• Review •

A systematic review of pseudophakic monovision for presbyopia correction

Georgios Labiris[1,2], Aspa Toli[2], Aslin Perente[2], Panagiota Ntonti[2], Vassilios P. Kozobolis[1,2]

[1]Department of Ophthalmology, University Hospital of Alexandroupolis, Dragana, Alexandroupolis 68100, Greece
[2]Eye Institute of Thrace, Alexandroupolis 68100, Greece
Correspondence to: Georgios Labiris. Department of Ophthalmology, University Hospital of Alexandroupolis, Dragana, Alexandroupolis 68100, Greece. labiris@usa.net
Received: 2016-10-17 Accepted: 2017-02-23

Abstract

• A systematic review of the recent literature regarding pseudophakic monovision as a reliable methods for presbyopia correction was performed based on the PubMed, MEDLINE, Nature and the American Academy of Ophthalmology databases in July 2015 and data from 18 descriptive and 12 comparative studies were included in this narrative review. Pseudophakic monosvision seems to be an effective method for presbyopia with high rates of spectacles independence and minimal dysphotopsia side-effects, that should be considered by the modern cataract surgeons.

• KEYWORDS: pseudophakic monovision; presbyopia correction; cataract extraction; mini-monovision; monofocal intraocular lens; lens implantation

DOI:10.18240/ijo.2017.06.24

Labiris G, Toli A, Perente A, Ntonti P, Kozobolis VP. A systematic review of pseudophakic monovision for presbyopia correction. *Int J Ophthalmol* 2017;10(6):992-1000

HISTORY OF PRESBYOPIA CORRECTION

Presbyopia is an age-related refractive condition, where the accommodation of eyes progressively weakens, subsequently leading to impairment of the ability to focus on near objects. The correction of presbyopia includes reading spectacles, contact lenses and a series of surgical techniques. In recent years, the patients have expressed a need for a spectacle-free life, which in turn has given great emphasis on the need for advancement in the field of the surgical correction of presbyopia.

Presbyopia symptoms are present in patients after cataract lens extraction. The treatment of such patients is a main challenge of modern ophthalmology. Pseudophakic presbyopia corrections primarily include: 1) implantation of multifocal intraocular lens (IOLs); 2) implantation of accommodative IOLs and; 3) pseudophakic monovision induced by monofocal IOLs[1].

Regarding monovision, one eye is corrected for distance vision and the fellow for near vision. In the majority of the cases, the dominant eye is corrected for distance vision and the recessive one for near vision (conventional monovision). When the recessive eye is chosen for distance vision, the technique is referred as crossed monovision. In the hybrid monovision technique, a diffractive multifocal IOL is implanted in the nondominant eye, whereas in the dominant eye a monofocal IOL is implanted[1].

Contact lenses monovision is known since the early 60s[2]. However, the first publication of pseudophakic monovision was performed in 1984, by Boerner and Thrasher[3]. In 1999, conventional monovision was firstly used for the correction of the presbyopia after cataract surgery[4-6].

Primary objective of this paper is to review published literature regarding the efficacy of pseudophakic monovision in the correction of presbyopia after cataract extraction, based on both subjective parameters of patients, such as satisfaction, spectacle independence and dysphotopsia symptoms and also clinical parameters, including visual acuity (VA) at all distances, contrast sensitivity stereopsis and possible complications postoperatively.

LITERATURE RESEARCH AND EVALUATION

A systematic search for relative studies was carried out based on PubMed, MEDLINE, Springer, Nature, Scopus, *Journal of Cataract and Refractive Surgery* and *American Academy of Ophthalmology* databases using the search terms below: pseudophakic monovision; monovision and presbyopia; monovision and cataract; mini-monovision; monovision review; monovision and monofocal IOLs; monovision and multifocal; monovision and lens implantation. The search took place in July of 2015. The initial search was performed without search filters and language restrictions. Afterwards, the results were checked and only articles related to the subject were selected. Subsequently, the eligible articles and abstracts were scanned diligently and the following data were extracted: article information, surgical data, patient selection, clinical parameters, spectacle independence, patients' satisfaction and possible complications. Both comparative and descriptive studies on adult patients were included in this review. Articles

Table 1 Studies design

Studies	Comparative studies	Descriptive studies	Prospective studies	Retrospective studies
References	22, 33	2, 3, 6-21	2, 9, 22, 26-29, 31-33	3, 10, 15, 16, 19
No. of studies	12	18	10	5

covering only techniques for presbyopia correction after cataract surgery, other than pseudophakic monovision or referring to children patients, or not available in English were excluded. When the eligible articles were not available in full text, abstracts were used as a source of information.

Studies' Design The present review included 18 descriptive[2-3,6-21], 12 comparative[22-33] studies. Among them 10 were prospective studies[2,9,22,26-29,31-33] and 5 retrospective[3,10,15-16,19], while there was not any relative statement in the rest of the studies. Nine[22-25,27,29-31,33] of the studies compared the pseudophakic-monovision technique with the multifocal IOLs implantation technique, using refractive[24] or diffractive[22,27,30-31,33] IOLs, as it was described in most of the studies. Beiko[28] compared mini-monovision with accommodating IOLs implantation, while two studies compared conventional monovision with modified[26] or crossed[9,32] monovision (Table 1).

Patient Selection Patient selection was presented to be very crucial for the success of pseudophakic monovision[14] and most surgeons dealt thoroughly with patients' inclusion and exclusion criteria.

The most frequent inclusion criterion was the desire for spectacle independence[9,12,22,28]. Zhang *et al*[22] excluded patients who did not have the demand to be spectacle free postoperatively. Osher *et al*[20] included only patients with cataract and longstanding acquired strabismus in order to evaluate the efficacy of pseudophakic monovision in diplopia. Among the exclusion criteria were the following: severe ocular disease, corneal astigmatism, strong ocular dominance, large exophoria, and inability to understand the concept of monovision design. Severe ocular disease was a common reason for exclusion from the studies, as it was believed to have unfavorable effect on visual rehabilitation[14]. Patients with glaucoma, retinal pathology, optic neuropathy, amblyopia and other ocular pathology that may affect visual performance were excluded from several studies[2,14,16,19,21,26,28-30]. Some of the studies had a restriction about corneal astigmatism. Most of them[21,24,28-30] excluded patients with corneal astigmatism of 1.00 D or greater. Finkelman *et al*[2] and Ito *et al*[10] did not select patients with astigmatism of 1.50 D or greater, while Greenbaum[12] excluded patients with astigmatism of 2.00 D or higher. Handa *et al*[6] studied the importance of ocular dominance in patient selection. Strong ocular dominance was reported to cause anisometropia and decrease of visual performance. Therefore, weak ocular dominance was considered to be a significant parameter for monovision success[14]. Patients with a history of strabismus or large exophoria were excluded from 6 studies[10,14,16,19,21,24]. Zhang *et al*[22] set a pupillary diameter restriction of 5.00 mm or larger, while other researchers excluded patients with pupil size smaller than 4.00 mm and 4.50 mm, respectively[26]. Finkelman *et al*[2] excluded patients who could not understand the concept of monovision design. In addition, another study excluded patients who had poor knowledge of English[30].

Regarding patients' age, only studies on adults were included in this review. The participants' age varied from 24[21] to 94[20], while in 8[3,6-8,13,23,27,32] studies there were no age data available. Ito *et al*[10-11,14] divided patients into three age-groups and analysed comparatively their parameters. Conventional monovision was compared to modified monovision by Hayashi *et al*[26] and the outcomes were associated with age. Iida *et al*[21] performed hybrid monovision technique and they found a significant association between age and satisfaction rate.

Monovision Methods Some researchers dealt with the different types of monovision technique. Kim *et al*[32] compared conventional with crossed monovision, while Hayashi *et al*[26] compared modified with conventional monovision. Iida *et al*[21] used a new technique called hybrid monovision, where a monofocal IOL was implanted in the dominant eye and a diffractive multifocal IOL in the nondominant eye.

Ito *et al*[10-11,14,16,19,24] performed conventional method of pseudophakic monovision, correcting the dominant eye as emmetropic (0.00 to +0.25 D) and the nondominant eye as myopic (-2.00±0.50 D). Zhang *et al*[22,33] adopted the traditional (conventional) monovision technique, with an approximate difference of 2.00 D between two eyes, while comparing it to multifocal IOL implantation. Stanojcic *et al*[31] corrected the dominant eye for distance vision 0 to -0.50 D and the nondominant for near vision -1.00 to -1.50 D in monovision group. Lubiński *et al*[18] used conventional pseudophakic monovision and corrected the dominant eye to emmetropia and the non-dominant eye to -2.00 D. Osher *et al*[20] evaluated the efficacy of pseudophakic monovision in longstanding diplopia. They corrected the dominant eye for distance vision and the non-dominant eye for near vision, with a mean difference between two eyes' correction of at least 3.00 D. Greebaum[12] selected the dominant eye for emmetropia correction and the non dominant eye for myopia correction of -2.75 D. Wilkins *et al*[30] performed a comparative study, where the "distance" eye was corrected to emmetropia and the other eye between -1.00 and -1.50 D. Finkelman *et al*[2] used modified monovision in patients with second-eye cataract surgery, after successful surgery in the first eye with emmetropia. They had a moderate

Table 2 IOLs used in monovision technique

IOLs	References	No. of studies
Monofocal Acrysof SN60WF IOLs	22, 25, 27, 33	4
Monofocal IOL (AQ110NV, Canon-Staar)	10, 16, 19, 24	4
Acrysof monofocal IOL	23	1
Hydrophobic acrylic IOL (ZCBOO, Abbot Medical Optics)	26	1
Tecnis 1-piece monofocal (nonaccomodating) control IOL , Abbott Medical Optics, Inc.	28	1
Akreos AO monofocal lenses (Bausch & Lomb, Rochester, NY)	4, 30	2
Alcon SA60AT monofocal IOL	18	1
Monofocal IOL (AQ31Ai)	21, 25	2
Monofocal IOL (Sensar -AMO)	9	1
Foldable hydrophilic acrylic IOL (SN60WF, Alcon Laboratories, Inc.)	29	1

Table 3 Studies design: comparative studies

Techniques	References	No. of studies
Multifocal IOL implantation *vs* pseudophakic monovision	22-25, 27, 29-31, 33	9
Diffractive multifocal IOLs	22, 27, 30, 31, 33	5
Refractive multifocal IOLs	24	1
Not stated	23, 25, 29	3
Accommodating IOLs implantation *vs* mini-monovision	28	1
Modified monovision *vs* conventional pseudophakic monovision	26	1
Crossed monovision *vs* conventional pseudophakic monovision	32	1

myopic target refraction of -1.00 to -1.50 D. Hayashi *et al*[26] compared the modified monovision with conventional monovision with 0.75 and 1.75 D anisometropia respectively. In another study[7] they evaluated the optimal target anisometropia for successful pseudophakic monovision to be circa 1.50 D. In Iida *et al's* study[21] for hybrid monovision, both eyes were corrected to emmetropia 0.00 to +0.25 D. Marques *et al*[9] did not take into account the ocular dominance while using pseudophakic monovision technique, but corrected the first eye between -0.50 and +0.50 D and the second eye to -2.00 D. In Zettl *et al*[15] clinical trial for pseudophakic monovision, there was a slight difference in correction between the two eyes 0.50 to 1.75 D. Beiko[28] set a target refraction between -0.25 and -0.75 D in the mini-monovision group, without accounting the dominance of the eye. Chen *et al*[25] adopted a mini-monovision formula, achieving correction of dominant eye for distance vision and and that of nondominant for near vision of -0.50 to -1.25 D. Labiris *et al*[29] corrected the dominant eye to -0.50 D and the nondominant to -1.25 D, in the mini-monovision group of their trial.

The number of surgeons was mentioned in 9 studies[2,9,22,25-26,28-30,33]. In most of these cases[9,22,25-26,28-29,33], surgeries were performed by the same surgeon, while there was a second surgeon in Finkelman *et al*'s study[2]. Wilkins *et al*[30] reported the participation of 9 cataract surgeons in their study.

The kind of IOLs used in monovision design in the eligible studies was reported in 18 studies. The IOLs used in each trial are presented in Table 2, among them monofocal Acrysof SN60WF IOLs[22,25,27,33] and monofocal IOL (AQ110NV, Canon-Staar)[10,16,19,24] were preferred in eight studies.

Comparative Studies This review included twelve comparative studies, among them 8 studies were prospective[22,26-29,31-33]. Methods compared to pseudophakic monovision technique were presented in Table 3.

Most of the studies compared the pseudophakic monovision with the implantation of multifocal IOLs[22-25,27,29-31,33]. It was shown that distance VA was significantly better postoperatively after both techniques[29,33]. Furthermore, between two groups there was not significant difference concerning distance VA[22-25,27,29-30]. Chen *et al*[23,25] compared the Acrysof monofocal IOL in mini-monovision with the ReSTOR multifocal IOL implantation and demonstrated that patients of both groups could achieve 20/30 distance VA and J3 near vision without spectacles after surgery.

Pseudophakic monovision and multifocal IOLs could achieve significant improvement of unaided near VA postoperatively (P<0.001)[33]. According to three studies the above methods did not show any statistically significant difference in postoperative near VA evaluation comparatively[24,27,29]. On the other hand, Zhang *et al*[22] pointed out a significant difference between monovision and multifocal groups in binocular uncorrected near visual acuity (UNVA). In the multifocal group 90% of

patients had 20/20 contrary to the respective percentage of 59% in monovision patients (P=0.018). However, there was no statistically significant difference between 2 groups in the percentage of eyes with a UNVA of 20/25 or better (P=0.331). Wilkins *et al*[30] found that binocular UNVA was significantly better in the multifocal group [(-0.03) logMAR] than in monovision group [(0.01) logMAR] (P=0.037).

Regarding the intermediate VA, Zhang *et al*[22] found that 73% of patients in monovision group had 20/30 or better uncorrected intermediate visual acuity (UIVA) in comparison with multifocal group (9%; P<001). In Wilkins *et al*[30] trial, the monovision arm showed significantly better UIVA than the multifocal arm (P=0.000). However, Mu *et al*[27] did not find significant difference in intermediate vision examination between multifocal and monovision group.

Zhang *et al*[22] observed no statistically significant difference between monovision and multifocal groups in stereovision analysis results. On the other hand, Mu *et al*[27] pointed out significant differences between monovision and multifocal groups in stereovision (Median: 150″, 525″; Z=-2.092, P=0.036). Another study, showed significantly better stereovision with multifocal IOLs, with mean binocular stereoacuity of 1.77 contrary to 1.99 of monovision group (P=0.000)[30]. Wilkins *et al*[30] compared the contrast sensitivity in monovision and multifocal patients, with statistically better results in monovision group (P=0.009).

According to Chen *et al's*[25] study, 95% of ReSTOR multifocal patients and 35% of mini-monovision group achieved spectacle independence (significant difference, P=0.013). It is worth mentioning that they considered the patient was independent from spectacles, if he/she declared independence from them. In another study, Chen *et al*[23] proposed Acrysof monofocal IOL using the mini monovision formula as a good alternative to array multifocal IOLs implantation for spectacle independence after cataract surgery, because monofocal group had similar to slightly better outcomes than multifocal group in spectacle independence. Mu *et al*[27] reported that less than 10% of patients in groups of monovision and multifocal groups, were spectacle dependent postoperatively. Labiris *et al*[29] assessed the spectacle dependence using the VF-14 questionnaire. They reported that patients of both groups had excellent spectacle independence for distance vision, while the dependence for near vision was significantly less in the multifocal arm of the study (P<0.01). In the total outcome, the spectacle independence rate for the monofocal group was 31.40% and for the multifocal group 65.70%. Wilkins *et al*[30] used the VF-14 visual function questionnaire to evaluate the spectacle independence postoperatively. According to their outcomes significantly more patients in the multifocal group than in the monovision declared that they never used glasses after surgery, with relative percentages of 71.30% and 25.80%, respectively (P<0.001). Another study[33] demonstrated that patients of multifocal and monovision group had statistically significant betterment in everyday life activities after surgery. Zhang *et al*[22] reported no significant difference between monovision and multifocal groups in the percentage of patients who never needed glasses for computer work. However, significantly more patients in monovision group reported no difficulty or little difficulty using computer without glasses (P=0.048). There was no significant difference between 2 groups in the percentage of patients who never required glasses for newspaper reading and for driving. Patient-reported driving problems and difficulty during day and night driving were also without significant differences. The 14% of monovision and 24% of multifocal patients reported they had moderate difficulty in driving at night.

A trial of Ito *et al*[24] evaluated the reading ability of patients who underwent bilateral cataract surgery with pseudophakic monovision and refractive multifocal IOLs implantation. They estimated the mean maximum reading speed, being not significantly different in two groups. However, a significant difference in the mean reading speed was observed in favor of the monovision team, at the character sizes from 0.30 to 0.10 logMAR (P<0.05). The researchers also evaluated the critical character size and showed that it was significantly better in the monovision group (P<0.05). Moreover, monovision group noted significantly better reading acuity than multifocal group (P<0.01).

Regarding patients' satisfaction, Wilkins *et al*[30] reported that there was no statistically significant difference between the monovision group and the multifocal group (P=0.46). Zhang *et al*[22] used VF-14 questionnaire for the evaluation of patient satisfaction in their comparative study of multifocal IOL implantation and pseudophakic monovision. They concluded that there were no significant differences in satisfaction with specific elements, including cost, willingness to recommend the procedure, and total satisfaction with the surgery/IOL styles, between the 2 groups. However, monovision scores were more auspicious in the above three elements.

Among the reasons for patients dissatisfaction was the presence of dysphotopsia symptoms. The researchers[22] found that significantly more patients in multifocal group than in monovision presented halo and glare symptoms (P<0.01 and P=0.024). The 82% and 36% of monovision group reported having halo and glare symptoms none of the time, respectively. On the other hand, 10% and 14% of multifocal group reported they never had such symptoms. No significant difference was observed in difficulty in day or night driving, or in driving with difficult conditions between the two groups. Labiris *et al*[29] mentioned that multifocal patients complained about significantly more unwanted shadows (P=0.02) and insignificantly more glare (P=0.08) than patients in mini-

monovision group. Wilkins *et al*[30] found that multifocal patients more often mentioned annoying or debilitating glare or dazzle than monovision group (P<0.0001). Symptoms such as unwanted images and unusual shadows did not differ significantly in both groups.

Mini-monovision technique was compared with implantation of accommodating IOL in Beiko *et al's*[28] study. They examined binocular distance, near/intermediate VA and photopic/mesopic contrast sensitivity, without finding any significant differences between two groups. Another study[32] compared conventional monovision with crossed monovision. They analysed binocular uncorrected distance and near VA, best corrected VA, stereopsis, spectacle independence after surgery and patients' satisfaction rate, without any significant differences between two groups.

Stanojcic *et al*[31] performed an exploratory study where they analysed the visual fields in monovision and multifocal IOL patients. Although there was not statistically significant difference in their results (P=0.662), 3/10 monovision plots had suboptimal hemi-fields (distance-dominant eye) compared with 0/15 multifocal plots.

Hayashi *et al*[26] compared conventional monovision (1.75 D anisometropia) with modified monovision (0.75 D anisometropia). They found that binocular intermediate VA at 1.00 m was significantly better in the modified monovision group than in the conventional monovision group (P=0.0001), while near VA and intermediate VA at 0.50 m was significantly worse in the modified monovision group (P<0.0001). On the other hand, there was no statistically significant difference between two groups in binocular distance VA at 5.00 m. Regarding the mean binocular photopic and mesopic contrast VA and glare VA the results tended to be better in the modified monovision group, but the difference was not statistically significant. In addition, it was reported that the mean stereoacuity was significantly better with modified monovision (P=0.002). The researchers correlated the outcomes with the age of patients. For the modified monovision group, it was indicated that younger age was significantly correlated with better binocular distance to intermediate VA (5.00, 3.00, 2.00, 1.00 m). There was no significant association between age and binocular intermediate VA at 0.70 and 0.50 and near VA at 0.30 m. Significant but weak correlation was also observed in conventional monovision group, between age and binocular intermediate VA at 0.50 m. Both groups presented statistically important correlation between younger age and better contrast VA with and without glare.

Descriptive Studies Ito *et al*[10-11,14,16,19] dealt with pseudophakic monovision in five of the eligible descriptive studies. In 2009, they emphasized the important role of patient selection in the outcome of pseudophakic monovision technique. They suggested that excellent UDVA in the dominant eye; near exophoria no more than 10.00 prism diopters (Δ); and patients' age over 60y were the principles for successful monovision[14]. In other studies, Ito *et al*[10-11] divided patients in three age groups: younger than 60y; 60 to 70y; older than 70y. They assessed the visual performance (VA at all distances, contrast sensitivity, near stereopsis) and patients' satisfaction after pseudophakic monovision. Patients over 70 years old presented higher percentage of satisfaction than the other age groups, while the lowest percentage of satisfaction was in the youngest group. Moreover, the highest rates of both dissatisfaction and spectacle use were measured in patients younger than 60y. The main reasons for dissatisfaction were lack of visual clarity, asthenopia, postoperative spectacle dependence and discomfort[10]. In a five-year clinical trial of 2012[19], the researchers supported that pseudophakic monovision could provide an over time stability for the presbyopia correction. During the follow-up period, patients showed good near stereopsis and VA outcomes, while spectacle independence and patients' satisfaction got better gradually.

In 2014, Ito *et al*[16] correlated visual function with ocular deviation in patients who underwent pseudophakic monovision surgery. The patients were divided in two groups according to ocular deviation: mild angle-exophoria (≤10.00 Δ) and moderate angle-exophoria (>10.00 Δ). They found that there was statistically significant difference in median value of stereopsis, with better scores for patients with exophoria <10.00 Δ. Furthermore, they proved a statistically important positive correlation between preoperative near exophoria angle and postoperative near stereopsis, suggesting the preoperative exophoria as inclusion criterion for successful pseudophakic monovision.

The optimal anisometropia for effective pseudophakic monovision was valued in two studies[7,17]. Hayashi *et al*[7] indicated that anisometropia of approximately 1.50 D was considered to be the optimal one for successful monovision, providing profitable outcomes in visual performance. Naeser *et al*[17] presumed that binocular problems were minimized with anisometropia of 1.00 D, which was thought to be ideal one.

Marques *et al*[9] reported the effectiveness of pseudophakic monovision in visual performance and patient satisfaction. The outcomes showed that 97.40% of patients had ≥20/30 UDVA and ≥J2 of UNVA. Intermediate uncorrected VA of J3 was measured in 90% of patients. Most patients (81.50%) presented an expected decrease of stereoacuity, but Titmus test showed an average of 197″. The 97.30% of patients declared satisfied and very satisfied with the monovision technique, intimating a high percentage of spectacle independence. Only one patient reported discomfort while playing soccer or driving at night and required optical correction.

In another study, Lubiński *et al*[18] also assessed visual function and patient satisfaction after conventional pseudophakic

monovision. The outcomes showed very good visual function, without any postoperative complications. There were high rates of spectacle independence at all distances and patient satisfaction of 9.40/10.

Handa *et al*[6] amplified the relationship between ocular dominance and patient satisfaction after monovision with IOL implantation. Patients who underwent successful monovision presented the reversal threshold only at low decreasing contrast. On the other hand, in patients who were operated with monovision unsuccessfully the reversal thresholds were at high decreasing contrast (20%) or not at all. However, all patients revealed high rates of satisfaction. Ocular dominance significantly affected patient satisfaction and monovision success.

Zettl *et al*[15] studied the contribution of pseudophakic mini-monovision for spectacle free life in patients after cataract surgery. All patients achieved good distance and intermediate visual acuities (logMAR 0 and 0.10 respectively), while a remarkable reduction of near vision was described (63.33% had logMAR 0.30). The reading ability outcomes showed median average reading speed for binocular uncorrected reading under photopic conditions of 145 words/min and under mesopic conditions 117 words/min, the critical font size was logRAD 0.60 (Jaeger 5-6), the anisoconia at 2% and stereopsis at 80 arc seconds. The overall spectacle dependence was assessed to 13%, postoperatively. The findings of high satisfaction scores were considered to be comparable to those of full-monovision and multifocal IOL implantation.

Osher *et al*[20] performed extreme anisometropic pseudophakic monovision in patients with longstanding diplopia, with excellent visual outcomes and high satisfaction for all patients. They found that postoperatively only one patient had diplopia occasionally but he was satisfied with the surgery. These findings made them suggest that extreme pseudophakic monovision could possibly be effective for elimination of diplopia.

Hybrid monovision was selected for presbyopia correction by Iida *et al*[21]. The mean binocular VA at all distances was at least 0.10 logMAR, with significantly better results for binocular vision than monocular vision from 0.50 to 5 m (P<0.05). In addition, binocular contrast sensitivity was better than monocular in the eye with multifocal IOL. The 62.50% of patients achieved normal range of near stereopsis. Evaluating the reading ability of patients, the researchers estimated the mean reading acuity of 0.10±0.10 logMAR, the mean maximum reading speed of 418.00±55.80 characters/min and the mean critical character size was 0.31±0.11 logMAR. The reading outcomes supported that patients could read newsprint without problems. Only 18.80% of patients used glasses postoperatively. The 84% of patients were satisfied with this technique. The satisfaction rate was better in patients younger than 60y. Dysphotopsia symptoms, such as glare, halo or waxy vision were not mentioned. However, lack of intermediate or near visual clarity made some patients dissatisfied.

In another study[2] that dealt with pseudophakic monovision technique, most patients achieved excellent visual function (UDVA/UNVA, stereopsis,contrast sensitivity). Only 1 patient was generally dependent on spectacles, but he had a satisfaction score of 8/10. Patients who used spectacles occasionally, more often for near vision, remained very satisfied. Although there was one patient who needed laser treatment for retinal tear without retinal detachment postoperatively, none of patients needed refractive correction.

Greenbaum[12] divided patients in two groups (clear lens group and cataract group) and evaluated the outcome of pseudophakic monovision correction. The 91% of cataract patients and 95% of patients in clear lens group reported at least 20/30 or J1 or both for distance and near vision without correction, respectively. The method was acceptable with high percentages for both groups (90% for cataract group and 100% for clear lens group). There was no morbidity related to pseudophakic monovision technique.

DISCUSSION

The present review assessed several clinical trials of pseudophakic monovision for presbyopia correction after cataract surgery. After an intensive research, both descriptive and comparative studies were elected from the scientific literature. In most comparative studies pseudophakic monovision technique was compared with the implantation of multifocal IOLs[2,9,22,25-26,28-30,33], while accommodating IOLs implantation was compared to mini-monovision technique in one study[28]. The researchers of one comparative study used conventional and crossed methods of pseudophakic monovision technique[32].

The evaluation of visual performance postoperatively was an important parameter that was worked out in many trials. It was demonstrated that monovision technique could provide very good[18] to excellent[15,19-20] distance visual outcome, without statistically significant differences when compared to multifocal or accommodating methods[28].

Pseudophakic monovision was considered to be an alternative option for correction of near vision[9], as it was significantly improved postoperatively. Researchers showed that there was not statistically significant difference in UNVA between monovision patients and multifocal or accommodating groups[24,27,29]. However, Wilkins *et al*[30] resulted that multifocal group dominated in the assessment of near VA, with a significant difference. Crossed monovision technique had similar results to the conventional method in visual outcomes from near to far[32].

Another parameter examined by researchers[2,10,30] was contrast sensitivity. Some data indicated that contrast sensitivity was decreased at high frequencies but still remaining in normal

range in some cases[2,10]. Wilkins *et al*[30] showed that patients of monovision group had significantly better outcomes than multifocal patients.

There is great concern about the effect of pseudophakic monovision in stereovision. Hayashi *et al*[34] supported that several parameters could influence the stereopsis outcomes of pseudophakic patients, including age, differences in VA and spherical equivalent, axial length between eyes, astigmatism, aniseikonia, pupil diameter, and IOL decentration. Ito *et al*[16] found positive correlation between preoperative near exophoria angle and postoperative near stereopsis, as exophoria less than 10.00 D provided significantly better stereopsis outcomes in pseudophakic monovision patients. In most trials[2,9-10,14,19,21], there was a relative reduction of stereoacuity in monovision patients. The percentage of patients who were within normal range of stereoacuity varied from 63%[19-20] to 87%[10,14], however it did not affect the rate of satisfaction with the technique. Few research data suggested that stereoacuity of patients postoperatively was significantly better in multifocal group than in monovision group[22,30]. However, further studies are needed to clarify the relationship of pseudophakic monovision and stereovision.

Spectacle independence after presbyopia correction remains the main demand of patients who undergo pseudophakic monovision, which renders this a challenge for contemporary ophthalmologists. Regarding this parameter, pseudophakic monovision could provide great reduction of spectacle use postoperatively[2-3,10,14-15,18-19,21], achieving comparable outcomes with the implantation of multifocal IOLs[23,27,33]. However, there were studies that showed significant superiority of multifocal technique in this field[25,29-30]. Results of another research demonstrated that multifocal patients had significantly less dependence on spectacles for near vision[29]. Further investigation is required in order to draw safer conclusions about the effect of monovision in spectacle independence, as the postoperative use of glasses has a significant influence in everyday life and general satisfaction of patients.

The effect of pseudophakic monovision in daily activities was one of the elements examined in the eligible studies[15,22,24,33]. According to the outcomes, monovision patients had significantly less difficulty during computer work without glasses[22,33]; they had also significantly better reading ability than multifocal patients[24]. Regarding driving the outcomes were slightly better for monovision group[22].

In order to come to a reliable conclusion, some researchers used questionnaires to estimate the functionality of patients postoperatively, the rate of spectacle use and possible complaints. The answers given affected the overall satisfaction with the method of monovision. Patients after pseudophakic monovision achieved high scores of general satisfaction[10-11,15,19,22,30-31,33], especially in age groups over 70y[10-11,14]. Both mini-and full-monovision methods provided similarly high levels of satisfaction, comparable to those of multifocal technique[15]. More specifically, pseudophakic monovision arm presented slightly higher satisfaction with cost, willingness to propose the procedure to family and total satisfaction as well[22], without statistically significant difference comparatively with multifocal arm[22,30]. The comparison of conventional and crossed monovision had similar outcomes concerning spectacle use and patients' satisfaction[32].

Main causes for dissatisfaction of monovision patients were spectacle dependence, asthenopia and lack of visual clarity for intermediate and near vision[14,19,21]. Patients younger than 60y had higher rate of dissatisfaction and spectacle use postoperatively[10,14], so the performance of monovision in these age groups should take place after careful patient selection. Among the reasons for patients' dissatisfaction were often dysphotopsia symptoms, which were significantly more often in multifocal groups[22,29-30].

Postoperative complications after pseudophakic monovision were reported in two of the eligible studies. In the first one[2], the patient required laser treatment for a retinal tear without retinal detachment 4mo after cataract surgery, without need for refractive correction or IOL exchange. In the other study[30], one patient received multifocal IOLs due to an administrative error and another underwent LASIK surgery to reduce myopia in the "near" eye.

To our knowledge, only one study[8] evaluated the effect of pupil size on VA in pseudophakic monovision technique. Researchers indicated that decrease of pupil diameter and increase of myopia gradually led to an improvement of near VA. We believe that these findings should be taken into consideration and more investigation in this direction is required to reveal a possible role of pupil size in the success of monovision technique. Another parameter affecting success of monovision is the optimal anisometropia which was estimated to be 1.00 to 1.50 D[7,17].

The new approach of hybrid monovision[21], where a monofocal IOL is placed in the dominant eye and a diffractive multifocal IOL in the non-dominant eye, was believed to be an effective option for patients with presbyopia symptoms. Patients who underwent this method had significantly better VA outcomes at all distances binocularly than monocularly. This new technique may be a suitable option for patients younger than 60y, as especially in this age group satisfaction rate was at high levels. Moreover, this could be a promising method for patients with unclear vision after multifocal IOLs implantation, as dysphotopsia symptoms did not appeared in the participants of this study. Nevertheless, in cases where perfect near vision would be essential for work or lifestyle requirements, hybrid monovision was believed not to be the optimal approach, as it was associated with the lack of visual clarity at near and

intermediate distances. However, to date, only few research data concerning hybrid monovision is available in literature.

In conclusion, pseudophakic monovision is a safe and promising alternative for presbyopia correction after cataract surgery, with comparable efficacy to other relative techniques. This review indicated that monovision technique can achieve equally good visual outcomes and probably less dysphotopsia symptoms than multifocal IOLs implantation. There is concern about some visual functions such as stereoacuity and contrast sensitivity, as few research data signified a relative decrease in postoperative evaluation. Satisfaction was kept in very high rates, especially for elderly patients. Spectacle independence rates were also high. There is some evidence that multifocal patients were more independent, however, even patients who declared not to be fully independent from glasses remained satisfied with monovision. Our review suggests that pseudophakic monovision is a viable and effective method for presbyopia correction after cataract extraction, approachable to all budgets[2,29,35]. However, careful patient selection is crucial for successful outcomes. Further investigation is required in order to clarify probable drawbacks, restrictions and new directions of monovision technique.

ACKNOWLEDGEMENTS

Conflicts of Interest: Labiris G, None; **Toli A,** None; **Perente A,** None; **Ntonti P,** None; **Kozobolis VP,** None.

REFERENCES

1 Charman WN. Developments in the correction of presbyopia II: surgical approaches. *Ophthalmic Physiol Opt* 2014;34(4):397-426.

2 Finkelman YM, Ng JQ, Barrett GD. Patient satisfaction and visual function after pseudophakic monovision. *J Cataract Refract Surg* 2009;35(6):998-1002.

3 Boerner CF, Thrasher BH. Results of monovision correction in bilateral pseudophakes. *J Am Intraocul Implant Soc* 1984;10(1):49-50.

4 Inoue T, Shimizu K, Niida T, Nitta A, Minei R. Patients' satisfaction with monovision after bilateral cataract surgery. *Rinsho Ganka* 2000;54:825-829.

5 Ito M, Shimizu K, Iida Y, Amano R. Five-year clinical study of patients with pseudophakic monovision. *J Cataract Refract Surg* 2012;38(8):1440-1445.

6 Handa T, Mukuno K, Uozato H, Niida T, Shoji N, Minei R, Nitta M, Shimizu K. Ocular dominance and patient satisfaction after monovision induced by intraocular lens implantation. *J Cataract Refract Surg* 2004;30(4):769-774.

7 Hayashi K, Yoshida M, Manabe S, Hayashi H. Optimal amount of anisometropia for pseudophakic monovision. *J Refract Surg* 2011;27(5):332-338.

8 Kawamorita T, Uozato H, Handa T, Ito M, Shimizu K. Effect of pupil size on visual acuity in a laboratory model of pseudophakic monovision. *J Refract Surg* 2010;26(5):378-380.

9 Marques FF, Sato RM, Chiacchio BB, Marques DM, Barreiro J, Caetano RL. Evaluation of visual performance and patient satisfaction with pseudophakic monovision technique. *Arq Bras Oftalmol* 2009;72(2):164-168.

10 Ito M, Shimizu K, Amano R, Handa T. Assessment of visual performance in pseudophakic monovision. *J Cataract Refract Surg* 2009;35(4):710-714.

11 Ito M, Shimizu K, Amano R, Niida T, Totsuka S, Iida Y, Shoji N. Assessment of visual function and satisfaction in pseudophakic monovision. *Nihon Ganka Gakkai Zasshi* 2008;112(6):531-538.

12 Greenbaum S. Monovision pseudophakia. *J Cataract Refract Surg* 2002;28(8):1439-1443.

13 Ye P, Xu W, Tang X, Yao K, Li Z, Xu H, Shi J. Conductive keratoplasty for symptomatic presbyopia following monofocal intraocular lens implantation. *Clin Exp Ophthalmol* 2011;39(5):404-411.

14 Ito M, Shimizu K. Pseudophakic monovision. *Cataract & Refractive Surgey Today (Europe)* 2009;(Oct):64-66.

15 Zettl S, Reiß S, Terwee T, Guthoff RF, Beck R, Stachs O. Effect of pseudophacic mini-monovision as an option for independence of spectacles in everyday life. *Klin Monbl Augenheilkd* 2014;231(12):1196-1202.

16 Ito M, Shimizu K, Niida T, Amano R, Ishikawa H. Binocular function in patients with pseudophakic monovision. *J Cataract Refract Surg* 2014;40(8):1349-1354.

17 Naeser K, Hjortdal JØ, Harris WF. Pseudophakic monovision: optimal distribution of refractions. *Acta Ophthalmol* 2014;92(3):270-275.

18 Lubiński W, Cholewa M, Podboraczyńska-Jodko K. Conventional pseudophakic monovision-visual function, patient satisfaction and complications. *Klin Oczna* 2013;115(3):189-193.

19 Labiris G, Ntonti P, Patsiamanidi M, Sideroudi H, Georgantzoglou K, Kozobolis VP. Evaluation of activities of daily living following pseudophakic presbyopic correction. *Eye Vis (Lond)* 2017;4:2.

20 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(8):1346-1351.

21 Iida Y, Shimizu K, Ito M. Pseudophakic monovision using monofocal and multifocal intraocular lenses: hybrid monovision. *J Cataract Refract Surg* 2011;37(11):2001-2005.

22 Zhang F, Sugar A, Jacobsen G, Collins M. Visual function and patient satisfaction: Comparison between bilateral diffractive multifocal intraocular lenses and monovision pseudophakia. *J Cataract Refract Surg* 2011;37(3):446-453.

23 Chen M, Atebara NH, Chen TT. A comparison of a monofocal Acrysoft IOL using the "blended monovision" formula with the multifocal array IOL for glasses independence after cataract surgery. *Ann Ophthalmol (Skokie)* 2007;39(3):237-240.

24 Ito M, Shimizu K. Reading ability with pseudophakic monovision and with refractive multifocal intraocular lenses: comparative study. *J Cataract Refract Surg* 2009;35(9):1501-1504.

25 Chen M, Chen M. A study of monofocal intraocular lens (AcrySof) in mini-monovision (MMV) and premium multifocal implantation of ReSTOR. *Clinical Optometry* 2010;2:1-3.

26 Hayashi K, Ogawa S, Manabe S, Yoshimura K. Binocular visual function of modified pseudophakic monovision. *Am J Ophthalmol* 2015; 159(2):232-240.

27 Mu J, Chen H, Li Y. Comparison study of visual function and patient satisfaction in patients with monovision and patients with bilateral multifocal intraocular lenses. *Zhonghua Yan Ke Za Zhi* 2014;50(2):95-99.

28 Beiko GH. Comparison of visual results with accommodating intraocular lenses versus mini-monovision with a monofocal intraocular lens. *J Cataract Refract Surg* 2013;39(1):48-55.

29 Labiris G, Giarmoukakis A, Patsiamanidi M, Papadopoulos Z, Kozobolis VP. Mini-monovision versus multifocal intraocular lens implantation. *J Cataract Refract Surg* 2015;41(1):53-57.

30 Wilkins MR, Allan BD, Rubin GS, Findl O, Hollick EJ, Bunce C, Xing W; Moorfields IOL Study Group. Randomized trial of multifocal intraocular lenses versus monovision after bilateral cataract surgery. *Ophthalmology* 2013;120(12):2449-2455.

31 Stanojcic N, Wilkins M, Bunce C, Ionides A. Visual fields in patients with multifocal intraocular lens implants and monovision: an exploratory study. *Eye (Lond)* 2010;24(11):1645-1651.

32 Kim J, Shin HJ, Kim HC, Shin KC. Comparison of conventional versus crossed monovision in pseudophakia. *Br J Ophthalmol* 2015;99(3):391-395.

33 Zhang F, Sugar A, Jacobsen G, Collins M. Visual function and spectacle independence after cataract surgery: bilateral diffractive multifocal intraocular lenses versus monovision pseudophakia. *J Cataract Refract Surg* 2011;37(5):853-858.

34 Hayashi K, Hayashi H. Stereopsis in bilaterally pseudophakic patients. *J Cataract Refract Surg* 2004;30(7):1466-1470.

35 Xiao J, Jiang C, Zhang M. Pseudophakic monovision is an important surgical approach to being spectacle-free. *Indian J Ophthalmol* 2011; 59(6):481-485.