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Comparison of the Binocular Vision Quality After Implantation of Monofocal and Multifocal Intraocular Lenses

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Aim. To compare binocular vision quality following unilateral implantation of either a monofocal or multifocal IOL.

Methods. A prospective randomized double-blind study of postoperative binocular vision quality that included 100 patients with monocular cataract from regular operating program at the Eye Clinic UCC Tuzla. Patients were randomized into two groups of 50 patients, with implanted refractive multifocal zone-progressive IOL(AMO model NXG1) or monofocal IOL (Alcon AcySof model MA60BM). Parameters essential to evaluate the binocular vision quality were tested 6 weeks after surgery. Function of fusion was tested with a Bagolini-Maddox test with striped glasses and a cross at 6m distance. Stereo vision was tested with the Titmus stereotest with polaroid glasses at 40cm distance.

Results. Unaided near visual acuity was significantly better in "multi" group, while unaided distance visual acuity was almost same in both groups. Analysis of intraocular implant influence on the basic binocular vision functions, showed that 42(84%) patients in "multi" and 36(72%) patients in "mono" group had normal finding and there was no statistically significant difference between the groups. In stereo vision test, threshold of 100 arc seconds was achieved in 34(68%) in "multi" and 11(22%) patients in "mono" group. This difference was statistically significant.

Conclusion. Lower levels of binocular vision are better after implantation of multifocal IOL rather than those with implanted monofocal IOL, but not statistically significant. In higher level of binocular vision there is a statistically significant improvement in binocular vision in favor of the multifocal IOL.

Keywords. *binocular vision, multifocal IOL, monofocal IOL*

INTRODUCTION

Cataract is the leading cause of blindness worldwide, concerning 47,8% of all cases[1]. In the absence of effective drug treatment, cataract extraction and implantation of artificial intraocular lens (IOL) is method of choice.

Binocular vision is a unique visual and mental perception of two monocular created images. According to Worth, binocular vision has three levels: simultaneous perception, fusion and stereo vision[2]. Requirements for stereo vision establishment are accommodation and convergence. Cataract extraction and artificial IOL implantation lead to loss of the normal accommodation reflex, which makes binocular vision recovery incomplete, particularly in depth or stereo vision. This happens regardless to the applied operation method, and it is particularly difficult to tolerate for younger patients with unilateral cataract[3]. Loss of accommodation and stereo vision in the pseudophakic eye, resulted with development of a multifocal IOL, which provide good functional unaided distance and near vision[4].

More studies were performed on patients with multifocal IOL implants, and they were based on visual acuity measurement at different distances, testing of photoptic phenomena and subjective difficulties in patients, but few of them were related to the exact testing of the binocular vision quality. These studies were also performed on patients with bilateral multifocal IOL implantation, and their results show good binocular function in bilateral IOL implantation, better than unilateral[5,6]. Previous studies did not show significantly better stereopsis results in patients with implanted multifocal compared to monofocal IOL implant[5,7,8].

The aim of this study is to compare binocular vision quality following unilateral implantation of either a monofocal or multifocal IOL.

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Competing interests
The authors declare no competing interests.

Table 1. Age and gender structure, and side of operation

Characteristics	Multi group	Mono group
Age structure		
Men	27 (54%)	29 (58%)
Women	23 (46%)	21 (42%)
Age	43 ± 10	50 ± 10
Side operated		
Right eye	28 (56%)	26 (52%)
Left eye	22 (44%)	24 (48%)

METHODS

This study included 100 patients from regular operation program for cataract surgery at the Eye Clinic University Clinical Centre Tuzla diagnosed with monocular cataract. After cataract extraction, all patients were implanted three-block acrylic foldable IOL's, with different refractive surfaces designs and optical properties. Patients included in the study were chosen randomly and fulfilled the following criteria:

negative history and clinical findings of: chronic inflammatory and degenerative diseases of the anterior and posterior eye segment, previous surgery on the eye and high refractive anomalies, astigmatism less than 1Dcyl,

patients where we, on the basis of patients history, laboratory tests and additional diagnostic procedures, excluded systemic diseases, which can cause changes in the eye, which significantly influence on the vision quality outcome after the operation, age of the participants between 14 and 80 years.

The tenets of the Declaration of Helsinki were followed, and informed consent was obtained from all patients after the nature and possible consequences of the study were explained. After completing consent, patients were divided into 2 groups: "MULTI" and "MONO". The "multi" group consisted of 50 patients with implanted refractive zone-progressive multifocal IOL's, while the "mono" group included 50 patients with implanted monofocal IOL's. Randomization was performed as follows: 100 small folded pieces of paper on which "multi" or "mono" was written, are folded and placed in an opaque bag. The nurse who did not participate in the study picked papers from the bag and divided patients into two groups. Also, surgeon who carried out the operations did not know which group does the patient belong, until the very moment of intraocular lens implantation.

This prospective randomized double-blind control study of postoperative binocular vision quality was conducted between February 2006. and January 2007. After preoperative preparation, which was identical for all patients, we did the surgery with phacoemulsification using machine Infinity (Alcon) with the use of Zeiss OPMI 150 operating microscope. Patients were operated in the local, peribulbar anesthesia, with 2ml of 2% lidocaine applied to the lower orbital fornix.

All patients were performed cataract extraction by phacoemulsification with minimal astigmatism "clear" corneal" incision size 3 mm. After cataract extraction, participants in "multi" group have been implanted ReZoom refractive zone-progressive NXG1 model IOL's, pharmaceutical company AMO, and to patients in "mono" group monofocal AcrySof model MA60BM IOL's, pharmaceutical company Alcon.

Distance visual acuity as decimal number	Multi group	Mono group
0.5	2 (4%)	1 (2%)
0.6	2 (4%)	4 (8%)
0.7	9 (18%)	13 (26%)
0.8	11 (22%)	12 (24%)
0.9	16 (32%)	14 (28%)
1.0	10 (20%)	6 (12%)
Overall	**M = 0.83 SD ± 0.131**	**M = 0.80 SD ± 0.124**

Table 2. Unaided subjective distance visual acuity

Table 3. Unaided subjective near visual acuity

Near visual acuity Jaeger value	Multi group	Mono group
J_1	12 (24 %)	2 (4 %)
J_2	23 (46 %)	5 (10 %)
J_3	14 (28 %)	6 (12 %)
J_4	1 (2 %)	12 (24 %)
J_5	0 (0 %)	25 (50 %)

Postoperative examination of the binocular vision quality was done 6 weeks after surgery (time needed for excluding the expected postoperative complications). Subjective distance visual acuity was measured with standard Snellen eye chart at distance of 6m without supplementary distance refractive correction. Results were expressed as decimal number ranging from 0,1 to 1,0. Near visual acuity was measured with Jaeger reading charts at distance of 40cm, without positive reading addition provided to aid near focus.

Influence of different unilateral optical design implants on binocular vision was accessed at two levels. Lower level, or function of fusion, was examined with the Bagolini-Maddox test with striped glasses and a cross at a distance of 6m. A positive finding was when the patient with Bagolini striped glasses on both eyes saw one source of light in the middle of Maddox cross, and saw arms of letter X under the mutual angle of 45 º.

Higher levels of binocular vision, such as stereo vision, were investigated with modified Titmus stereotest with polaroid glasses at a distance of 40 cm. The quality of stereo vision is quantified with the help of the map with „raised" circles, that allows testing of stereoscopic vision disparity of 800-40 arc seconds. Threshold of stereoscopic vision was 100 arc seconds and better.

STATISTICAL ANALYSIS

Standard tests of descriptive statistics were used in the statistical analysis,. Data were analyzed using $\chi 2$-square test, t-test and correlation tests for nonparametric analysis of small, independent samples. Statistical hypotheses were tested at a significance level of $\alpha = 0.001$. For data analysis we used statistical program SPSS for Windows, version 12.0.

RESULTS

Gender and age structure analysis (Table 1.) show balanced gender distribution in both groups and similar number of operations on the left or right side. Youngest patient with implanted multifocal IOL was 20 years old and oldest 57. In "mono" group youngest patient was 26 and oldest 64 years old. Majority of patients in both groups were presbyopic which can be seen from average age structure. We must underline slight difference between the groups in the average age, with M = 43 ± 10 in "multi" and M = 50 ± 10 in the "mono" group. This difference was found not to be statistically significant ($p < 0.05$, $t = 0.062$). 28 (56%) patients in "multi" and 26 (54%) patients in "mono" group operated right eye. Statistical analysis showed no statistical difference between the groups regarding the side of operation.

Subjective distance visual acuity (Table 2.) was similar in both groups. All patients in both groups achieved distance visual acuity 0,5 and better. 46 (92%) patients in "multi" and 45 (90%) patients in "mono" group achieved distance visual acuity of 0,7 and better. Although "multi" group show slightly better results with M = 0.83 SD ± 0.131 in "multi" and M = 0.80 SD ± 0.124 in "mono" group. Statistical analysis did not show statistically significant difference with p=0,083, and t=1,769. In the conclusion, neither of optical designs did not show statistically better unaided distance visual acuity.

In "multi" group, unaided near visual acuity Jaeger value of J3 (0,5 as decimal number) and better, was found in 49 (98%) patients. Only one patient had Jaeger value of J4 for near visual acuity. On the other hand, in "mono" group 13 (26%) patients had Jaeger value of J3 and better for near visual acuity, while 37 (74%) patients had Jaeger value of J4 and worse. Statistical analysis showed statistically significant difference t=-21,50, df=49 in favor of "multi" group which leads to conclusion that multifocal IOL's provide better near visual acuity.

Analysis of intraocular implant influence on the basic binocular vision functions with Bagolini striped glasses (Table 4.) showed that 42 (84%) patients in the "multi" group gave positive and only 8 (16%) negative response. At the same time, in the "mono" group, 36 (72%) patients gave a positive response, and 14 (28%) negative response. In both groups majority of patients gave a positive answer, and findings were normal, with small difference between the groups. Nonparametric $\chi 2$ test did not reveal statistically significant differences between groups tested with Bagolini test with striped glasses ($\chi 2 = 9680$, df = 1.0, P> 0001 = 0.002). Accordingly, we conclude that the choice of monocular multifocal IOL or monofocal implant does not have statistically significant effect on lower levels of binocular vision in patients tested with Bagolini test with striped glass.

Examination results of stereo vision with Titmus stereotest (Table 5.) show that 34 (68%) patients achieved

Table 4. Results of fusion testing with Bagolini test

Bagolini test	Multi group	Mono group
Positive	42 (84%)	36 (72%)
Negative	8 (16%)	14 (28%)

threshold stereopsis of 100 arc seconds in the "multi" and 11 (22%) in the "mono" group. With statistical methods we found statistically significant differences between the groups ($\chi 2$ = 25,960, df = 8, P = 0.001). Based on the data analysis, we conclude that patients with implanted multifocal IOL's achieved better stereopsis compared to patients with implanted monofocal IOL's.

DISCUSSION

For a long time choice of optical design for implanted IOL was observed only as a possibility for correction of unilateral postoperative aphakia and recovery of the basic binocular vision functions. Technological advances and new designs have brought visual acuity and binocular vision quality after implantation of modern IOL closer to natural lens quality. The present study attempted to determine quality of binocular visual quality in higher and lower levels of binocular vision after implantation of multifocal and monofocal IOL's.

Results revealed that unaided distance visual acuity is almost same in patients with implanted multifocal IOL's and monofocal IOL's. Unaided near visual acuity was significantly better in patients with implanted multifocal IOL. Previous studies have shown that unaided distance visual acuity is similar with multifocal IOL's and monofacal IOL's1. Previous researchers explained that, patients with implanted multifocal IOL's show better uncorrected and distance corrected near visual acuities and reported better overall vision than patients with bilaterally implanted monofocal IOL's2.

Results of previous studies considering binocular vision after implantation of different types of IOL's are quite contrary to each other. Study that was done by Liekfeld et all. in 1995 provided results with better stereopsis, but not statistically significant better in groups of patients with multifocal implants in relation to group of patients with monofocal implants[5]. On the other hand, Bi HS and associates in 2007 did not record significantly better stereovision in patients with multifocal implants versus patients with monofocal implants[3].

In our study, we analyzed lower and higher levels of binocular vision separately. With analysis of monocular implant impact on the basic binocular vision functions, we found that majority of respondents gave a positive response, with (84%) in the "multi" group and (72%) in "mono" group. Our results showed that lower levels of binocular vision are better in "multi" than in "mono" group, but did not reveal statistically significant differences between both groups which is consistent with the results of previous researches.

Other authors suggest that unilateral implantation of multifocal IOL gives slightly lower values of stereovision unlike bilateral multifocal implantation[4]. Also, various combinations of "mixed" implantation with aspherical-diffractive, refractive multifocal compared to monofocal IOL, found reduced binocular function for monocular implant, especially in the near vision[5]. Our results relate to the patients with monocular cataract where the healthy eye completely preserved its function of accommodation and thus created the conditions for binocular sight. This means, there is no interference to examine the direct contribution of implanted IOL in the creation of binocular vision.

Stereovision and visual acuity are related. Titmus stereotest has been used to demonstrate and quantify

Table 5. Results of stereo vision testing with Titmus stereotest

Stereopsis angle in arc seconds	Multi group	Mono group
800	1 (2%)	12 (24%)
400	1 (2%)	10 (20%)
200	2 (4%)	9 (18%)
140	12 (24%)	8 (16%)
100	11 (22%)	6 (12%)
80	9 (18%)	4 (8%)
60	6 (12%)	1 (2%)
50	5 (10%)	0 (0%)
40	3 (6%)	0 (0%)
Overall	**M = 116 SD ± 114**	**M = 346 SD ± 281**

this relationship in several studies[6, 7, 8]. Dioptric blur resulting from uncorrected refractive error or induced anisometropia is a significant factor in loss of binocularity[9]. This effect may even be worse if the blur is monocular, although individual tolerances are notable[16, 10]. Previous investigators demonstrate that stereo acuity is more sensitive to unilateral than bilateral symmetrical changes in visual acuity in the 1,0 to 0,5 range[3,15]. Jacobi and associates in 2002 investigated the influence of unilateral progressive multifocal implant on the binocular vision functions. They presented data that are different for higher and lower binocular vision levels, which is consistent with our results. According to the results of this study, in lower binocular vision levels results were the same for both groups. Testing of higher binocular vision levels with the "raised" Titmus circles, as we did, showed a significant difference in favor of unilateral multifocal IOL implant. This study was done with the first generation of progressive multifocal zone-Array intraocular lenses, and results are somewhat lower than our results. This data can be explained by an improved optical design of intraocular lenses ReZoom, we implanted to our patients[3]. In our study, stereopsis analysis, as higher levels of binocular vision, showed a significant difference between multifocal and monofocal IOL implants. Better results in near vision acuity for patients in "multi" group create better conditions for binocular vision recovery, especially in higher levels. Patients with implanted multifocal IOL's achieved a better stereopsis compared to patients with implanted monofocal IOL's.

Different results for higher and lower binocular vision levels have a logical explanation in the very structure of the multifocal IOL. The existence of multiple focuses on the retina in patients implanted with the Array multifocal intraocular lenses unilaterally or bilaterally, interferes with binocular vision. Similar to our result, testing of binocular vision with the Lang test was positive in 87% of patients with multifocal unilateral implants and 93% positive in the binocular multifocal implants[11]. This discrepancy may be explained by the lower and upper levels of binocular vision, which we noted in our and previous researches. Authors explain the superior stereo vision of multifocal lens compared to monofocal, refractive optics, with the progressive zone-Array intraocular lens, which stimulates more receptors on the retina within the spread of light. In this way, a progressive multifocal zone-IOL can mimic the optical properties of the natural lens, and it is better than conventional monofocal IOL, which has only one focus on the retina.

As we previously stated, in our study we did not use additional correction to obtain best results which might resulted with better binocular vision quality in "multi" group. Also slight but not statistically significant age difference in favor of "multi" group does give some advantage to patients in "multi" group. Hence, study of presbyopic subjects wherein monovision was introduced (albeit with a bifocal contact lens rather than by a multifocal IOL) suggested that stereopsis at near (using Titmus stereotest) might be improved further by using a supplementary optical near addition – stressing the necessity for a full optical correction appropriate for the fixation distance whenever stereopsis is to be measured12. In our study we decided to compare direct influence of ocular implant to binocular vision quality without additional correction.

Data collected in this study confirmed opinions expressed previously in the literature, that binocular vision is better after implantation of multifocal IOL. Despite these results, today ophthalmo-surgeons still have divided opinions about the advantages and disadvantages of a particular optical design and in practice there are several types of multifocal IOL's. Also, in today's practice there is still a significant financial difference in price of monofocal and multifocal IOL's, which can also be one of the important factors in the selection of IOL.

CONCLUSION

Our results show that unaided distance visual acuity is similar in patients with implanted zone-progressive multifocal IOL and monofocal IOL. Unaided near visual acuity is significantly better in patients with implanted multifocal IOL. Lower levels of binocular vision tested with the Bagolini test in patients with implanted multifocal IOL are not better than in those with implanted monofocal IOL. Stereopsis investigated with "raised" circles in Titmus stereotest is better in patients with implanted progressive multifocal IOL compared to patients with implanted monofocal IOL. Analyzing the results of our study we can confirm the results of previous studies which indicate that the zone-progressive multifocal IOL optical design, which uses aspherical progressive circles, provide useful pseudoaccommodation. Zone-progressive multifocal IOL at current level of technological development is good alternative for correction of postoperative aphakia. Proper patients selection, good surgical technique and implantation of zone-progressive multifocal IOL in a patient with extracted cataract leads to good recovery of visual acuity and the binocular vision preservation, particularly stereopsis.

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