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Comparison of contrast sensitivity after implantation of diffractive lens SA60D3 and monofocal lens MA60BM

Porównanie czułości kontrastu po wszczepieniu soczewki dyfrakcyjnej SA60D3 oraz monofokalnej MA60BM

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Summary:
Purpose: Comparison of CSF in groups with diffractive lens SA60D3 and with monofocal lens MA60BM, and applying results to healthy population.
Material and methods: The study included 3 groups of patients. First group consisted of 10 patients, who have undergone implant surgeries with diffractive lenses SA60D3 in both eyes; second group included 9 patients after implant surgeries with monofocal lenses MA60BM in both eyes. Third group included 10 patients with clear own lens. Groups were homogenous to number of patients, age and gender structure, as well as BCVA. CSF was determined for each eye. In the case of operated patients studies were performed 6 months after surgery. Homogeneity of groups was determined with Kruskal-Wallis test, but results of the studies were tested with variance. Results were shown in normalized CSF version.
Results: In conducted studies there was no statistical difference in specific evaluated cpd (3, 6, 12, 18) between SA60D3 group and MA60BM group after 6 months from surgery ($p=0.892$, $p=0.926$, $p=0.564$, $p=0.9953$). The above results were obtained by testing variance at confidence level $p\leq0.01$. At the higher confidence level $p\leq0.05$ there was significant difference between SA60D3 group, MA60BM group and healthy control.
Conclusions: Diffractive lenses SA60D3 decrease CSF in comparable range as monofocal MA60BM lenses, which does not change acceptable standard for quality vision for monofocal lenses, that is currently accepted.

Słowa kluczowe: wieloogniskowa soczewka wewnątrzgałkowa, dyfrakcyjna soczewka wewnątrzgałkowa, chirurgia zaćmy, CSF
Key words: multifocal intraocular lens, diffractive intraocular lens, cataract surgery, CSF.

Phacoemulsification with implant of foldable monofocal lens is currently a standard in cataract surgery in the world. Advantages and faults of this method are commonly recognized. The most important disadvantage is dependence on glasses for far sight or near sight correction depended on original lens calculation. This problem is important especially for people with active lifestyle, being in high position for the company, public administration or working with close objects. Multifocal lenses with refractive or diffractive characteristics seem to solve the problem with dependence on corrective glasses after cataract surgery. Capability of visual system and central nervous system to steer attention at different foci in space without the use of accommodation was the basis for construction of multifocal lenses. As a matter of fact, lens is only a physical setting distributing light energy between far sight and near sight foci and in-between foci, and alternative visual capability that we posses allows, depending on its construction, to take advantage with better or worse effect. Both lenses refractive and diffractive allow for near sight and in-between distances. Comparison of their virtue is not the goal of this paper, but the question comes up whether usage of this type of lenses has diminished quality of far sight and is changing achieved standard?

Apodized diffractive lens SA60D3 by Alcon is one part lens constructed from hydrophobic acryl. Diameter of the optical part is 6.0 mm. Central part of anterior surface with diameter of 3.6 mm is constructed according to diffractive lens technology by Fresnel (1). Apodization is based on gradual reduction of the height of particular diffractive zones from 1.3 um in the center to 0.4 um on the periphery of the zone. Thanks to used technology the addition in its plane was achieved in the magnitude of 4,0 D. Large addition makes possible division by retina and cortical centers created on retinal surface energetic foci responsible for far sight and near sight (2, 3). The most important advantage from the point of quality vision is achievement of proportional light distribution responsible for creation of far sight picture on the retina determined by pupil diameter. With the pupil diameter of 1.0 mm light is divided 1:1 (far sight-near sight), and with enlargement of the pupil ratio is higher, so at pupil diameter 3.0 mm is around 3:2. Such construction is determined to eliminate or diminish lighting side effects that appear with large contrast between the viewing object and little illumination of the background (e.g. driving at night). Monofocal lens MA60BM by Alcon, the entire light energy focusing in one place, but at the same time is introducing to the optical system of the eye as a spherical lens aberration spherical and chromatic (2). It is important, to note that clear lens has compensating property from positive spherical aberration of the cornea (1, 2). This fact is not considered in construction of MA60BM lens, but apodization corrects the degree of light refraction dependent on refractive zone, and the lens is behaving similar to aspherical lens (1).

The goal of this paper is comparison of the quality of the vision for far sight based on contrast sensitivity function (CSF) curve in the group of eyes after lens MA60BM implantation and SA60D3 implantation, and applying results to healthy population.

Material and methods

Three groups of patients were studied. First group consisted of 10 patients, who received binocular pseudoaccomodative lens SA60D3 implant; second group included 9 patients after monofocal lens MA60BM implant in both eyes. Third group included 10 patients with clear lenses of their own. Excluding criteria from group SA60D3 and MA60BM included eye diseases besides cataracts, which were the indication for surgery. They included diseases of the cornea, optic nerve with neuropathy characteristic, age related macular degeneration, diseases of the retina, uncontrolled glaucoma, and pupil reaction abnormalities. In the case of SA60D3 patients were selected according to motivation for surgery, willingness to be independent from corrective glasses for near sight and the level of daily activity. Diseases of the visual system were also the exclusion from the third group of patients. Patients with corneal astigmatism greater than 1.5 D were also excluded from all the groups.

Groups were homogenous considering structure, age, number of patients, sex as well as best corrected visual acuity (BCVA). There was no statistical difference between groups at tested level of probability ($p<0.05$). Statistical analysis was performed with Kruskal-Wallis test. Results are shown in tab. 1.

Characteristics	MA60BM	SA60D3	Healthy	p
Number of eyes	18	20	20	1,000
Age	65,2 ±7,5	65,2 ±7,9	65,1 ± 8,1	0,537
Sex F/M	5/4	6/4	5/5	0,816
BCVA log MAR	0,007 ± 0,016	0,005± 0,022	0,009 ± 0,025	0,540

Tab. I. Statistical characteristic of studied groups.
Tab. I. Charakterystyka statystyczna badanych grup.

One surgeon performed cataract surgeries with ultrasound phacoemulsification method using droplet anesthesia. The power of intraocular lenses was calculated with SRK/T method. The main opening with 2.8 mm diameter was done in clear temporal cornea. Lenses SA60D3 and MA60BM were implanted with the Monarch system by Alcon. There were no complications noted in post surgical period.

Calculation of contrast sensitivity function (CSF) was done using table CSV-1000 (Vector Vision, Dayton, OH USA). Visual acuity was tested with the ladder formula in four spatial frequencies (3, 6, 12, 18 cpd) with sinusoidal change of stimulus illumination. Illumination of CSV-1000 table background controlled by system of automatic calibration is held at the same level 85 cd/m^2 ±0.1 without consideration for surrounding illumination, where tests are performed. The change of stimulus contrast in each spatial frequency is done in logarithmic progress by 0.15 in tests 1, 2, 3 and by 0.17 of the logarithmic unit in tests 4, 5, 6, 7 and 8. The change between tests A, B, C, D and 1 equal 0.3 of the logarithmic unit. Contrast is defined with Michelson's equation.

$$C = \frac{L_{max} - L_{min}}{L_{max} + L_{min}} \times 100$$

C- contrast in %

L – stimulus illumination in cd/m^2

Tests were done from the distance of 3.0 m after correction of refraction with glasses for far sight. Threshold of contrast vision was tested for every spatial frequency. There are 17 wheels with 0.0381 m diameter each in every row. In the first stage patient should recognize ladder formula with the high contrast at the beginning of the row, marked, depending on spatial frequency, with letters A, B, C or D. In the case of identification of the ladder formula at the entrance level the other levels were also tested. Every level out of eight was presented to the patient as a choice test. The last correct answer was determined, as a test result.

Testing was done for every eye separately in three groups. In SA60D3 and MA60BM groups testing was done 6 months after surgery. Results in particular spatial frequencies were shown in logarithmic scale for statistical analysis. One way analysis of variance (ANOVA) was done with the help of statistical packets STATISTICA 6.0.

Results shown in decimal logarithm were normalized to show them in the graph. Normalization was performed according to Boxer Walcher and Krueger method (4).

Results

The results of one way analysis of variance of the Scheffer test post-choc are collected in Tab. II, III, IV and V and Fig. 1.

The most important result of the analysis is lack of statistical significance in all spatial frequencies between SA60D3 group and MA60BM group, after 6 months from the surgery. In case of 6cpd there was no statistical difference between SA60D3 group and the third group and 12 cpd there was no statistical difference between MA60BM group and third group. The above results were obtained by testing variance at confidence level $p<0.01$ and they have to be taken as significant. At the higher level of confidence $p<0.05$ there's significant difference between SA60D3 group, MA60BM group and the control group.

Groups Grupy	SA60D3	MA60BM	Healthy
SA60D3		0,892	0,004
MA60BM	0,892		0,001
Healthy	0,004	0,001	

Tab. II. Level p for 3 cpd (ANOVA)
Tab. II. Poziom p dla 3 cpd (ANOVA)

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Groups Grupy	SA60D3	MA60BM	Healthy
SA60D3		0,926	0,028
MA60BM	0,926		0,009
Healthy	0,028	0,009	

Tab. III. Level p for 6 cpd (ANOVA)
Tab. III. Poziom p dla 6 cpd (ANOVA)

Groups Grupy	SA60D3	MA60BM	Healthy
SA60D3		0,564	0,002
MA60BM	0,564		0,044
Healthy	0,002	0,044	

Tab. IV. Level p for 12 cpd (ANOVA)
Tab. IV. Poziom p dla 12 cpd (ANOVA)

Groups Grupy	SA60D3	MA60BM	Healthy
SA60D3		0,953	0,000
MA60BM	0,953		0,000
Healthy	0,000	0,000	

Tab. V. Level p for 18 cpd (ANOVA)
Tab. V. Poziom p dla 18 cpd (ANOVA)

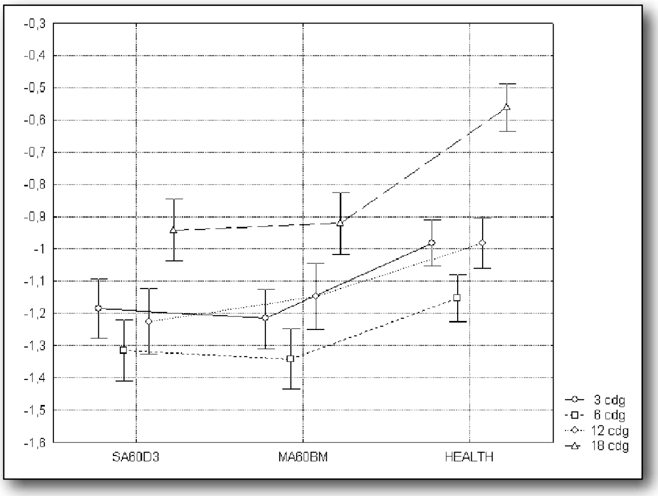

Fig. 1. Graphic presentation ANOVA
Ryc. 1. Graficzna prezentacja ANOVA.

Normalized graphs for mean spatial frequencies in studied groups are shown in Fig. 2.

Discussion

Human natural lens compensates positive spherical aberrations of the cornea (1). Aging makes this natural balance changed or completely imbalanced due to cataract development. Quality vision depends on the quality of the eye optical

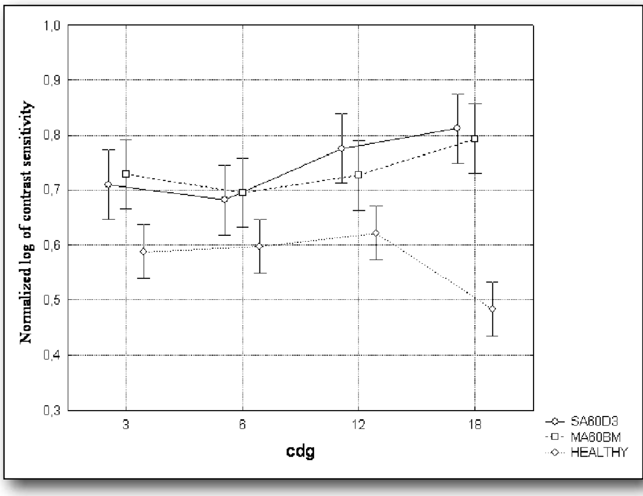

Fig. 2. Normalized CSF for particular studied groups. Normalization was done for CSF with parameters for particular cpd 3, 6, 12, 18-1.67; 1.93; 1.58; 1.16 logarithmic
Ryc. 2. Normalizowana CSF dla poszczególnych badanych grup. Normalizację przeprowadzono względem CSF o parametrach dla poszczególnych cpd 3, 6, 12, 18 – 1,67; 1,93; 1,58; 1,16 jednostek logarytmicznych.

system on one side and from the other side its imperfections are compensated by neuronal processes in the retina and central nervous system (3). The optical eye system after lens implant, either monofocal or multifocal is not perfect. Spherical lenses increase positive aberrations, but multifocal lenses distribute light energy into several foci (1, 5, 6). As a consequence of these imperfections is lowering of contrast sensitivity function (CSF) in relation to healthy population (7). Similar results were obtained in our work (Fig. 2). Differences in low and medium ranges cpd (3, 6, 12) after 6 months observation were about 0.1 logarithmic units in comparison to healthy population ($p<0.05$, Tab. II, III, IV). The difference of contrast vision between group I, II and III within the range of 18 cpd was about 0.3 logarithmic units ($p<0.01$, Tab. V). Indeed lower contrast sensitivity in the range of 18 cpd after implant of MA60BM and SA60D3 as compared to healthy population confirms observations by other authors (8). Montés-Micó et al. think, that decrease in contrast sensitivity in the range of high spatial frequencies is due to defocusing of the light energy and spherical aberrations (8, 9).

Among many authors it is dominant belief, that multifocal lenses either refractive or diffractive lower contrast sensitivity function (CSF) (10, 11, 12, 13). There is no difference in contrast sensitivity in particular spatial frequencies if we compare two groups of lenses (14). Studies that were done did not include diffractive, apodized lenses, but lenses technologically inferior; therefore we cannot generalize this tendency. Studies comparing multifocal lens AMO Array SA-40N with unifocal lens AMO SI-40NB in 18 months observation did not find any significant statistical differences in CSF in photopic conditions (9). It is important to emphasize, that contrast sensitivity for multifocal lenses was lower and CSF was in the lower range of population standard (9). Montés-Micó et al. performed studies in similar conditions as presented in our work, but it is impossible to make comparison because they did not show normalized

CSF (9). Rocha et al. were comparing aberrations of the optic system of the eye and contrast sensitivity in the group of lenses SA60D3, MA30AC and SA60AT (1). The authors concluded lower spherical aberrations in the group of patients with implanted SA60D3 lens as compared to monofocal lenses ($p<0.05$). But in testing of contrast sensitivity SA60D3 lens was inferior to MA30AC and SA60AT lenses ($p=0.02$). Studies were done only 2 months after surgery and included only one cpd. Similar results were obtained by Schmitz et al. in the group of lenses Array SA-40N after 5 months of observation (15). In other studies with multifocal Array SA-40N lenses, significant statistical differences in relation to monofocal SI-40NB were seen in the range 1.5-18 cpd up to 6 months from surgery (5). Neuroadaptation may be a process longer than 2 months. From the other side low spatial frequencies do not seem to be the best measure of the changes that occur in the optical system of the eye with multifocal lens implantation (5, 8, 9). In cited studies authors do not state statistical differences in all tested spatial frequencies after 6 months from surgery between the group of patients with multifocal lens implant and monofocal lens implant (5). We established similar conclusions in our work ($p>0.05$, Tab. II-V). However our studies included comparison of SA60D3 lens with MA60BM, defocus and introduced aberrations into the optical system, likely as in the case of multifocal lenses are phenomena responsible for lowering of contrast sensitivity (8, 9). Minimally lowered contrast sensitivity in the range 12 and 18 cpd of magnitude 0.05 logarithmic units in relation to group MA60BM is preserved in our studies after 6 months from the implant of SA60D3 lens (Fig. 2). Lowering of the contrast sensitivity in high ranges cpd is not statistically significant ($p<0.05$, Tab. IV, V)

Evaluation of contrast vision for far sight in patients with diffractive SA60D3 lens implant and monofocal MA60BM lens implant is comparable. Implant of SA60D3 lens does not change the current standard in cataract surgery.

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