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Original Article

Visual quality after pseudophakic monovision in cataract patients

Yuheng Tao, Dan Liu, Qian Tan

Department of Ophthalmology, Xiangya Hospital Central South University, Changsha, Hunan Province, China

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Abstract: Objective: To observe the effect of pseudophakic monovision (MV) on the visual quality of cataract patients. Methods: A total of 68 patients diagnosed as cataract were divided into MV group (n=34) and control group (n=34) according to patients' surgical will. Moreover, MV group was divided into near-vision group (n=14) and far-vision group (n=20), according to their dominant eye. All patients were implanted with Tecnis ZCB00. In the MV group, the refractive error of the biometry calculation was programmed for 0-0.5D in the far vision eye and -1.5D-2.0D in the near vision eye; in the control group, both eyes were 0-0.5D. Near, middle-distance and distance visions as well as contrast sensitivity, distance and near stereopsis, VF-14 score, and rate of with no need for optical eyewear were observed in follow-up. Results: Firstly, there were significant differences in the middle-distance and near binocular visions 3 months after operation (P<0.001), but there was no significant difference in distance, middle distance and near visions between the far-vision group and the near-vision group. Secondly, the difference in contrast sensitivity at each spatial frequency was not significant between the MV group and the control group both in bright and dark environments, while the far-vision group had higher the contrast sensitivity than the near-vision group at spatial frequency of 0.9 cpd, 1.5 cpd and 3.0 cpd in both environments. Thirdly, the near stereopsis in MV group was better than that in control group (P<0.001), but there was no significant difference in distance stereopsis between the two above groups. There were also no significant differences in both distance and near stereopsis between the far-vision group and the near-vision group. Next, the VF-14 scores of MV group and control group were higher 3 months after operation than those of pre-operation, and the MV group enjoyed significantly higher postoperative score compared with the control group. While there was no significant difference in VF-14 between the far-vision group and the near-vision group preoperatively and postoperatively. Lastly, rate of no need for optical eyewear in MV group was higher than that in control group, while there was no significant difference between the far-vision group and the near-vision group. Conclusion: Pseudophakic MV can achieve favorable visual quality after operation, and no significant difference was found in visual quality and quality of life between patients with a far-vision dominant eye and with a near-vision dominant eye.

Keywords: Pseudophakia, monovision, cataract, dominant eye

Introduction

Cataract is one of the most common eye diseases with the highest prevalence rate, and has become the main cause of blindness in the elderly [1, 2]. The main cause of cataract is a clouding of crystalline lens and phacosclerosis leading to regulatory function loss. There is still no effective drug to treat it, and surgical removal is the only effective method [3]. Intraocular lens implantation has been gradually applied in clinic in order to avoid poor visual quality caused by crystalline lens removal, and shows good results [4]. The types of intraocular lenses are plentiful, mainly including single-focus intraocular lenses, multi-focus intraocular lenses and adjustable intraocular lenses, and the functions of intraocular lenses are gradually enhanced with the progress of material science [5, 6].

Monovision (MV) is the use of single-vision lenses (one focal point per lens) to focus an eye (typically the dominant one) for distance vision and the other for near work, because the cerebral cortex can suppress the blur image and accept the clear image of the other eye, thereby obtaining clear images of both far and near views. MV has advantages in correcting patients' vision, and helping patients to obtain satisfactory distance and near vision at the same time [7, 8], which is effective in cataract surgery. Pseudophakic MV for cataract has been reported before. Xiao et al. found that the pseudophakic MV can improve the postoperative near vision of cataract patients without affecting the naked distance vision of both eyes [9]. Luo et al. showed that MV for both eyes could obtain favorable distance and near naked visions, and normal near stereopsis, but the distance stereopsis was affected to some extent [10]. However, few researches studied the effect of MV on the postoperative visual acuity of dominant eye, and it is of great significance to explore the influence on the postoperative visual quality of cataract patients. The present study preliminaryly observed the visual quality after pseudophakic MV in both eyes, and discussed the efficacy.

Materials and methods

Subjects

Sixty-eight patients with age-related cataract diagnosed in Xiangya Hospital Central South University from March 2017 to September 2018, and willing to undergo intraocular lens implantation were selected. The design and principle of pseudophakic MV, as well as the advantages and disadvantages of the operation method were fully explained to all the subjects before operation. Patients were divided into control group (34 cases, 68 eyes) and MV group (34 cases, 68 eyes) according to their intention of operation plan and eye habits. Holed-card (a self-made card of 25 cm long and 15 cm wide with a round hole 3 cm in diameter) was used for determining dominant eye before operation. The procedures were as follows: when patient (upright position) facing a butterfly mark on the wall, the card was lifted horizontally to enable the butterfly mark could be seen by both eyes from the hole at the same time. Next, the right eye of patient was covers and he/she was asked if he/she could see the butterfly. For patients did see the butterfly, dominant eye was the left eye, and for patients did not see the butterfly, dominant eye was the right eye. The dominant eye was confirmed if three repeated tests got the same results [11]. Patients in the MV group was divided into the near-vision group (14 cases, 28 eyes) and the far-vision group (20 cases, 40 eyes), according to their dominant eye. All patients were implanted with Tecnis ZCB00 (Abbott Medical Optics, Inc. USA). The present study was approved by the Ethics Committee of Xiangya Hospital Central South University, and written informed consent was obtained from all subjects.

Inclusion criteria & exclusion criteria

Inclusion criteria: patient diagnosed with age-related cataract, had a strong desire for cataract surgery and a voluntary request for implantation of intraocular lens, and had axial length of 22-24.5 mm; stiffness of patients' lens nuclei met the operation requirements: grade II-IV [12].

Exclusion criteria: patients with congenital or traumatic cataract, or other diseases serious effecting postoperative visual recovery, such as glaucoma, macular degeneration, keratopathy, or diabetic retinopathy; patients with corneal astigmatism >1.0D (examined through corneal curvature), or strabismus.

Surgical methods

Before surgery, compound topicamide eye drops were used to fully dilate the pupil, and then 0.4% oxybuprocaine was used for corneal surface anesthesia. A 3 mm transparent incision was made at 10 o'clock at the corneal margin, and the anterior chamber was injected with sodium hyaluronate viscoelastic agent (Shandong Bausch & Lomb-Freda Pharmaceutical Co., Ltd.) to maintain the stability of the anterior chamber and protect the corneal endothelium. Continuous annular capsulorhexis was performed with a capsule diameter of about 5 mm. The lens and capsule membranes were separated by 0.9% normal saline, and the lens nucleus and lens cortex were separated by water. After phacoemulsification, the nucleus and part of the cortex of the cataract were extracted, and irrigation and aspiration of the residual cortex of the lens were performed. Then the integrity of the posterior capsule was observed. The anterior chamber and pouch were stabilized with viscoelastic agent. After implantation of foldable aspherical single-focus instraocular lens in posterior chamber of ZCB00 (Abbott Medical Optics, Inc., Santa Ana, CA), irrigation and aspiration of residual viscoelastic agent and lens cortex in the eyes were performed. The clear corneal incision was hydrated to watertight, and the operation was completed after the anterior chamber was stabilized. All procedures were performed by a skilled surgeon [13].

Table 1. General data

	Cases	Eyes	Gender		Age (year)	Naked-eye vision		
			Male	Female		<0.1	0.1-0.3	0.3-0.5
Monovision group	34	68	18	16	63.23±6.19	2	28	4
Control group	34	68	20	14	65.61±6.33	3	29	2
t/χ^2/z			0.239		-1.567		-0.900	
P			0.625		0.122		0.368	
Far-vision group	14	28	8	6	63.84±5.25	1	11	2
Near-vision group	20	40	10	10	62.35±7.45	1	15	4
t/χ^2/U			0.169		-0.687		130	
P			0.681		0.497		0.743	

Table 2. Vision at different distances after operation

Group	Cases	Vision 3 months after operation		
		Distance vision (5 m)	Middle-distance vision (0.8 m)	Near vision (0.4 m)
Monovision group	34	1.03±0.14	0.90±0.12	0.88±0.15
Control group	34	1.05±0.15	0.54±0.17	0.21±0.14
t		-0.796	-17.054	-0.127
P		0.429	<0.001	<0.001
Near-vision group	14	1.01±0.17	0.86±0.12	0.87±0.17
Far-vision group	20	1.04±0.12	0.94±0.11	0.88±0.14
t		-0.596	-2.031	-0.072
P		0.555	0.051	0.943

Outcome measures

Binocular vision: The patients' near (0.4 m), middle-distance (0.8 m) and distance (5 m) visions were examined with a logarithmic visual acuity chart at 1 week, 1 month and 3 months after operation, and the results were recorded as decimals.

Contrast sensitivity: Vision Monitor (Metro-Vision, France) was used to examine the contrast sensitivity with corrected visual acuity at six different spatial frequencies (0.9 cpd, 1.5 cpd, 3.0 cpd, 6.0 cpd, 12.0 cpd, 19.0 cpd). The instruments mainly included stimulator, amplifier, computer and printer. Stimulation conditions: A 50 cm color photoelectric stimulator with high brightness, high resolution and high refresh rate was used for stimulation, with the minimum brightness less than 0.001 cd/m^2, and maximum brightness 300 cd/m^2. The contrast sensitivity was tested after they were in the bright or dark environment for 5 min. The patient was sitting upright with a test distance of 2 m and facing the stimulation screen. The refractive state of the test eye was corrected, with pupil maintaining natural, and the other eye was completely covered with an opaque eye mask. Grating stripes in sinusoidal distribution with spatial frequencies at 0.9 cpd, 1.5 cpd, 3.0 cpd, 6.0 cpd, 12.0 cpd and 19.0 cpd were used as stimulation patterns, and the contrast ratio of stripe was gradually increased from 0%. Patients were supposed to press the button in his hand when they could distinguish the stripes. The test was repeated for 5 times at each spatial frequency.

Stereoscopic vision: Binocular visual perception evaluation system developed by the Chinese National Engineering Research Center for Healthcare Devices was used to detect binocular stereoscopic vision, and the stimulation template was generated by Matlab. The subjects were seated, and the height of the middle point of the display was adjusted to be equal to the height of eyes. The distance (5 m) and near (1 m) stereopsis were measured respectively, with the wear of polarized glasses, and the feedback was obtained through mouse. First, random-dot zero-order disparity: subjects were supposed to tell the direction of E-mark with the wear of polarized glasses, and click the corresponding button on the interface for feedback. Four pictures with parallax of 400, 300, 200, and 100 were showed in sequence. Second, first-order motion random dot: The background started from high-speed motion, subjects were supposed to tell the direction of E-mark in the picture, and click the corresponding button on the interface for confirmation.

Table 3. Comparison of contrast sensitivity

Environment	Group	Spatial frequency (cpd)					
		0.9	1.5	3	6	12	19
Bright	Monovision group	16.58±2.30	19.84±1.94	21.70±1.87	19.75±1.85	16.07±2.45	10.17±2.50
	Control group	16.31±1.78	19.10±1.41	20.94±1.41	19.60±2.25	16.01±1.98	11.05±1.54
	t	0.551	1.790	1.900	0.299	0.093	-1.761
	P	0.583	0.078	0.060	0.766	0.926	0.083
	Near-vision group	15.20±2.32	18.67±1.75	20.95±1.93	19.39±1.62	16.66±2.48	9.41±2.46
	Far-vision group	17.55±1.75	20.66±1.66	22.23±1.67	19.99±2.00	15.65±2.40	10.69±2.45
	t	-3.361	-3.360	-2.054	-0.927	1.184	-1.498
	P	0.002	0.002	0.048	0.361	0.245	0.144
Dark	Monovision group	13.72±3.27	16.88±3.05	19.41±2.43	15.87±1.84	12.86±1.77	7.10±2.09
	Control group	13.33±1.45	17.03±1.48	18.85±1.55	15.53±2.45	12.34±2.09	7.24±1.42
	t	0.634	-0.253	1.113	0.636	1.093	-0.310
	P	0.528	0.801	0.261	0.527	0.278	0.757
	Near-vision group	10.65±1.29	13.96±1.43	17.49±2.30	15.52±1.72	12.76±1.77	6.80±2.11
	Far-vision group	15.87±2.38	18.92±2.02	20.75±1.44	16.10±1.93	12.92±1.82	7.32±2.11
	t	-7.472	-7.897	-5.085	-0.898	-0.262	-0.701
	P	<0.001	<0.001	<0.001	0.376	0.795	0.488

Table 4. Comparison of distance stereopsis

Group	Cases	1 week after operation	1 month after operation	3 months after operation
Monovision group	34	10	22	31
Control group	34	9	19	26
χ^2		0.073	0.553	2.711
P		0.787	0.457	0.100
Near-vision group	14	5	10	13
Far-vision group	20	5	12	18
χ^2		0.455	0.471	0.084
P		0.500	0.493	0.773

Patients passed the test if they got a correct rate of 100%. The detection was carried out from high-speed to low-speed.

Visual quality: Visual Function scale (VF-14) was used to evaluate the postoperative visual quality, including 4 items: subjective vision, visual adaptation, peripheral vision and stereoscopic vision [14]. Each item was graded from 1 point to 5 points; higher score indicated higher visual satisfaction. The final score of patients was the average value times 20; higher scores indicated better postoperative life and visual quality.

Rate of no need for optical eyewear: The rate was observed in follow up period. No need for optical eyewear meant that patients did not need optical eyewear for myopia or hypermetropia after surgery.

Statistical methods

Data in this study were statistically analyzed by SPSS 22.0. Measurement data were expressed as mean ± standard deviation ($\overline{x}$ ± sd); independent t-test was used for comparison between the two groups, and paired t-test was used for comparison before and after operation within groups. Count data was expressed as number or percentage (n, %), and compared by χ^2 or Wilcoxon rank sum test between two groups. P<0.05 was considered statistically significant.

Results

General data

Comparison of general data showed that there was no significant difference in gender, age, and uncorrected visual acuity between MV group and control group, or between far-vision group and near-vision group, suggesting that the corresponding groups were comparable. See **Table 1**.

Vision at different distances after operation

There were significant differences in the middle-distance and near binocular visions 3

Table 5. Comparison of near stereopsis

Group	Cases	1 week after operation	1 month after operation	3 months after operation
Monovision group	34	13	20	31
Control group	34	5	8	20
χ^2		4.836	8.743	9.490
P		0.028	0.003	0.002
Near-vision group	14	6	10	12
Far-vision group	20	7	10	19
χ^2		0.215	1.561	0.106
P		0.643	0.211	0.745

Table 6. Comparison of rate of no need for optical eyewear

	Cases	No need for optical eyewear	Partially no need for optical eyewear	χ^2	P
Monovision group	34	28 (82.35%)	6 (17.65%)	34.000	<0.001
Control group	34	4 (11.76%)	30 (88.24%)		
Near-vision group	14	12 (85.71%)	2 (14.29%)	0.252	0.615
Far-vision group	20	16 (80.00%)	4 (20.00%)		

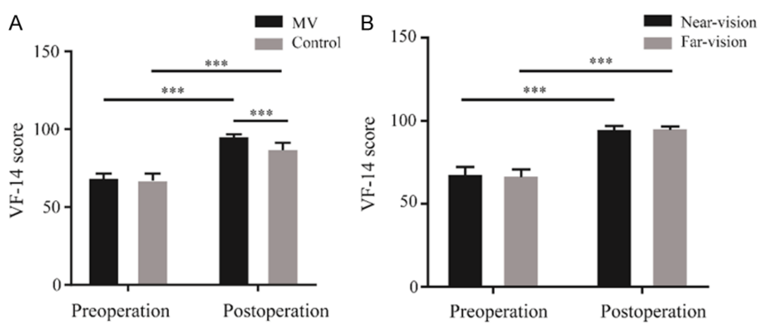

Figure 1. Comparison of VF-14 score. A: Preoperative and postoperative VF-14 score between MV group and control group; B: Preoperative and postoperative VF-14 score between near-vision group and far-vision group. MV: monovision; ***P<0.001.

months after operation (P<0.001), but there was no significant difference in distance binocular vision. Difference in near, middle-distance, and distance visions between the far-vision group and the near-vision group were also not significant. See **Table 2**.

Comparison of contrast sensitivity

There was no significant difference in contrast sensitivity at spatial frequency 0.9 cpd, 1.5 cpd, 3.0 cpd, 6.0 cpd, 12.0 cpd and 19.0 cpd between MV group and control group in both bright and dark environments at 3 months after surgery. The contrast sensitivity at spatial frequency 0.9 cpd, 1.5 cpd and 3.0 cpd were higher in the far-vision group than in the near-vision group (all P<0.05), but there were no significant differences in contrast sensitivity at other spatial frequencies. See **Table 3**.

Comparison of distance stereopsis

The difference in distance stereopsis at 1 week, 1 month and 3 months after operation were not significant between the MV group and the control group, or between the near-vision group and the far-vision group. See **Table 4**.

Comparison of near stereopsis

The near stereopsis at 1 week, 1 month and 3 months after operation were significantly better in the MV group than in the control group (all P<0.05), while the differences between the near-vision group and the far-vision group were not significant. See **Table 5**.

Comparison of rate of no need for optical eyewear and VF-14 score

The rates of no need for optical eyewear were 82.35% in MV group and 11.76% in control group, with significant difference. While the rate was 80.00% in the far-vision group and 85.71% in the near-vision group, with no statistical difference. See **Table 6**.

The VF-14 score was significantly higher in MV group and control group 3 months after surgery (both P<0.001), and the improvement was significantly higher in MV group than in the control group (P<0.001). There was no significant difference between the far-vision group and near-vision group preoperatively and postoperatively. See **Figure 1**.

Discussion

The prevalence rate of cataract has gradually increased in recent years with the aging process [15]. Conventional cataract surgery can only correct patients' naked distance vision, and the visual acuity and quality of life after surgery are often impacted due to eyewear for the myopia [16]. Implantation of multifocal, adjustable intraocular lens, or pseudophakic MV can help patients to obtain well vision and improve the rate of no need for optical eyewear [17, 18]. However, multifocal intraocular lens reduces visual sensitivity with halo and other complications [19]; adjustable intraocular lens has a limited adjustable range and disadvantage of high cost, so that the application of the two above lenses are limited [20]. Pseudophakic MV has been widely used in clinic for it effectively improves patients' distance and near visions, based on mechanism of cerebral cortex, which receives clear images and suppresses blurred images [8]. Pseudophakic MV is of great significance for patients in improving the visual quality and quality of life after surgery.

The present study found that middle-distance vision in MV group was significantly higher than that in control group 3 months after operation, but no significant difference was found in distance and near visions between the two groups. Xiao et al. adopted pseudophakic MV for cataract patients, and found no significant difference between MV group and control group, which is consistent with the results of this study. However, his study also suggested better near vision in MV group than in control group, which may be related to its small sample size [9]. There were significant differences in the middle-distance and near visions of binocular naked eyes, but there was no significant difference in distance vision, which was consistent with the results of Xiao et al. No significant difference was found in the distance, middle-distance and near vision of dominant eye between the near-vision group and the far-vision group. Vision often refers to central vision, which can only reflect the spatial resolution of the central fovea of macula to small targets with high contrast [12]. Contrast sensitivity can effectively combine viewing angle and contrast by measuring the resolution contrast of human eyes at different spatial frequencies. The contrast sensitivity function can reflect vision more comprehensively [21]. The results of low frequencies mainly reflect the visual contrast, and the high frequencies mainly reflect the visual acuity, and the intermediate frequencies comprehensively reflect the visual contrast and the central vision [22]. The present study found no significant difference in contrast sensitivity at spatial frequency 0.9 cpd, 1.5 cpd, 3.0 cpd, 6.0 cpd, 12.0 cpd and 19.0 cpd between MV group and control group in both bright and dark environments at 3rd month after surgery, indicating that the contrast sensitivity was better in both groups after surgery. The contrast sensitivity at low spatial frequencies were higher in the far-vision group than that in the near-vision group in both environments, suggesting that the contrast sensitivity in the far-vision group was significantly higher than that in the near-vision group at low frequencies, which may be related to increased inhibition of Y cell channels and increased opening of X cell channels [23], but there were no significant differences in contrast sensitivity at 6.0 cpd, 12.0 cpd and 19.0 cpd between the two subgroups.

Stereoscopic vision is the perception ability of visual organs to accurately judge the three-dimensional spatial position of an object, which is formed through the joint action of both eyes [24, 25]. Some studies have shown that distance stereopsis is static stereopsis, while near stereopsis is dynamic stereopsis with the participation of regulation, convergence and pupil reaction. The information processing of distance and near stereopsis in brain is somehow different [26]. Koetting reported that the near stereopsis of patients with pseudophakic MV can reach the normal range [27]. This study found that MV group were superior to the control group, which was consistent with the studies above. The distance and near stereopsis between near-vision group and far-vision group were significantly different, indicating that pseudophakic MV had no significant influence on the distance and near stereopsis of dominant eye after operation.

VF-14 is often used to evaluate patients' quality of life after cataract surgery. Presently, the implanted intraocular lens usually cannot adjust automatically, so near vision is often sacrificed to meet the needs of distance vision, thus improving patients' quality of life [28]. This study found that VF-14 in the MV group was significantly higher than that in the control group, indicating improved quality of life in MV group. Moreover, there was no significant difference in VF-14 between the near-vision group and the far-vision group, indicating that pseudophakic MV had no significant influence on the VF-14 score of the dominant eye.

The rate of no need for optical eyewear is a direct indicator to compare the postoperative results. A study found that the rate in MV group was 92.5%, which was obviously superior to the conventional design [29]. The present study also found that the rate in the MV group was significantly higher than that in the control group, similar to the study above. Additionally, there was no significant difference between the near-vision group and the far-vision group, indicating that pseudophakic MV had no significant influence on the dominant eye about the rate of no need for optical eyewear.

This study observed the visual quality of cataract patients after pseudophakic MV, but the small sample size may lead to bias in result, so study with larger sample size should be carry out. In addition, this study only compared the visual acuity at 3 months after surgery, and failed to find changes of the patients' visual acuity. Longer follow-up time is suggested for subsequent studies.

To sum up, pseudophakic MV can effectively improve patient's visual quality and contribute to the improvement of patients' quality of life after surgery, and there is no significant difference in visual quality after operation between patients with a far-vision dominant eye and with a near-vision dominant eye.

Disclosure of conflict of interest

None.

Address correspondence to: Qian Tan, Department of Ophthalmology, Xiangya Hospital Central South University, No.87 Xiangya Road, Changsha 410008, Hunan Province, China. Tel: +86-0731-89753021; E-mail: tyh124334465@126.com

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