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Optical Aberrations and Contrast Sensitivity of Spherical and Aspheric Intraocular Lenses – A Prospective Comparative Clinical Study

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Abstract

Purpose: To compare visual acuity, aberrometry, and contrast sensitivity in eyes with spherical intraocular lens (IOL) and aspheric IOL implanted after uncomplicated phacoemulsification.

Setting: Department of Ophthalmology, University Hospital, Hradec Králové, Czech Republic.

Methods: A prospective clinical study involving 90 patients (105 eyes) having cataract surgery, with implantation of spherical IOL AcrySof Natural (SN60AT) in 45 patients (50 eyes) with a mean age of 62.5 years, and aspheric IOL AcrySof IQ (SN60WF) in 45 patients (55 eyes) with a mean age of 64.5 years. A control group involved 22 eyes of similar age with clear lens crystallina. Postoperatively, visual acuity (ETDRS charts), aberrometry (ORK Wavefront Analyser, Schwind), and contrast sensitivity tests (CSV 1000, Contrast Sensitivity 8010 System) were evaluated. Statistical analyses were performed using Student t-test.

Results: No statistical differences were found regarding visual acuity among eyes. A lower level of higher order aberrations was achieved in the aspheric group. In the contrast sensitivity test, no statistical differences between groups under photopic conditions were noted. In mesopic conditions better performance was observed in eyes with aspheric IOLs, mainly in low spatial frequencies (statistically significant). The control group (lens crystallina) was better in all frequencies.

Conclusions: Cataract surgery outcomes cannot be measured by means of visual acuity alone. In this study, the aspheric IOLs AcrySof IQ (SN60WF) demonstrated better visual function, especially contrast sensitivity in low spatial frequences, when compared with spherical IOLs AcrySof Natural (SN60AT).

Keywords: Higher order aberrations; Spherical lens; Aspheric lens

Introduction

Both ophthalmologists and patients currently approach cataract surgery as not only a “visual rescue operation” but also as a refractive procedure. Phacoemulsification and intraocular lens (IOL) implantation is considered the gold standard for cataract treatment. Topical anesthesia, small incisions, and sophisticated microsurgery techniques and technologies, including femtosecond lasers have led to better surgical results and better visual outcomes. However, for “perfect” vision we need also a “perfect” IOL. Even though conventional spherical IOL implantation provides higher contrast sensitivity than aphakia with spectacle correction, the contrast sensitivity in pseudophakic eyes is significantly lower than in normal phakic eyes [1]. Higher order aberrations (HOA) can reduce the quality of images in the optical system. With the new generation of aspheric IOLs, the anatomical and functional success of cataract surgery can be determined by improvement in visual acuity and its effects on the optical quality of the eye [2,3].

For better understanding of the visual system, new technologies were developed. Wavefront technology can quantify low and high-order aberrations present in the optical system. The high resolution imaging in the ophthalmic optics can be affected by higher order aberrations such as coma and spherical aberration. Conventional spherical IOLs can degrade imaging quality, increasing the HOAs of the optical system, such as coma and spherical aberrations. The light rays at the peripheral zones of a positive lens are refracted with larger angles and intersect the optical axis closer to the lens than the paracentral rays, producing positive spherical aberration. Aspherical IOL design can optimize image quality by limiting ray diffraction.

The other aspect of the quality of vision is so-called “functional vision”. This term describes the effect of visual functions, especially visual acuity, on a patient’s quality of life. This includes the ability to recognize faces, drive a car, especially at night, read, work with a computer, and perform workplace and leisure activities. This functional vision cannot be entirely evaluated by means of visual acuity charts (Snellen or similar) alone [4]. Contrast sensitivity tests are efficient indicators of visual function and can detect functional vision deficiencies that standard visual acuity tests are unable to identify [5,6].

The AcrySof IQ (model SN60WF, Alcon Laboratories, Inc.) is a posterior chamber IOL with a modified posterior surface for improving contrast sensitivity. The AcrySof IQ IOL was designed using a proprietary modeling process after analyzing the aberration of more than 700 corneas. The single-piece AcrySof Natural IOL (model SN60AT) was the platform for the AcrySof IQ IOL, and filters blue light with a proprietary blue-light filtering chromophore. The AcrySof IQ IOL shares the basic design features of the AcrySof Natural IOL including a 6.0 mm optic, 13 mm overall length, and modified-L haptics.

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The purpose of this study was to compare visual acuity, HOAs, and contrast sensitivity of eyes implanted with aspheric IOLs AcrySof IQ (SN60WF) with those of eyes implanted with spherical IOLs AcrySof Natural (SN60AT), and with a control group of eyes with clear crystalline lenses.

Materials and Methods

This prospective clinical trial comprised 90 patients (105 eyes) scheduled for cataract surgery at the Department of Ophthalmology, University Hospital, Hradec Králové. Patients were selected from the department queue. The study purpose, procedures, and responsibilities were explained to all potential participants, and informed consent was obtained from all selected patients. Exclusion criteria were any ocular diseases, such as corneal opacities or irregularity, dry eye, amblyopia, anisometropia, glaucoma, retinal abnormalities, and surgical complication.

All patients underwent complete ophthalmic examination, including uncorrected visual acuity (UCVA), and best corrected visual acuity (BCVA) measurement using the Early Treatment of Diabetic Retinopathy Study (ETDRS) chart (Precision in Vision) at a viewing distance of 4 m, slit-lamp biomicroscopy, applanation tonometry, fundus examination, corneal topography (Keratron SCOUT, Opticon), and biometry with IOL calculation preoperatively. All patients were targeted for emmetropia. The cataract operations were performed using the same standardized phacoemulsification techniques under topical anesthesia: clear corneal incision of 2.4 mm, two paracenteses for bimanual irrigation/aspiration (I/A), continuous curvilinear capsulorrhexis with an approximate diameter of 5.0 mm, hydrodissection, nucleus phacoemulsification using the modified "quick-chop" technique, bimanual I/A of the residual cortex, and IOL implantation in the bag with an injector.

Implantation of spherical IOL AcrySof Natural (SN60AT) was performed in 50 eyes of 45 patients with a mean age of 62.5 years (range 50 – 70 years), and the aspheric IOL AcrySof IQ (SN60WF) was implanted in 55 eyes of 45 patients with a mean age of 64.5 years (range 57 -74 years). There were no significant differences between the groups in age, corneal curvature, axial length, IOL power, or mean follow-up. The control group consisted of 22 eyes of 20 patients of similar age (mean 62.0 years, range 57- 80 years) with clear lens crystallina and BCVA 1.0 or better.

Postoperatively patients were followed-up routinely: visual acuity with the ETDRS chart, applanation tonometry, slit-lamp biomicroscopy and fundus examination. Corneal topography, wavefront analysis and contrast sensitivity testing were performed in addition to this ophthalmologic examination between six and eight weeks after surgery. Contrast sensitivity testing was performed under photopic (85 cd/m^2) and mesopic (6 cd/m^2) conditions. Photopic contrast sensitivity was evaluated (CSV 1000, Contrast Sensitivity 8010 System, Oculus) at spatial frequency values of 3, 6, 12, and 18 cycles per degree (cpd). Mesopic contrast sensitivity was evaluated (Contrast sensitivity 8010 System, Neuroscientific Corp, Farmingdale, USA) at 0.74, 1.97, 3.69, 14.77, and 29.55 cpd. Eyes were not dilated for the contrast sensitivity test, and therefore the patient´s pupil size was normal.

The wavefront aberration of the whole eye was measured with the ORK Wavefront Analyser (Schwind) with a pharmacologically dilated pupil. The wavefront maps were analyzed using a 6 mm pupil diameter and up to the eighth order of Zernike coefficients.

Statistical analysis was performed by means of Student t-test.

Results

The mean preoperative topographic corneal spherical aberration (SA) was 0.32 ± 0.09 µm (range 0.18 – 0.51 µm).

All eyes in both pseudophakic groups had mean postoperative BCVA 1.0 or better. Mean postoperative UCVA was 1.0 or better in 77.8% of eyes in the AcrySof SN60WF group and in 80% eyes in the AcrySof SN60AT group (Figure 1). The difference was not statistically significant.

The postoperative wavefront analysis including mean HOA root mean square (RMS) values, coma, higher order aberrations, and spherical aberration for both pseudophakic groups are demonstrated in figure 2. No statistically significant difference was found between Acrysof Natural and AcrySof IQ regarding coma and higher order

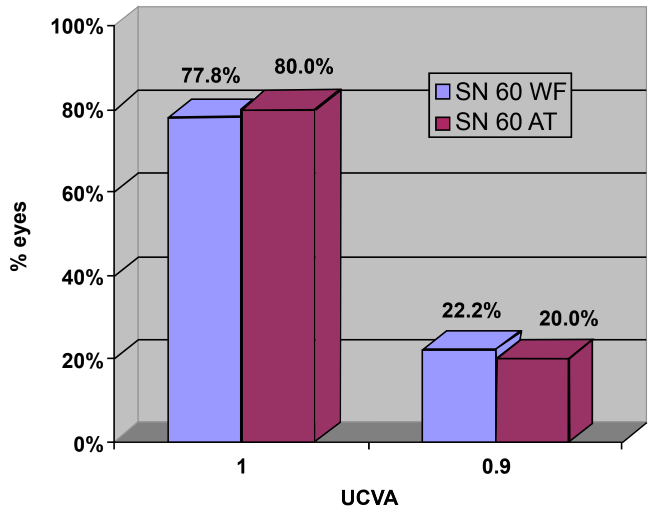

Figure 1: Mean postoperative UCVA in patients with AcrySof IQ and AcrySof Natural.

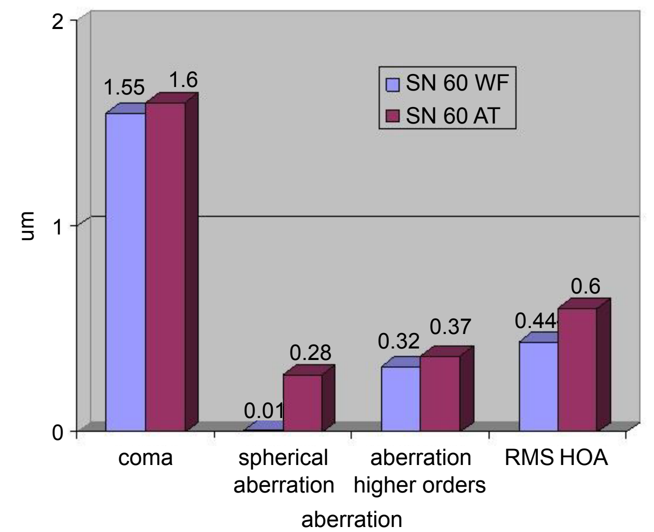

Figure 2: Postoperative wavefront analysis of coma, spherical aberration, higher order aberrations, and RMS HOA (root mean square higher order aberration).

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aberrations. The AcrySof IQ IOL obtained statistically significant less spherical aberration when compared with the spherical AcrySof Natural IOL (IQ 0.01 ± 0.018 µm; Natural 0.28 ± 0.08 µm). Wavefront analysis using 6 mm pupil diameter also demonstrated that AcrySof IQ IOL showed statistically significant lower HOA RMS mean values (IQ 0.44 ± 0.2 µm; Natural 0.6 ± 0.48 µm).

Figures 3 and 4 show contrast sensitivity in photopic and mesopic conditions. Mean pupil diameter was similar between the groups in both conditions. There were no statistically significant differences in contrast sensitivity between the AcrySof SN60WF and AcrySof SN60AT groups in all spatial frequencies. Mesopic contrast sensitivity was higher in patients with AcrySof IQ compared to AcrySof Natural, statistically significant in low frequencies, insignificant in medium and high frequencies. The control group (clear lens crystallina) was better in all frequencies.

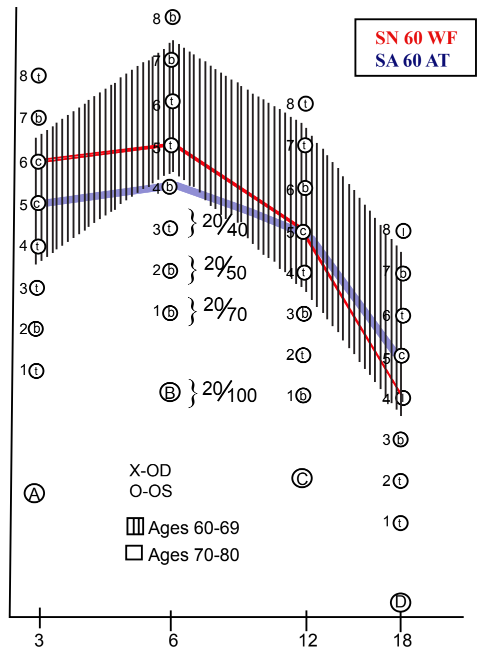

Figure 3: Contrast sensitivity in patients with AcrySof IQ and AcrySof Natural – photopic lighting conditions (85 cd/m²).

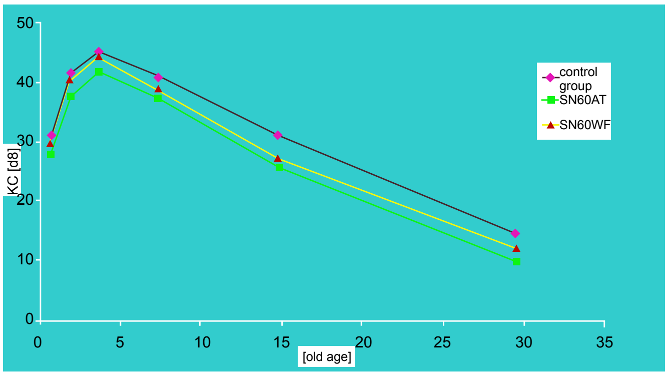

Figure 4: Contrast sensitivity in patients with AcrySof IQ and AcrySof Natural. Control group are patients with clear lens crystallina – mesopic lighting conditions (6 cd/m²).

Discussion

In phakic eyes, the decrease in visual acuity and in contrast sensitivity that occurs with age is usually attributed to lens changes. In young subjects, the crystalline lens compensates with its negative spherical aberration for the positive spherical aberration of the cornea, resulting in a low level of spherical aberration of the entire eye. After the age of 40 years, the spherical aberration of the lens progressively turns positive, adding to the spherical aberration of the cornea to increase the total aberrations of the eye [7-9]. Conventional monofocal plane-convex or biconvex IOLs can introduce only positive spherical aberration decreasing image quality [10,11]. Some pseudophakic patients complain about glare, halos, and starburst that could be attributed to spherical aberration [12]. Based on these findings, it was postulated that an aspheric IOL that restored the conditions of the young eye with respect to spherical aberration would produce a pseuphakic eye with improved contrast sensitivity as compared to pseudophakic eyes implanted with spherical IOLs. In this study, we found statistically significant lower spherical aberration and HOA RMS mean values after implantation of the AcrySof IQ when compared with implantation of AcrySof Natural.

The most significant differences between aspheric and spherical IOLs related to contrast sensitivity occurred at mesopic levels. Mester et al. [13] found statistically significant improvement in the aspheric IOL group (Tecnis Z9000) in mesopic contrast sensitivity at low spatial frequences. These authors also found no difference between the aspheric and spherical IOL in photopic conditions. In our study we have found similar results for spherical IOL AcrySof Natural and its "aspheric variation" AcrySof IQ. There were no statistically significant differences in photopic contrast sensitivity between the AcrySof SN60WF and AcrySof SN60AT groups in all spatial frequencies. Mesopic contrast sensitivity was higher in patients with Acrysof IQ compared to Acrysof Natural, statistically significant in low frequencies, insignificant in medium and high frequencies. The control group (clear lens crystallina) was better in all frequencies.

In conclusion, the adoption of ocular wavefront technology in clinical ophthalmology has made it possible to quantify total ocular aberrations and better understand the benefits of a customized IOL to correct aberrations of the eye. The aspheric AcrySof IQ induced significantly less spherical aberration than the AcrySof Natural. It also presented better contrast sensitivity only under mesopic conditions at low frequencies.

Conflict of Interest

None of the authors has a financial or proprietary interest in any product mentioned.

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