoma from eye to eye [24]. Monofixation syndrome patients are typically asymptomatic. They have straight or near straight eyes, with average fusional vergence amplitudes as bifixators and appreciation of gross stereopsis and do not get worse with aging [21]. Monofixation syndrome can be primary without any noticeable etiology, or secondary to small angle strabismus, anisometropia, or monocular macular lesion. The presence or absence of Monofixation can be tested either with the 4-diopter prism base out test (4ΔBO) at distance or distance fusion on the Worth 4-dot test [21,23]; it can also be tested with Bagolinistriated lenses, Polaroid vectographic slide and Binocular perimeter [21]. Worth 4 dot test was noted to be the most reliable and 4 prism diopter base-out test to be the least reliable method to detect monofixation by Parks [21]. Of note, a patient with normal fusion function with Worth 4 Dot test at 13 inches does not rule out monofixation since the average monofixation syndrome patients can fuse at 10 feet [21]. The diagnosis of monofixation syndrome becomes clinically important when a cataract surgeon plans to offer a crossed IOL monovision. Conventional monovision will risk break down in the balance of stable asymptomatic monofixation syndrome due to monovision-induced anisometropia. Monofixation syndrome patients can also experience diplopia after LASIK induced monovision [25]. Since most of the scotoma of mono fixating patients is approximately about 3 degrees, most, if not all, monofixation syndrome can fuse at 13 inches with Worth 4 Dot test but unable to fuse at distance 20 feet [21]. There has not much attention to the question if monofixation syndrome can be candidate for conventional monovision. The extra burden of anisometropia of even conventional IOL monovision will further compromise their peripheral fusion balance and aggravate the condition. Given the fact that the affected eye vision/stereo vision can be near normal and the deviation of the angle can be small or even orthophoric, it is not always that easy to screen out these patients before we make the decision for IOL monovision. Modest monovision with anisometropia at 1.0 -1.25 D levels rather than traditional 2D or more level also helps a lot. With mild anisometropia, dominancy becomes less important. It is a challenge to screen monofixation syndrome out of IOL monovision candidates, but a combination of thorough history and careful examination should work for vast majority situations. Most of them have some component of amblyopia. With careful cover/uncover test, if I find any manifest tropia, poor stereo and no fusion then I would be worried about post op diplopia developing with monovision.

Case 2

Sixty-year-old female executive with preoperative history of hyperope. Refractive lens exchange OD Restore 3D with LRI, 20/25 distance without correction, J8 at near without correction and J3 with correction for OD. OS +3. 5D 20/20. There was no high order aberration in I Trace with perfect optics OU. Two month postoperative, not happy, came for a second opinion for the operated

OD. With more questions for past history, the patient did recall that she had patch over her left eye during childhood. 4-diopter prism base out test (4ΔBO) supported the diagnosis of monofixator of OS. The long duration weaker OD now is the fixating eye, which was most likely the reason why the patient was not happy. Author's speculation: If the OS is corrected with a mono focal IOL at plano with 20/20 or better vision without correction, the patient might be doing ok. No follow up information available due to the nature of consultation.

Natural monovision

History of preexisting anisometropia, especially prior to cataract formation, can be a concern. We sometimes see patients with natural monovision as preexisting anisometropia. They might have normal bilateral visual function and indeed natural monovision. If that anisometropia was congenital, however, it could be amblyopia and monofixation syndrome. In young children, > 1.5 D of anisometropia puts the patient at approximately a 50% risk of becoming a monofixation syndrome; >2. 0 D increases the risk to almost 100% [24]. The eyes can be present to be straight or near straight. So a large preexisting anisometropia should be a red flag for the clinician and it deserves further exploration and tests. These patients may have such a history of "my left eye is always weaker than my right eye ever since I can remember"; or they might have patch treatment for amblyopia during childhood. Cover and uncover test may detect some deviation, but not always. If IOL monovision given, the outcome may be unsatisfactory. If conventional monovision is used, the patient may not have well near vision coverage due to strong ocular dominance. The original balanced peripheral fusion may deteriorate and the amblyopic eye may develop a manifest deviation. Crossed monovision may be more troublesome due to possible fixation switch diplopia. Detailed history will help but not all the patients will be able to provide you a valid history. The Worth 4 dot test and 4-diopter prism base out test (4ΔBO) will be helpful if the cataract is not too dense to detect the small central macular scotoma of the weaker eye. Worth 4 Dot test at near may be normal but at distance is likely seeing fewer than 4 dots. Stereopsis will also be compromised.

We do see natural monovision among our cataract population. Most of time it is hard for us clinicians to tell if it has been present since childhood; or was due to a gradual refraction change or related to cataract formation. Stereopsis, Worth 4 Dot test and 4ΔBO are all likely in normal range. Of course, these patients would be the best candidates for conventional IOL monovision when they are ready for cataract surgery but it is not advisable to target crossed IOL monovision, nor should multifocal IOLsbe offered.

Amblyopia

The main purpose of induced monovision, whether from glasses, contact lenses, refractive surgery or IOL, is to decrease the dependence on glasses. When the amblyopic eye is elected to be the near eye, we typically do not expect any specific major problem, but the chance of glasses freedom is limited. The speculation is that the fellow eye has a strong ocular dominance but for near work, the healthy dominant eye lacks blur suppression. In cases of amblyopia, where strong ocular dominance is known to exist, patients tend to suppress information originating from the no dominant eye regardless of its clarity. These patients are not good candidates for contact lens monovision [26]. From a few cases of IOL monovision with a history of amblyopia in my practice; I did not find the outcome was impressive in terms of spectacle independence.

When a child has amblyopia and is hyperopic, typically the amblyopic eye has a greater refractive error. The myopic shift that occurs during growth may change the fixation pattern. The original fixing eye may become more myopic and the no dominant eye still being slightly hyperopic. If the amount of hyperopia is mild and if the vision is pretty good in the amblyopic eye, the clinician may assume that the current fixation eye can be the dominant eye for distance and the myopic eye for near. That can cause unbalanced binocular function, or even fixation switch diplopia [19].The nature of this mistake is due to crossed IOL monovision.

Case 3

61-year male with hyperopia OU and history amblyopia OD came for clear lens extraction with the hope no need for glasses far and near. No history of external ocular muscle surgery or prism use or double vision. Preoperative refraction OD +5.75+0.25x39 at 20/40 and OS +6.00 sphere at 20/20. Dominant eye test noted OS as dominant with hole in card as well as with camera. Ocular exam was normal except with questionable trace epiretinal membrane in OD but OCT was unremarkable. W4D at near showed 4 dots: 2 green and 2 yellow. W4D at distance 2 dots: 1 green and 1 yellow. Cover and uncover test distance with glasses: 4 Esophoria at primary gaze, left gaze and right gaze. Monovision was planed with OD aiming at -1.0 and OS plano. Surgery was uneventful OU. Three months post operative follow up noted distant vision uncorrected OD 20/50, OS 20/20, near vision uncorrected OD J5 and OS J3. Corrected distance vision OD -1. 0+0.50x27 20/25 and OS Plano 20/20. Corrected near vision with +2.50 add OD J1 and OS J1+. He stated that he did no need glasses for far, but he needed glasses for arm length such as computer as well as for all near work. The fact that the anisometropia was low might also play some role for his poor near vision, but uncorrected near vision was J5 OD, which was worse than J3 OS. Uncorrected near vision was expected to be better in OD than OS should he not have amblyopia in OD. At one year postoperative visit, his ocular condition was the same as 3 month follow up. Monovision just did not work out well for this gentleman for his intermediate vision and his near vision. Fortunately, he remains pretty happy and his cover and uncover test was still about the same with no deterioration.

Systemic situations

Parkinson's disease: Patients with degenerative central nervous system diseases, where motor muscular movement is compromised, should not be considered candidates for IOL monovision. Parkinson's disease is a typical sample. The motor symptoms of Parkinson's disease result in the most obvious shaking, rigidity and slowness. All three fundamental types of eye movements can be involved in Parkinson's disease: saccadic, pursuit and vergence. All of them, especially the vergence, are important for focusing, fusion and binocular visual function. In Parkinson's disease, the saccades tend to be slow. Some people with Parkinson's disease require a blink to change their saccadic position (Wilson's sign). When pursuit movements become decreased, this can produce what is called jerky or cogwheel slow eye movements. Inadequacy or slowness of accommodation can result in eyestrain, vision fluctuation, headaches and double vision when working on near tasks. Convergence insufficiency and ocular motor function were demonstrated much worse in Parkinson's disease than age matched control group [27].

Graves' eye disease (GED): Also known as thyroid eye disease. In this autoimmune condition, the body's immune system attacks external ocular muscle and orbit connective tissues.

GED may occur in patients, who already know they have thyroid disease, or sometimes it's the first problem that brings the person to the doctor's office. The major problems of GED from an IOL monovision perspective are the tight orbit and eyelids, and the swelling of external ocular muscles, any and all of which can affect focusing, fusion and double vision.

Meniere's disease: Vestibular system disease patients probably should not be offered to have IOL monovision. The vestibular system includes the parts of the inner ear and brain that process the sensory information involved with controlling balance and eye movements. If disease or injury damages these processing areas, vestibular disorders can result. Meniere's disease is one of the most commonly diagnosed vestibular disorders. It is probably advisable to avoid IOL mono vision to any patient who has had repeated history of vertigo episodes because those diseases are often chronic in nature. Monovision itself may not necessarily make Meniere's disease worse, but extra anisometropia load may make balance and visual function system complicated.

Profession selection

There are some concerns about profession selection. Some professions may need perfect stereovision and we may need to avoid IOL monovision. Medical-legal case reported [28] for an airplane accident related to contact lens monovision pilot. The practitioner was not aware of the occupation of the patient. Truck driver, professional sport athletics such as basketball, tennis, baseball and golf likely do well with modest monovision, but may not be the ideal candidates for full mono vision.

IOL monovision is a very popular modality in the management of presbyopia in the cataract patient population. The vast majority of them are doing well, but it is not risk free. Not all patients can be safe candidates. Due to limitations on the scope and length, this paper did not discuss those situations which are well known to avoid for IOL monovision, such as tropia, significant phoria, history of double vision, prism usage, ocular muscle surgery, significant ocular comorbidities, extremely demanding personality, etc. , but rather focused on some less well known limitations but still potentially problematic with regard to the outcome. After near 2 decades of IOL monovision practice, I have had only one case, which I took back to operating room with a piggyback IOL to reverse the monovision, although that does not mean all the rest of IOL monovision in my practice have been successful, because some of them might have been wearing glasses/contact lenses to reverse the IOL monovision. Having said that, I can still reasonably state that IOL monovision is a very safe modality in the management of presbyopia as long as we have a thorough preoperative history and examination to avoid potential contraindications, accurate biometry measurement and seamless surgery.

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References

1. Westsmith RA. Uses of a monocular contact lens. Am J Ophthalmol. 1958; 46: 78-81.
2. Bujak MC, Leung AK, Kisilevsky M, Margolin E. Monovision correction for small-angle diplopia. Am J Ophthalmol. 2012; 154: 586-592.
3. Greenbaum S. Monovision pseudophakia. J Cataract Refract Surg. 2002; 28: 1439-1443.
4. Fonda G. Presbyopia corrected with single vision spectacles or corneal lenses in preference to bifocal corneal lenses. Trans Ophthalmol Soc Aust. 1966; 25: 78-80.
5. Boerner CF, Thrasher BH. Results of monovision correction in bilateral pseudophakes. J Am Intraocul Implant Soc. 1984; 10: 49-50.
6. Zhang F, Sugar A, Jacobsen G, Collins M. Visual function and patient satisfaction: Comparison between bilateral diffractive multifocal intraocular lenses andmonovision pseudophakia.J Cataract Refract Surg. 2011; 37: 446-453
7. Finkelman YM, Ng JQ, Barrett GD. Patient satisfaction and visual function after pseudophakic monovision. J Cataract Refract Surg. 2009; 35: 998-1002.
8. Kim J, Shin HJ, Kim HC, Shin KC. Comparison of conventional versus crossed monovision in pseudophakia. Br J Ophthalmol 2015; 99: 391-395.
9. Labiris G, Giarmoukakis A, Patsiamanidi M, Papadopoulos Z, Kozobolis VP. Mini-monovision versus multifocal intraocular lens implantation. J Cataract Refract Surg. 2015; 41: 53-57.
10. Zhang F, Sugar A, Arbisser L, Jacobsen G, Artico J. Crossed versus conventional pseudophakic monovision: Patient satisfaction, visual function, and spectacle independence, J Cataract Refractive Surg. 2015: 41: 1845–1854.
11. Ito M, Shimizu K, Iida Y, Amano R. Five-year clinical study of patients with pseudophakic monovision. J Cataract Refract Surg. 2012; 38: 1440-1445.
12. Henson DB. Visual Fields. Oxford: Oxford University Press. 1993.
13. Osher RH, Golnik KC, Barrett G, Shimizu K. Intentional extreme anisometropic pseudophakic monovision: new approach to the cataract patient with longstanding diplopia. J Cataract Refract Surg. 2012; 38: 1346-1351.
14. London R. Monovision correction for diplopia. Journal of the American Optometric Association. 1987; 58: 568-570.
15. Migneco MK. Alleviating vertical diplopia through contact lenses without the use of prism. Eye & Contact Lens.2008; 34: 297-298.
16. Pratt-Johnson JA, Tillson G. Intractable diplopia after vision restoration in unilateral cataract. American Journal of Ophthalmology. 1989; 107: 23-26.
17. Pratt-Johnson JA, Tillson G. Why does the patient have double vision? Management of strabismus and amblyopia: A practical guide. New York NY. Thieme Medical Publishers Inc. 1994: 242-246.
18. Ruben CM. Unilateral aphakia. The British Orthoptic Journal. 1962; 19: 39-60.
19. Kushner BJ. Fixation Switch Diplopia. Arch Ophthalmol. 1995; 113: 896-899.
20. Boyd TAS, Karas Y, Budd GE, Wyatt HT. Fixation switch diplopia. Canad. J Ophthal 1974; 9: 310-315.
21. Parks MM. Monofixation Syndrome. Trans Am Ophthalmol Soc 1969; 67: 609-657.
22. Fawcett SL, Herman WK, Alfieri CD, Castleberry KA, Parks MM, Birch EE. Stereoacuity and foveal fusion in adults with long-standing surgical monovision Journal of American Association for Pediatric Ophthalmology and Strabismus. 2001; 5: 342–347.
23. Weakley DR. The association between anisometropia, amblyopia and binocularity in the absence of strabismus. Trans Am Ophthalmol Soc. 1999; 97: 987-1021.
24. Parks, MM. Monovision: The case for two binocular vision systems. The 1999 Gunter K. von Noorden Visiting Professorship Lecture. Binocular Vision & Strabismus Quarterly. 2000; 15: 13-16.

25. Buckley EG. Diplopia after LASIK surgery. At the Crossings: Pediatric Ophthalmology and Strabismus, pp 55-66. Proceedings of the 52nd Annual Symposium of the New Orleans Academy of Ophthalmology. New Orleans, LA, USA, February 14-16, 2003. Edited by Robert J. Balkan, George S. Ellis Jr. and H. Sprague Eustis. ©2004 Kugler Publications, The Hague, The Netherlands.

26. Schor C, Erickson P. Patterns of binocular suppression and accommodation in monovision. Am J Optom Physiol Opt. 1988; 65: 853-861.

27. Almer Z, Klein KS, Marsh L, Gerstenhaber M, Repka MX. Ocular motor and sensory function in Parkinson's disease. Ophthalmology 2012; 119:178-182.

28. Nakagawara VB. Veronneau SJ. Monovision contact lens use in the aviation environment: a report of contactlens-related aircraft accident. Optometry. 2000; 71: 390-395.