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Comparison of higher order aberrations with spherical and aspheric IOLs compared to normal phakic eyes

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PURPOSE. *To compare higher order aberrations (HOA) in AcrySof SN60AT and Acrysof IQ SN60WF intraocular lenses (IOLs) and natural crystalline lenses in an age-matched population.*

METHODS. *Sixty-nine eyes of 55 patients were examined. Group I included AcrySof spheric lenses, group II AcrySof aspheric lenses, and group III included patients with the natural crystalline lens. The HOA data were obtained with a LADARWave aberrometer (Alcon Inc.). Analysis was based on the RMS of coma, spherical aberrations (SA), and HOA. Statistical comparisons were performed with Kruskal Wallis variance analysis.*

RESULTS. *In the case of coma, there were statistically significant differences between spheric and aspheric AcrySof (p<0.005) and between spheric AcrySof and natural crystalline lenses (p<0.005). The differences between aspheric AcrySof and natural crystalline lens group were not significant (p>0.05). SA were significantly different between spheric and aspheric AcrySof group, and spheric AcrySof and natural crystalline lens group (p<0.005), as well as between aspheric AcrySof and natural crystalline lens group (p<0.05). In case of HOA no significant differences were observed between aspheric AcrySof and natural crystalline lens group (p>0.05), but differences between groups AcrySof spheric and aspheric, and spheric AcrySof and natural crystalline lens, showed high significance (p<0.005).*

CONCLUSIONS. *The AcrySof Natural IQ aspheric model SN60WF IOL did not change the optical quality of vision compared to a healthy population of 60–80 years of age. The AcrySof Natural model SN60AT spherical IOL resulted in higher HOAs relative to both the natural crystalline lens population and eyes after aspheric AcrySof IQ model SN60WF IOL implantation. (Eur J Ophthalmol 2008; 18: 728-32)*

KEY WORDS. *Phacoemulsification, Aspheric IOLs, Aberrations of optical system*

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INTRODUCTION

Cataract is a frequently diagnosed problem by ophthalmologists not only in persons with advanced age, but also in young, professionally active people. Providing patients with good quality vision after surgery depends on the safety of the surgical method as well as the type of implanted intraocular lens (IOL). Nowadays the surgeon who performs cataract surgery has a wide variety of IOLs to choose from. New IOL materials have been developed allowing for different structure, flexibility, thickness, and shape, and at the same time providing new optical and biological properties. The goal is to achieve the optimal quality of vision by the patient after implantation, independent of lighting conditions, achieving useful visual acuity and elimination of adverse optical phenomena such as blurred vision, halos, reflections, and shadows. Currently used surgical techniques allow for achieving satisfactory visual acuity, with quick rehabilitation and minimal risk of postsurgical complications. A new target is

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to provide patients with unaided visual acuity similar to healthy phakic persons. Some IOLs cause problems with driving in the night, due to adverse lighting phenomena like glare or halo. Some unexplainable phenomena can be detected through measurement of irregularity in the refractive power of the eye's optical system. The total aberrations of the human eye increase threefold between the 20th and 70th year of life (1). The implantation of an IOL during cataract surgery creates a new optical system, which can be analyzed with aberrometers. Higher order aberration (HOA) analysis allows the examination of imperfections of this system that have an influence on the quality of vision.

The goal of this study was to compare HOAs in pseudophakic eyes after implantation of spherical (SN60AT) and aspheric (SN60WF) IOLs and in phakic eyes of patients in the same age group.

METHODS

A retrospective analysis was conducted of 69 eyes of 28 women and 27 men. The eyes were divided into three groups. Patients were randomly selected into groups from older than 60 years. Groups I (SN60AT) and II (SN60WF) included patients operated for cataracts in the Department of Ophthalmology of the Military Health Service Institute in Warsaw from May 2005 to April 2006. In Group I the spheric AcrySof model SN60AT IOL and in Group II the aspheric AcrySof IQ model SN60WF IOL was implanted. Patients were assigned randomly to receive one type of IOL. Twenty-one patients were in Group I (12 women and 9 men), with 24 eyes (11 right eyes and 13 left eyes), and in Group II 22 eyes of 19 patients (11 women and 8 men) were analyzed (9 right eyes and 13 left eyes). Group III (healthy) included 24 natural crystalline lens eyes (13 right and 11 left) of 15 patients.

The indication for surgery in Groups I and II was cataract (NO1NC1 to NO6NC6) according to the Lens Opacities Classification System II (LOCS II). Patients from Group III did not have cataracts and did not undergo any ophthalmic surgery. General exclusion criteria from tested groups were retinal and corneal diseases, optic nerve diseases of the neuropathy type, age-related macular degeneration, uncontrolled glaucoma, pupillary reflex disorders, history of prior ocular inflammation, and astigmatism greater than 1.0 D.

Axial length was measured with the OcuScan biometer (Alcon, Inc.). The SRK-T formula was used for IOL power calculation. The targeted refraction was emmetropia. The cataract surgeries were performed by one surgeon (M.R.) with droplet anesthesia by proxymetacaine hydrochloride 0.5% eyedrops (Alcaine). The main clear corneal temporal incision size was 2.6 mm. A 5.0 mm anterior continuous curvilinear capsulorhexis after that phacoemulsification using the Infiniti machine (Alcon Surgical, Fort Worth, TX) was performed. IOLs were implanted with the Monarch II system (Alcon Inc.). There were no intraoperative complications. For 4 weeks after surgery all patients received antibiotic with steroids into the conjunctival sac as well as nonsteroidal anti-inflammatory drugs. There were no complications in the postsurgical period.

The ophthalmologic examination in Group SN60AT and SN60WF performed 6 months after surgery included distance best-corrected visual acuity (DBCVA) and near best-corrected visual acuity (NBCVA), applanation tonometry, examination of the anterior chamber with a biomicroscope, and funduscopic examination. The same tests were performed with Group III.

In all cases, aberrometric data were collected with the LADARWave aberrometer (Alcon Inc.), which is based on the Hartmann-Shack wavefront sensor (2). Results were obtained at 5.0 mm pupil diameter. Analysis of RMS errors of coma included Zernike coefficients Z_3^{-1} and Z_3^{1}, spherical aberration (SA) was calculated from Z_4^{0}, and HOA included all third, fourth, and fifth order Zernike coefficients.

Statistical analysis was performed with the Kruskal-Wallis method of variance analysis and post hoc analysis was done with multiple comparison chi-square tests.

Data analysis was performed using Statistica PL for Windows version 8.0 (StatSoft Polska, Inc.). Differences were considered to be statistically significant when $p<0.05$.

RESULTS

Demographic data for the studied groups are shown in Table I. The groups were homogenous according to age, gender, and number of studied eyes as well as pupil diameter and postoperative astigmatism ($p>0.05$).

Aberrations in the three groups were compared with the use of analysis of variance tests and the following results were obtained: coma ($p=0.027$), SA ($p=0.000$), and HOA ($p=0.002$) (Fig. 1). Preliminary analysis showed significant differences between studied groups in particular aberra-

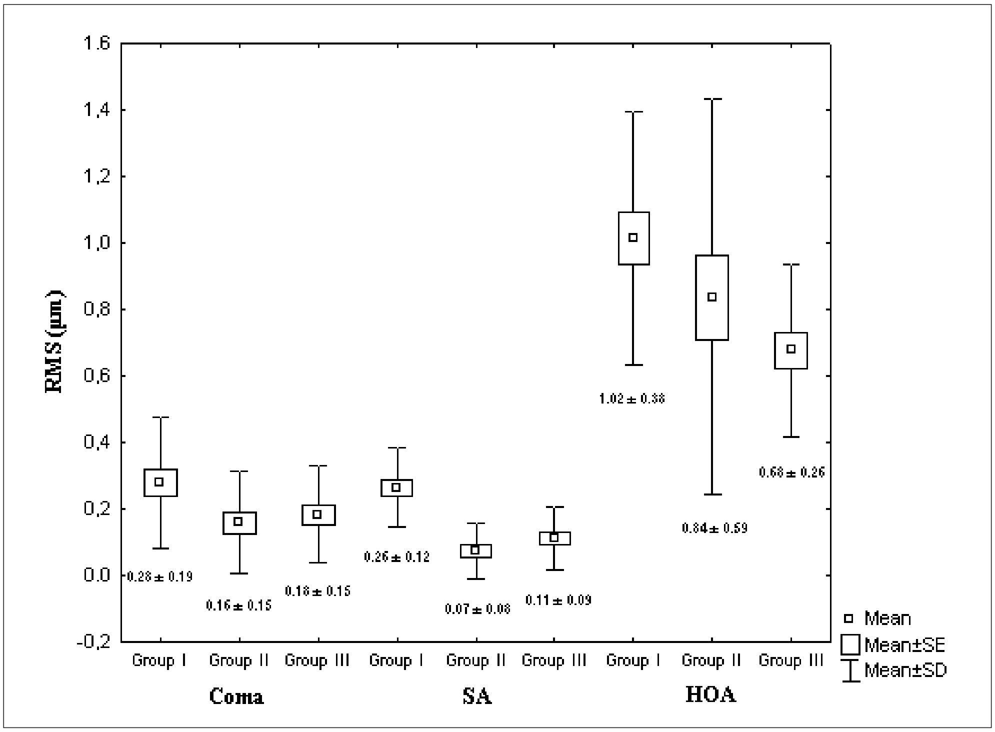

Fig. 1 - *Analysis of coma, spherical aberration, and higher order aberration for all studied groups (Kruskal-Wallis analysis of variance).*

tions and to test individual pairings multiple chi-square tests were performed. In the case of coma statistical differences were shown between Group I (SN60AT) and Group III (healthy) ($p<0.005$), and also between Group I (SN60AT) and II (SN60WF) ($p<0.005$). There was no difference between Group II (SN60WF) and Group III (healthy) ($p>0.05$) (Fig. 1). Similar results were obtained comparing SA, where differences were noted between Groups I and II as well as I and III ($p<0.005$). However, unlike coma, there was a statistically significant difference between Group II (SN60WF) and Group III (healthy) ($p<0.05$). The aspheric IOL showed the lowest average SA in the three groups (Fig. 1). In case of HOA, there were no differences between Group II (SN60WF) and

TABLE I - DEMOGRAPHIC DATA

Demographic data	SN60AT	SN60WF	Healthy	p*
Age, yrs				
Mean ± SD	71.3±4.8	70.4±5.6	68.3±5.7	0.151
Range	61–76	62–84	61–78	
Cases (n)				0.223
Female	12 (21)	11 (19)	5 (15)	
Male	9 (21)	8 (19)	10 (15)	
Eye (n)				0.659
Right	11 (24)	9 (22)	13 (24)	
Left	13 (24)	13 (22)	11 (24)	
Pupil (mm)				
Mean ± SD	5.06±0.40	4.95±0.49	4.91±0.58	0.681
Range	4.38–5.82	4.14–6.02	4.02–5.59	
Postop astigmatism				
Mean ± SD	0.54±0.25	0.58±0.24	0.60±0.19	.586
Range	0.1–1.0	0.23–1.0	0.35–1.0	

*Kruskal-Wallis analysis of variance

TABLE II - RESULTS OF POST HOC ANALYSIS (p values)

	SN60AT	SN60WF
Coma		
Healthy	0.000736	0.098999
SN60AT		0.000084
Spherical aberration		
Healthy	0.000004	0.005343
SN60AT		0.000000
HOA		
Healthy	0.000008	0.080089
SN60AT		0.000108

*Multiple comparisons chi-square test.
HOA = Higher order aberration

Group III (healthy) ($p>0.05$), but in case of other comparisons they showed high statistical significance ($p<0.005$) (Fig. 1). The results of multiple comparisons are shown in Table II.

DISCUSSION

Cataract surgery combined with IOL implantation causes a change in the aberration pattern of the eye. This is one of the elements that influence the quality of vision after surgery. Recent attempts to modify IOLs to reduce HOA after implantation have been made with the desire to provide postoperative unaided vision equivalent to a healthy age-matched emmetropic patient.

IOLs manufactured by different companies differ in various aspects, and while the majority of the optical principles are similar, attempts to correct SA vary by manufacturer. In our study we compared SA, coma type aberrations, and HOA in vivo with two different IOLs (SN60AT, SN60WF) and compared these results to age-matched normal phakic eyes.

Spherical aberrations

In an earlier study, Barbero et al measured HOA in a group of patients before cataract surgery and after surgery with implantation of spherical IOLs. They showed that SA after implantation of spherical IOLs was similar to that of older phakic patients but was more positive than in younger phakic patients. It was postulated that the spherical shape of the IOL surfaces induced positive SA (3).

In our study, SA after implantation of the spherical SN60AT IOLs were higher than in the group of healthy people, but after implantation of the aspheric SN60WF IOLs were smaller in comparison to population of healthy people above 60 years of age.

Similar results are shown by Kasper et al, who in their work with the Tecnis aspheric IOLs observed SA values averaging 0.089±0.144 µm for pupil diameters of 6 mm, slightly lower than the values in phakic eyes of young people (4). In turn, Mester et al concluded that the Tecnis Z9000 aspheric IOLs significantly reduce SA relative to aspheric SI40 IOLs (5). In a similar study, Padmanabhan et al reported lower SA in the eyes of 93.8% of studied patients implanted with the Tecnis aspheric IOL compared to their eye with a spherical implant (6).

Our results demonstrate that the spherical SN60AT IOLs increases SA in comparison to the population of healthy people as well as in comparison to eyes after aspheric SN60WF IOL implantation. Choi et al studied 51 eyes, in which three different spherical implants were used, and compared to 12 phakic eyes. There was no difference in SA between the groups with IOLs and the normal phakic eyes (7); aspheric IOLs were not studied. Obtained differences with our study may be due to pupil diameter used for obtaining aberrometric results. While pupil diameter is increasing spherical IOL may generate greater increase of SA than natural crystalline lens. On the other hand, wider pupil reveals real quality of vision in particular light conditions after spherical IOL implantation. Other works confirm the increase of SA in eyes with spherical IOL implantation (8, 9).

Higher order aberrations

Our study suggests no statistically significant difference in HOA after implantation of aspheric SN60WF IOLs and in the healthy eye in a similar age population. However, the spherical SN60AT IOLs increase aberrations of the coma type and spherical as well as other HOA in comparison to the population of healthy people, and all these aberrations are higher than with the aspheric SN60WF IOLs. This is different than the result found by Mierdel et al in their study, where they concluded that the mean HOA in 10 eyes with an IOL were not statistically significantly different from the ones measured in natural crystalline lens eyes. These results were based on a small group of studied eyes and there was no specification on types of IOLs used (10).

Coma type aberrations

Our study concludes that aberrations of the coma type do not differ statistically in comparison to population of healthy people in a comparable age group after implantation of the aspheric SN60WF IOLs. Kasper et al did not observe higher values of aberrations of the coma type in the group of patients with aspherical IOLs (4). Our results suggest the spherical SN60AT IOLs increased coma as well as SA. Choi et al studied patients after implantation of three different types of spherical IOLs and compared them with a group of patients with natural crystalline lens (7). Despite the different properties of the IOLs there were no statistically significant differences in Zernike factor except for C_3^3 (7). It was significantly higher in all studied groups of IOLs in comparison to normal phakic eyes (7). Again, aspheric IOLs were not tested.

Wavefront analysis applied to pre- and postoperative cataract surgery patients provides new insights into the effects of IOLs. The application of this technology to improve postoperative SA (e.g., with the AcrySof IQ model SN60WF IOLs) has been successful. This reduction in postoperative aberrations is likely to produce better quality of vision in patients after cataract surgery. The spherical SN60AT IOLs increased HOA in relation to healthy population as well as to eyes after implantation of the SN60WF IOLs. HOA after implantation of the aspheric SN60WF IOLs was not statistically significantly different in comparison to natural crystalline lens eyes of an age-matched population.

Proprietary interest: None.

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REFERENCES

1. Artal P, Berrio E, Guirao A, Piers P. Contribution of the cornea and internal surfaces to the change of ocular aberrations with age. J Opt Soc Am A Opt Image Sci 2002; 19: 137-43.
2. Cerviño A, Hosking SL, Montés-Micó R, Bates K. Clinical ocular wavefront analyzers: a review. J Refract Surg 2007; 23: 603-16.
3. Barbero S, Marcos S, Jimenez-Alfaro I. Optical aberrations of intraocular lenses measured in vivo and in vitro. J Opt Soc Am A Opt Image Sci Vis 2003; 20: 1841-51.
4. Kasper T, Bühren J, Kohnen T. Intraindividual comparison of higher-order aberrations after implantation of aspherical and spherical intraocular lenses as function of pupil diameter. J Cataract Refract Surg 2006; 32: 78-84.
5. Mester U, Dillinger P, Anterist N. Impact of a modified optic design on visual function: clinical comparative study. J Cataract Refract Surg 2003; 29: 652-60.
6. Padmanabhan P, Rao S, Jayasree R, et al. Monochromatic aberrations in eyes with different intraocular lens optic designs. J Refract Surg 2006; 22: 172-7.
7. Choi J, Kim T, Tchah H. Comparison of wavefront aberration after cataract surgery with acrylic intraocular lens implantation. J Cataract Refract Surg 2005; 31: 324-9.
8. Miller JM, Anwaruddin R, Straub J, Schwiegerling J. Higher order aberrations in normal, dilated, intraocular lens, and laser in situ keratomileusis corneas. J Refract Surg 2002; 18: 579-83.
9. Holladay JT, Piers PA, Koranyi G, et al. A new intraocular lens design to reduce spherical aberration of pseudophakic eyes. J Refract Surg 2002; 18: 683-91.
10. Mierdel P, Kaemmerer M, Krinke HE, Seiler T. Effects of photorefractive keratectomy and cataract surgery on ocular optical errors of higher order. Graefes Arch Clin Exp Ophthalmol 1999; 237: 725-9.