Wavefront Analysis and Contrast Sensitivity of Aspheric and Spherical Intraocular Lenses: A Randomized Prospective Study

KAROLINNE MAIA ROCHA, MD, EDUARDO S. SORIANO, MD, MARIA REGINA CHALITA, MD, ANA CAROLINA YAMADA, MD, KÁTIA BOTTÓS, MD, JULIANA BOTTÓS, MD, LISANGELA MORIMOTO, BS, AND WALTON NOSÉ, MD

• PURPOSE: **To compare visual performance, total and high order wavefront aberrations (coma, spherical aberration, and other terms), and contrast sensitivity in 120 eyes implanted with one monofocal aspheric intraocular lens (IOL) and two spherical IOLs.**

• DESIGN: **Randomized prospective study.**

• METHODS: **Sixty patients were randomized to receive three IOL types: Alcon AcrySofIQ (40 eyes), AcrySofNatural (40 eyes), and advanced medical optic (AMO)Sensar (40 eyes). Complete ophthalmologic examination including uncorrected visual acuity (UCVA), best-spectacle corrected visual acuity (BSCVA), corneal topography, and wavefront analysis were performed preoperatively, 30 days, and 90 days postoperatively. Pelli-Robson chart test and functional acuity contrast testing (FACT-Optec6500) were performed approximately 50 days after surgery. Statistical analyses were performed using analysis χ^2, analysis of variance (ANOVA), and multiple comparisons Tukey test.**

• RESULTS: **After 90 days, all eyes had postoperative BSCVA ≥20/32. The AcrySofIQ IOL showed statistically significant less induction of spherical aberration ($P < .001$) when compared with the AMOSensar and the AcrySofNatural IOLs. The AMOSensar presented significantly less spherical aberration then the AcrySofNatural ($P < .05$). The AcrySofIQ also had lower values of total and high-order aberration (HOA) ($P < .05$) when compared with the AMOSensar and the AcrySofNatural. The mean values of trefoil 9, coma, and HOA root mean square (RMS) decreased between one and three months ($P < .001$, $P < .001$, $P = .023$, $P < .001$, respectively) in all groups. Mean Pelli-Robson contrast sensitivity values in photopic condition were similar between the groups. The AcrySofIQ showed better results in 3cpd spatial frequency in mesopic condition using FACT-Optec 6500 ($P = .008$), although there were no statistical differences in photopic and mesopic with glare conditions. (Am J Ophthalmol 2006;142:750.e1–750.e10. © 2006 by Elsevier Inc. All rights reserved.)**

Modern cataract surgery and lens replacement attempt not only to restore visual acuity, but also to improve visual function and protect the retina against light toxicity.

Deficiencies on optical quality of vision not detected by visual acuity measurement can be effectively evaluated by wavefront analysis and contrast sensitivity test. Wavefront technology can quantify low and high-order aberrations (HOA) present in an optical system. The high-resolution imaging in ophthalmic optics can be affected by high order aberrations such as coma and spherical aberration.[1–3] Conventional spherical intraocular lens (IOLs) can degrade imaging quality, increasing the spherical aberration of the optical system.[4–6] 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.[5,7]

Aspherical IOL designs can optimize image quality by limiting rays diffraction. They have been described to improve visual function by means of reducing spherical aberration.[4,8,9] The benefits of an IOL with short wave absorbing chromophores in terms of elevating the threshold for photochemical damage may provide more retinal protection than usual IOLs.[10,11] It was also described that UV-absorbing IOLs do not cause contrast sensitivity and chromatic vision disturbance.[12] The AcrySof IQ IOL includes blue light filter properties associated with a posterior aspheric design.

This randomized prospective study aims to clarify the relationships between total and high-order wavefront aberrations (coma, spherical aberration, and other terms of

AJO.com Supplemental Material available at AJO.com.

Accepted for publication Jun 8, 2006.

From the Ophthalmology Department, Federal University of Sao Paulo, Sao Paulo, Brazil.

Inquiries to Karolinne Maia Rocha, MD, Rua 3 de Maio, 130 ap 124., Sao Paulo, SP, 04044-020 Brazil; e-mail: karolinne@oftalmo.epm.br

0002-9394/06/$32.00
doi:10.1016/j.ajo.2006.06.031

HOA) and contrast sensitivity under photopic and mesopic conditions in eyes implanted with three different IOLs: AcrySof IQ (aspheric IOL with blue light filter), AcrySof Natural (spherical IOL with blue light filter), and advanced medical optics (AMO) Sensar (spherical IOL with no blue light filter).

METHODS

A RANDOMIZED PROSPECTIVE STUDY COMPARING THREE IOLs types, Alcon AcrySof IQ (SN60WF) (40 eyes), AcrySof Natural (SN60AT) (40 eyes), and AMO Sensar (AR40) (40 eyes), was carried out at the Federal University of Sao Paulo. Patients with bilateral visually significant senile cataract, corneal astigmatism less than 2.0 diopters, and potential acuity meter (PAM) better than 0.2 logMAR units were eligible for inclusion in the study. Exclusion criteria were any ocular diseases, such as corneal opacities or irregularity, dry eye, amblyopia, anisometropia, glaucoma, retinal abnormalities, surgical complications, IOL tilt, decentration (estimated by retro illumination and digital photo) greater than 0.4 mm,[13] or loss of follow-up. The IOL power ranged from 19.0 to 25.0 diopters. The randomization was obtained with six IOL implantation sequences, and the patients received one different IOL for each eye. The protocol was approved by the Ethical Committee of Federal University of Sao Paulo and it was in compliance with the Declaration of Helsinki. Informed consent was obtained from all participants.

Clear corneal phacoemulsification and IOL implantation were performed from February to October 2005. All surgeries were performed by two experienced surgeons (E.S. and W.N.) using the same three-step clear corneal incision (2.75 mm) at 180 degrees (temporal for right eyes and nasal for left eyes) and quick-chop technique. Continuous curvilinear capsulorrhexis with an approximate diameter of 5.0 mm was created. The IOLs were implanted in the capsular bag.

The patients were examined preoperatively, and one, seven, 15, 30, and 90 days after surgery. At that time, complete ophthalmologic examination including uncorrected visual acuity (UCVA), best-spectacle corrected visual acuity (BSCVA) early treatment diabetic retinopathy study (ETDRS) chart, biomicroscopy, applanation tonometry, fundus examination, and contrast sensitivity were performed. Corneal topography (EyeSys Corneal Analysis System: EyeSys Technologies, Dallas, Texas, USA) and wavefront analysis with the LADARWave aberrometer (Alcon Laboratories, Fort Worth, Texas, USA) were performed preoperative, one month and three months postoperatively. The wavefront maps were analyzed using 4 and 5 mm pupil diameter and up to the sixth order of Zernike coefficients. Functional acuity contrast testing (FACT)[14,15] was measured between one and two months after surgery using the Optec 6500 vision testing system (Stereo Optical Co, Inc, Chicago, Illinois, USA) with best spectacle correction under photopic condition (target luminance value of 85 cd/m^2), mesopic (target luminance value of 3 cd/m^2), and mesopic with glare. The log base 10 contrast sensitivity values were used to construct a graphic for each spatial frequency tested.

TABLE 1. Demographics of All Studied Groups According to Age, Gender, and Final Visual Acuity

IOL Groups	AcrySof IQ	AcrySof Natural	Sensar
Gender - n (%)			
Female	25 (62.5)	26 (65.0)	23 (57.5)
Male	15 (37.5)	14 (35.0)	17 (42.5)
Mean Age (SD)	70.2 (7.3)	71.1 (7.3)	69.4 (6.7)
Mean Final BSCVA			
logMar (SD)	0.02 (0.05)	0.03 (0.04)	0.02 (0.05)
Eye n (%)			
OD	19 (48.7)	20 (50.0)	20 (51.3)
OS	20 (51.3)	20 (50.0)	19 (48.7)

BSCVA = best-spectacle corrected visual acuity; IOL = intraocular lens; OD = right; OS = left; SD = standard deviation.

The Pelli-Robson contrast sensitivity test (Pelli-Robson chart, Clement Clarke International, London, United Kingdom) was performed at the same visit using a distance of 1m (corresponding to a spatial frequency of approximately one cycle/degree) and a luminance of approximately 85 cd/m^2 (Gossen-Starlite).[16] Absolute values of log contrast sensitivity were obtained for each eye. Pupil diameter was measured using Colvard pupillometer (OASIS, Glendora, California, USA) at photopic (85 cd/m^2), mesopic (3 cd/m^2), and scotopic (1.5 cd/m^2) conditions. Statistical analysis was performed using absolute frequency (n) and relative frequency (%) for the qualitative variables and mean and standard deviation (SD) for quantitative variables. The χ^2 test was used to compare qualitative variables between groups. The comparison of quantitative variables was performed using analysis of variance (ANOVA) and the differences were calculated using the multiple comparison Tukey test. The differences between right and left eye when analyzing ocular aberrations were adjusted using a variation of ANOVA. For multiple measurements, Bonferroni correction was applied when necessary.

RESULTS

ONE HUNDRED TWENTY EYES (60 PATIENTS) WERE ENrolled in this study. There were 36 female (60%) and 24 male (40%) patients. The ages ranged from 50 to 83 years. All eyes in all groups had mean postoperative BSCVA 20/32 or better. The final BSCVA was similar between the groups (Table 1). The mean topographic astigmatism pre- and postoperative was, respectively, 0.621 ± 0,39 and

TABLE 2. Individual Analysis of High Order Aberrations (Coma, Spherical Aberration, and Other Terms) for All Intraocular Lens Groups

Aberrations	Defocus	RMS Total	RMS HOA	Spherical Aberration	Coma	Astigmatism	Trefoil 6	Trefoil 9
AcrySof IQ								
1 month	0.58 ± 0.51	1.00 ± 0.50	0.42 ± 0.19	0.03 ± 0.05	0.21 ± 0.17	0.57 ± 0.42	−0.10 ± 0.22	0.12 ± 0.13
3 months	0.57 ± 0.56	0.99 ± 0.51	0.35 ± 0.18	0.03 ± 0.05	0.18 ± 0.14	0.57 ± 0.41	−0.10 ± 0.19	0.06 ± 0.11
AcrySof Natural								
1 month	0.62 ± 0.59	1.64 ± 0.51	0.47 ± 0.11	0.25 ± 0.05	0.23 ± 0.13	0.63 ± 0.36	−0.08 ± 0.17	0.13 ± 0.10
3 months	0.64 ± 0.57	1.55 ± 0.44	0.41 ± 0.09	0.24 ± 0.04	0.19 ± 0.13	0.61 ± 0.33	−0.09 ± 0.14	0.09 ± 0.09
AMO Sensar								
1 month	0.70 ± 0.53	1.33 ± 0.46	0.45 ± 0.17	0.13 ± 0.07	0.19 ± 0.10	0.64 ± 0.36	−0.09 ± 0.21	0.15 ± 0.18
3 months	0.64 ± 0.54	1.31 ± 0.44	0.40 ± 0.16	0.14 ± 0.07	0.17 ± 0.11	0.63 ± 0.36	−0.07 ± 0.16	0.11 ± 0.16

RMS = root mean square; RMS HOA = root mean square high order aberration.
AcrySof IQ n = 39; AcrySof Natural n = 40; Sensar n = 39.
5 mm pupil diameter analyzed.

0.643 ± 0.37 (P = .444), while the effective refractive power was 44.11 ± 1.86 and 44.22 ± 1.90 (P = .652). There were no significant differences between the groups in age, corneal curvature, axial length, IOL power, or mean follow-up. One patient who had AcrySof IQ and Sensar implanted in right and left eye, respectively, was excluded from statistical analysis because he could not complete three months of follow up (the patient had a stroke).

The one and three months postoperative wavefront analyses including mean total aberration root mean square (RMS) values, mean HOA values, coma, spherical aberration, astigmatism, trefoil 6, and trefoil 9 for all three groups are demonstrated in Table 2. No statistically significant difference was found between Natural, IQ, and Sensar IOLs regarding defocus, coma, astigmatism, and trefoil values. The AcrySof IQ IOL showed statistically significant less total RMS mean values (P < .001) than AcrySof Natural and AMO Sensar, and also lower HOA RMS mean values (P = .009) than AcrySof Natural.

The AcrySof IQ IOL obtained statistically significant less spherical aberration when compared with the spherical monofocal IOLs tested (IQ 0.03 ± 0.05 μm; Sensar 0.14 ± 0.07 μm; and Natural 0.24 ± 0.04 μm) (P < .001). Yet, the difference between the Sensar and Natural IOLs was statistically significant (P < .001). Wavefront analysis using 4 mm pupil diameter also demonstrated that AcrySof IQ IOL obtained statistically significant less spherical aberration when compared with the other IOLs tested (IQ −0.0008 ± 0.05 μm; Sensar 0.0352 ± 0.04 μm; and Natural 0.0841 ± 0.02 μm) (P < .001). No statistically significant difference was found between Natural, IQ, and Sensar IOLs regarding defocus, coma, astigmatism, and trefoil values using 4 mm pupil diameter.

Comparing wavefront analysis between one and three months postoperative, there were no statistical significant differences in defocus, spherical aberration, trefoil 6, and astigmatism between the three groups. Otherwise, the mean values of trefoil 9, coma, total RMS, and HOA RMS decreased between one and three months (P < .001, P < .001, P = .023, P < .001, respectively). These results suggested that the three-step clear cornea at 180 degrees incisions could be related to trefoil and coma induction. Temporal incision (right eye) presented more quadrifoil 10 (P = .003), while nasal incisions (left eye) showed higher values for coma (P < .001) (Table 3). Spherical aberration did not change after dividing temporal and nasal incisions (right and left eyes).

Four eyes in the AcrySof IQ group, four eyes in the AcrySof Natural group, and five eyes in the AMO Sensar group presented capsular bag contraction and mild IOL decentration (<1.0 mm). The wavefront analysis of these cases separately showed increased values of coma and secondary astigmatism, but it did not affect final visual acuity in any case (Table 4). Mean contrast sensitivity values, measured by Pelli-Robson test, were 1.61 ± 0.09 (IQ), 1.60 ± 0.10 (Natural), and 1.61 ± 0.08 (Sensar).

Figures 1 to 3 show contrast sensitivity in photopic, mesopic, and mesopic with glare conditions. Under mesopic condition, the AcrySof IQ presented statistically better contrast sensitivity than the other two IOLs, only in 3cpd spatial frequency. There were no statistically significant differences in contrast sensitivity between the three groups in photopic and mesopic with glare conditions. Mean pupil diameter was similar between the groups in photopic, mesopic, and scotopic conditions (Table 5). See Supplementary Figures at AJO.com).

DISCUSSION

THE OPTICAL QUALITY DEGRADATION WITH AGE IS caused in part by the increase of the spherical aberration of the optical system. Early in life, the crystalline lens compensates for the cornea positive spherical aberration

TABLE 3. Individual Analysis of Mean High Order Aberrations (Coma, Spherical Aberration, and Other Terms) for All Groups Implanted in Right and Left Eye (Temporal and Nasal Incisions)

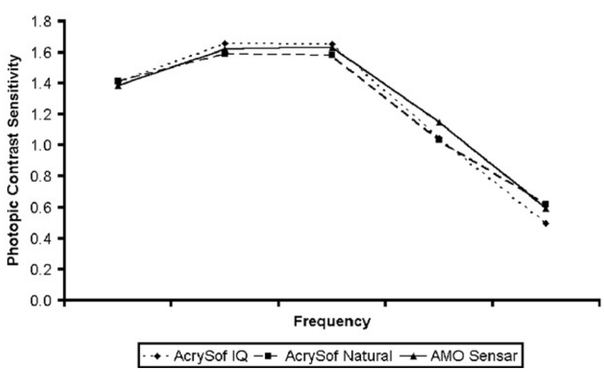
Aberrations	RMS Total		RMS HOA		Spherical Aberration	
	OD	OS	OD	OS	OD	OS
AcrySof IQ						
3 months	1.09 ± 0.50	0.90 ± 0.53	0.38 ± 0.23	0.33 ± 0.12	0.03 ± 0.05	0.03 ± 0.06
AcrySof Natural						
3 months	1.41 ± 0.43	1.71 ± 0.41	0.39 ± 0.08	0.44 ± 0.10	0.24 ± 0.03	0.23 ± 0.05
AMO Sensar						
3 months	1.27 ± 0.40	1.36 ± 0.49	0.34 ± 0.15	0.45 ± 0.15	0.13 ± 0.08	0.15 ± 0.06

RMS = root mean square; RMS HOA = root mean square high order aberration; OD = right; OS = left.
AcrySof IQ OD n = 19 OS n = 20; AcrySof Natural OD n = 20 OS n = 20; Sensar OD n = 20 OS n = 19.
5 mm pupil diameter analyzed.

TABLE 4. Wavefront Analysis of Pseudophakic Eyes with Intraocular Lens Capsular Bag Contraction and Intraocular Lens Decentration Greater Than 0.4 mm

Aberrations	RMS Total	RMS HOA	Spherical Aberration	Coma	Astigmatism	Trefoil 6	Trefoil 9
AcrySof IQ							
3 months	1.53 ± 0.46	0.72 ± 0.25	0.70 ± 0.05	0.48 ± 0.24	0.98 ± 0.49	−0.20 ± 0.48	−0.06 ± 0.21
AcrySof Natural							
3 months	1.87 ± 0.73	0.56 ± 0.10	0.22 ± 0.02	0.47 ± 0.14	0.70 ± 0.55	0.07 ± 0.08	0.11 ± 0.10
AMO Sensar							
3 months	1.61 ± 0.59	0.65 ± 0.05	0.17 ± 0.11	0.27 ± 0.13	0.80 ± 0.49	−0.15 ± 0.30	0.29 ± 0.20

RMS = root mean square; RMS HOA = root mean square high order aberration.
AcrySof IQ n = 4; AcrySof Natural n = 4; Sensar n = 5.
5 mm pupil diameter analyzed.

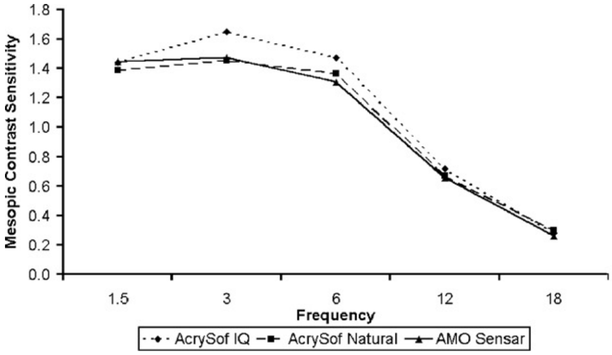


Frequency (cpd)	Photopic Contrast Sensitivity			ANOVA
	AcrySof® IQ n = 39	AcrySof® Natural n = 40	AMO Sensar® n = 39	
1.5	1.41 (0.14)	1.41 (0.18)	1.38 (0.17)	p = 0.738
3	1.66 (0.17)	1.59 (0.19)	1.62 (0.19)	p = 0.258
6	1.65 (0.23)	1.58 (0.33)	1.63 (0.35)	p = 0.577
12	1.05 (0.54)	1.03 (0.53)	1.15 (0.50)	p = 0.564
18	0.50 (0.48)	0.62 (0.45)	0.60 (0.44)	p = 0.447

FIGURE 1. Postoperative functional acuity contrast test (FACT) measured under photopic conditions for all intraocular lens (IOLs) types.

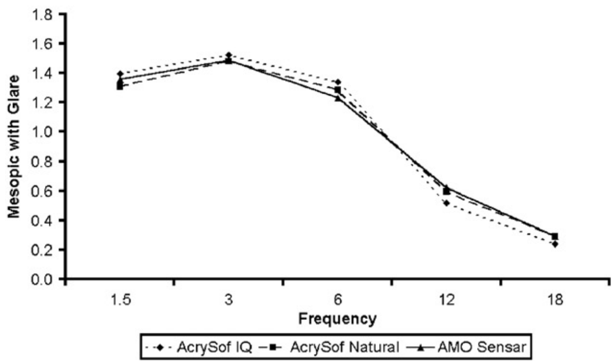
The aging crystalline lens becomes less negative (or even more positive), increasing the total optical spherical aberration of the eye by adding to the positive corneal spherical aberration.[17–21] Wavefront assessment of cataract patients has become an important instrument to evaluate quality and functional vision.[1–4,9,22,23] In this study, after the surgery, the Hartmann Shack spot patterns could only be appropriately measured and analyzed when the pupil diameter analyzed was smaller than the IOL optical zone.

Conventional monofocal plane-convex or biconvex IOLs can introduce only positive spherical aberration decreasing image quality.[24,25] Some pseudophakic patients complain about glare, halos, and starburst that could be attributed to spherical aberration.[25,26] Other authors have demonstrated



Frequency (cpd)	Mesopic Contrast Sensitivity			ANOVA
	AcrySof® IQ n = 39	AcrySof® Natural n = 40	AMO Sensar® n = 39	
1.5	1.44 (0.17)	1.39 (0.17)	1.44 (0.19)	p = 0.311
3	1.65 (0.17)	1.45 (0.39)	1.47 (0.30)	p = 0.008 *
6	1.47 (0.42)	1.36 (0.52)	1.31 (0.57)	p = 0.357
12	0.72 (0.64)	0.67 (0.59)	0.65 (0.63)	p = 0.892
18	0.28 (0.40)	0.30 (0.41)	0.26 (0.37)	p = 0.922

FIGURE 2. Postoperative functional acuity contrast test (FACT) contrast sensitivity measured under mesopic conditions for all intraocular lens (IOLs) types.



Frequency (cpd)	Mesopic with Glare Contrast Sensitivity			ANOVA
	AcrySof® IQ n = 39	AcrySof® Natural n = 40	AMO Sensar® n = 39	
1.5	1.40 (0.16)	1.31 (0.25)	1.35 (0.14)	p = 0.107
3	1.53 (0.18)	1.48 (0.16)	1.48 (0.17)	p = 0.418
6	1.34 (0.51)	1.28 (0.48)	1.23 (0.56)	p = 0.666
12	0.52 (0.65)	0.59 (0.56)	0.62 (0.59)	p = 0.737
18	0.24 (0.38)	0.29 (0.38)	0.29 (0.34)	**p = 0.771**

FIGURE 3. Postoperative functional acuity contrast test (FACT) contrast sensitivity measured under mesopic with glare conditions for all intraocular lens (IOLs) types.

that aspheric IOLs can provide lower spherical aberration values, without interfering in coma and other terms of HOA 1, 2, 4, 8, 13 as demonstrated in this study. The AcrySof IQ IOL induced statistically significant less spherical aberration (0.03 ± 0.05 μm) than the other two IOLs. The AcrySof Natural showed the highest values (0.24 ± 0.04 μm), leaving the AMO Sensar in an intermediate position.

Marcos and associates[27] found that corneal aberrations increased after IOL implantation, particularly astigmatism and trefoil terms. Guirao and associates[28] suggested that small incision surgeries introduce changes in corneal aberrations, such as coma, trefoil, and astigmatism, especially in nasal incisions. In our study, we found a statistically significant decrease in trefoil 9 and coma between one and three months corresponding to qualitative topographic changes attributable to incision healing, while other aberrations did not change (spherical aberration, trefoil 6, and astigmatism) (Table 2). This result suggests that the three-step 180 clear cornea incision could be related to this trefoil 9 induction. Although the mean topographic astigmatism and the effective refractive power did not change with the cataract surgeries, further vector analysis should be conducted to explore this matter.

The most significant differences between aspheric and spherical IOLs related to contrast sensitivity occurred at mesopic levels. Mester and associates[4] found statistically significant improvement in the aspheric IOL group (Tecnis Z9000) in mesopic contrast sensitivity at low spatial frequencies (1.5, 3, and 6 cpd). The authors also found no difference between the aspheric and spherical IOLs in photopic conditions. Parker[8,29] demonstrated that aspheric IOL (Tecnis) provided significantly better contrast sensitivity results at some spatial frequencies (3 and 6 cpd under photopic conditions and at 1.5, 3, and 6 cpd under mesopic conditions). In our study, there were no statistically significant contrast sensitivity differences between the three groups under photopic conditions using the Pelli-Robson test and FACT (Optec 6500). Otherwise, applying the FACT under mesopic conditions, the aspheric IOL (AcrySof IQ) showed better results at 3cpd spatial frequency. The reduction of trefoil 9, coma, total RMS, and HOA RMS three months after phacoemulsification could affect the contrast sensitivity tests, perhaps even leading to a better performance of these tests with a longer follow-up.

The Pelli-Robson contrast sensitivity test is a reliable and easy to apply method.[16,30,31] In our study, including pseudophakic patients implanted with AcrySof IQ, AcrySof Natural, and AMO Sensar IOLs, there were no statistically significant differences in photopic conditions (1.61 ± 0.08, 1.60 ± 0.10, and 1.61 ± 0.08, respectively).

TABLE 5. Pupil Size Under Different Light Conditions

Light Conditions	AcrySof IQ n = 35	AcrySof Natural n = 36	AMO Sensar n = 34	ANOVA
Photopic	3.56 (0.52)	3.32 (0.55)	3.50 (0.55)	$P = 0.160$
Mesopic	4.14 (0.51)	3.89 (0.54)	4.04 (0.48)	$P = 0.112$
Scotopic	4.66 (0.59)	4.33 (0.56)	4.46 (0.58)	$P = 0.063$

ANOVA = analysis of variance; AMO = advanced medical optic.

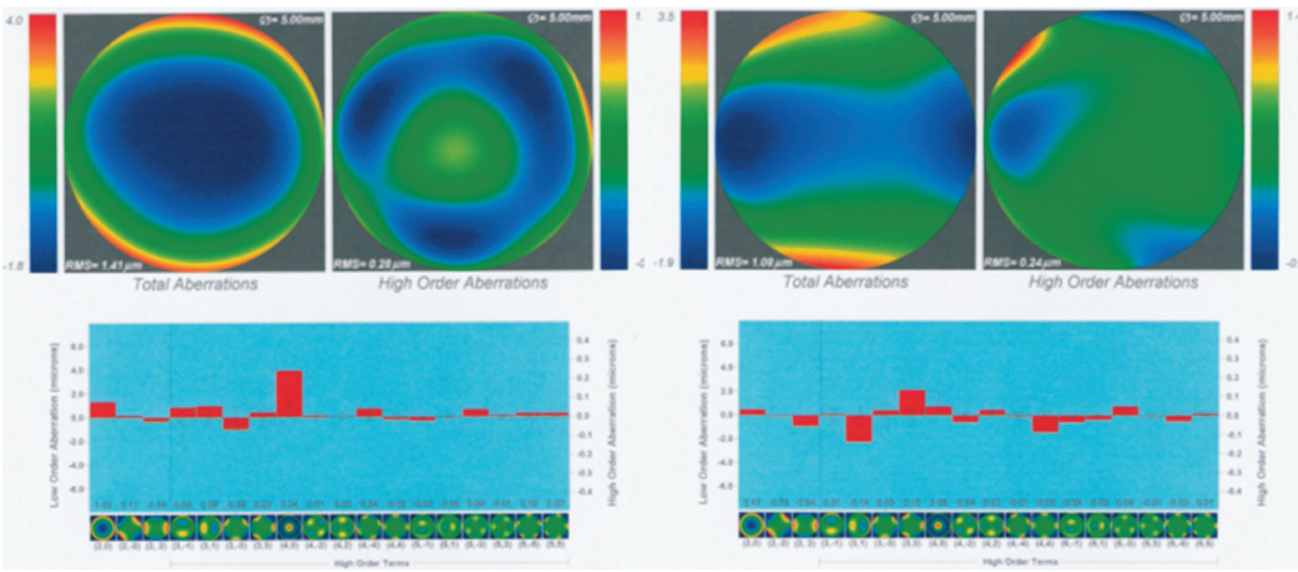


FIGURE 1S. Wavefront analysis of a patient implanted with AcrySofNatural in right eye and AcrySofIQ in left eye.

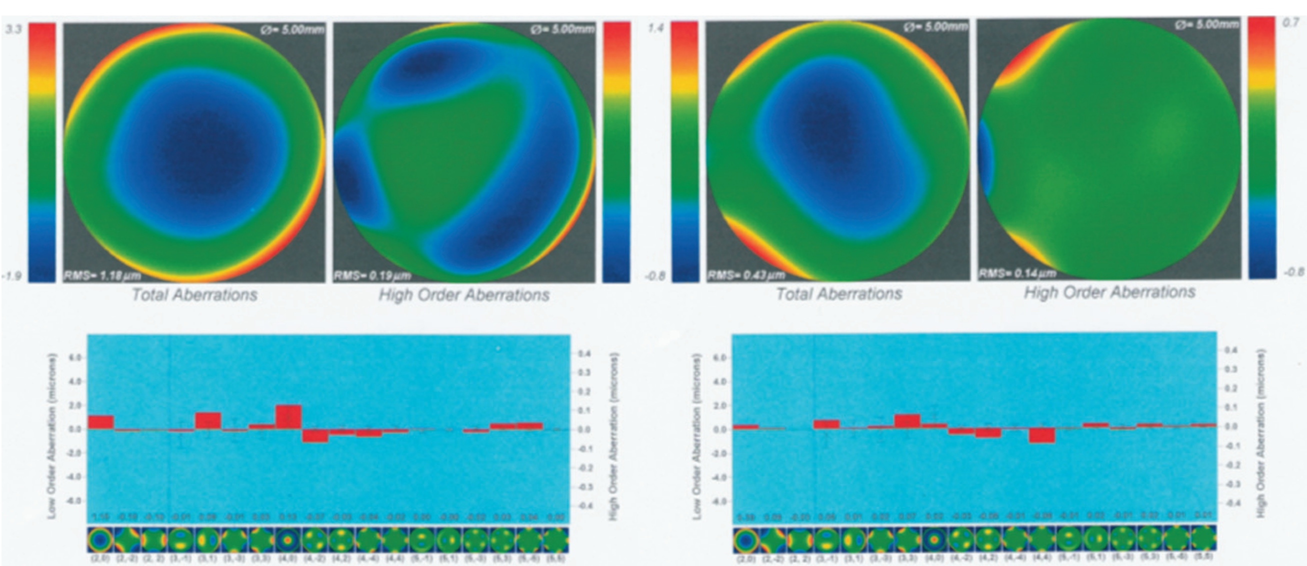


FIGURE 2S. Wavefront analysis of a patient implanted with AMOSensar in right eye and AcrySofIQ in left eye.

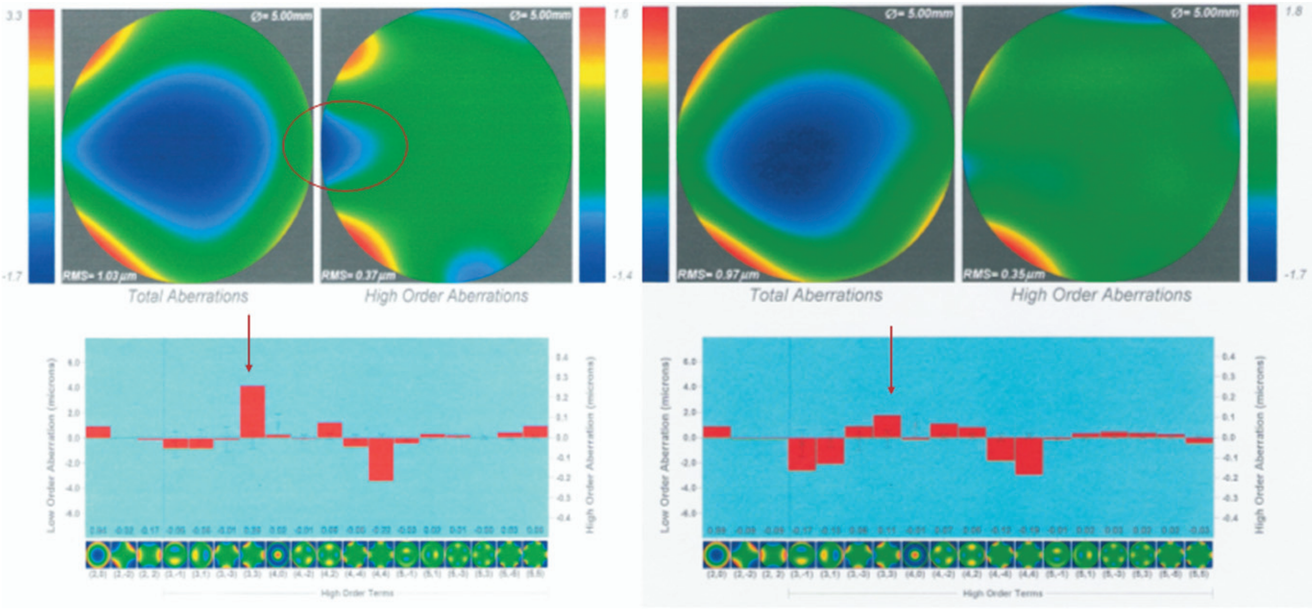


FIGURE 3S. Wavefront analysis of a patient implanted with AcrySofIQ in right eye 1 and 3 months postoperative, showing trefoil 9 reduction.

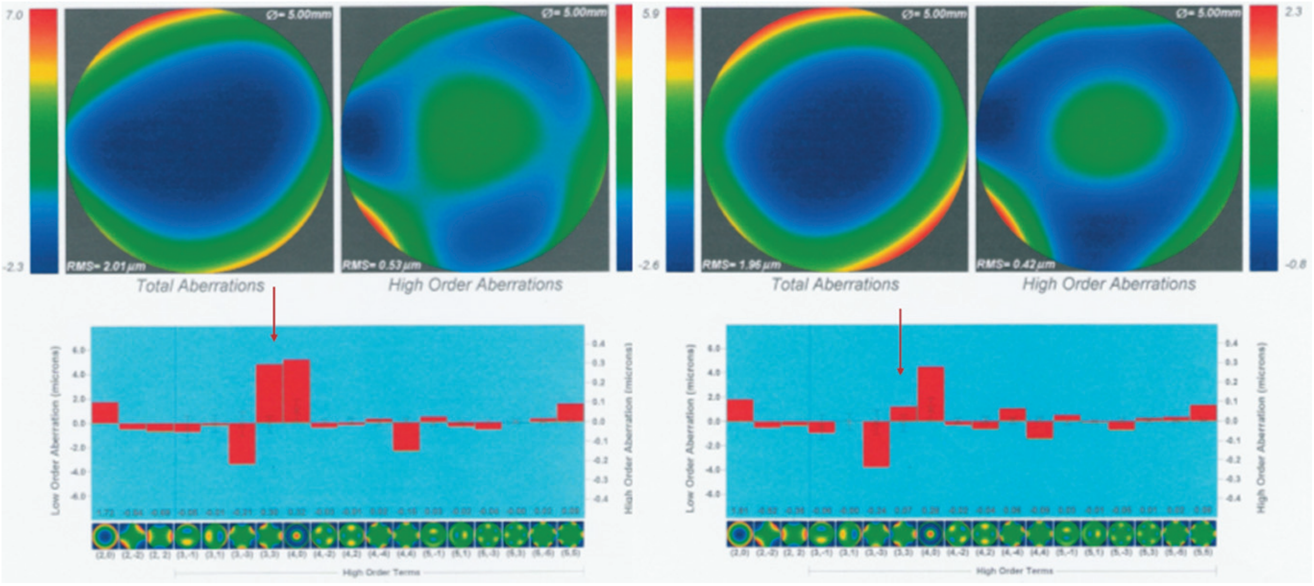


FIGURE 4S. Wavefront analysis of a patient implanted with AcrySofNatural in right eye 1 and 3 months postoperative, showing trefoil 9 reduction.

Elliot and Whitaker[32] published normal values for Pelli-Robson test in phakic individuals above 50 years of age and found mean values of log 1.50, while Mäntyjärvi and Laitinen[16] showed a mean value of log 1.72 ± 0.08 in a group of phakic patients with 60 to 75 years. The intraocular lens tilt and decentration creates asymmetrical HOA, related to coma and secondary astigmatism. Several studies predict that tilt and decentration are more deleterious in aspheric than in spherical surfaces.[2,13,33,34] Holladay and associates[13] demonstrated that decentration >0.4 mm and tilt >7 degrees would cancel the optical benefits of correcting spherical aberration. In this study, there were few cases of IOL decentration, but we also found increased values of coma and secondary astigmatism in these cases.

Current UV-absorbing IOLs do not closely match the light-transmission spectrum of the human crystalline lens. Blue-light absorbing IOL design to absorb wavelengths below 500 nm approximates the light transmission of a healthy adult human lens. Sparrow and associates[35] suggested that yellow-tinted IOL (AcrySof

Natural) protect lipofuscin-containing retinal pigment epithelial cells from blue-light damage. Studies showed no statistically significant differences in distance contrast sensitivity at any spatial frequencies between AcrySof Natural and AcrySof SA60AT.[12,36] In our study, there were no statistically significant differences under FACT photopic, mesopic, and mesopic with glare conditions in all spatial frequencies between AcrySof Natural and AMO Sensar. Then, the asphericity was the factor that provided better contrast sensitivity in mesopic conditions at 3cpd spatial frequency.

The adoption of ocular wavefront technology in clinical ophthalmology made it possible to quantify total ocular aberrations and better understand the potential benefits of a customized IOL to correct the aberrations of the eye. It can give quantitative measurements, aberrometry, that can be translated in qualitative functions like contrast sensitivity. Cataract lens replacement using wavefront-corrected IOL would improve visual quality. In conclusion, the aspheric AcrySof IQ induced significantly less spherical aberration then AcrySof Natural and AMO Sensar. It also presented better contrast sensitivity only under mesopic conditions at intermediate spatial frequencies. The clear cornea incision induced trefoil 9 and coma that decreased along the postoperative period.

REFERENCES

1. Bellucci R, Morselli S, Piers P. Comparison of wavefront aberrations and optical quality of eyes implanted with five different intraocular lenses. J Refract Surg 2004;20:297–306.
2. Altmann GE. Wavefront-customized intraocular lenses. Curr Opin Ophthalmol 2004;15:358–364.
3. Packer M, Fine IH, Hoffman RS. Wavefront technology in cataract surgery. Curr Opin Ophthalmol 2004;15:56–60.
4. Mester U, Dillinger P, Anterist N. Impact of a modified optic design on visual function: clinical comparative study. J Cataract Refract Surg 2003;29:652–660.
5. Rawer R, Stork W, Spraul CW, Lingenfelder C. Imaging quality of intraocular lenses. J Cataract Refract Surg 2005; 31:1618–1631.
6. Guirao A, Redondo M, Geraghty E, Piers P, Norrby S, Artal P. Corneal optical aberrations and retinal image quality in patients in whom monofocal intraocular lenses were implanted. Arch Ophthalmol 2002;120:1143–1151.
7. Norrby NE, Grossman LW, Geraghty EP, et al. Determining the imaging quality of intraocular lenses. J Cataract Refract Surg 1998;24:703–714.
8. Packer M, Fine IH, Hoffman RS, Piers PA. Improved functional vision with a modified prolate intraocular lens. J Cataract Refract Surg 2004;30:986–992.
9. Bellucci R, Scialdone A, Buratto L, et al. Visual acuity and contrast sensitivity comparison between Tecnis and AcrySof SA60AT intraocular lenses: a multicenter randomized study. J Cataract Refract Surg 2005;31:712–717.
10. Mainster MA and Sparrow JR. How much blue light should an IOL transmit? Br J Ophthalmol 2003;87:1523–1529.
11. Werner JS. Night vision in the elderly: consequences for seeing through a "blue filtering" intraocular lens. Br J Ophthalmol 2005;89:1518–1521.
12. Rodriguez-Galietero A, Montes-Mico R, Munoz G, Albarran-Diego C. Comparison of contrast sensitivity and color discrimination after clear and yellow intraocular lens implantation. J Cataract Refract Surg 2005;31:1736–1740.
13. Holladay JT, Piers PA, Koranyi G, van der Mooren M, Norrby NE. A new intraocular lens design to reduce spherical aberration of pseudophakic eyes. J Refract Surg 2002;18: 683–691.
14. Ginsburg AP. A new contrast sensitivity vision test chart. Am J Optom Physiol Opt 1984;61:403–407.
15. Ginsburg AP. Contrast sensitivity and functional vision. Int Ophthalmol Clin 2003;43:5–15.
16. Mantyjarvi M, Laitinen T. Normal values for the Pelli-Robson contrast sensitivity test. J Cataract Refract Surg 2001;27:261–266.
17. McLellan JS, Marcos S, Burns SA. Age-related changes in monochromatic wave aberrations of the human eye. Invest Ophthalmol Vis Sci 2001;42:1390–1395.
18. Guirao A, Redondo M, Artal P. Optical aberrations of the human cornea as a function of age. J Opt Soc Am A Opt Image Sci Vis 2000;17:1697–1702.
19. Amano S, Amano Y, Yamagami S, et al. Age-related changes in corneal and ocular higher-order wavefront aberrations. Am J Ophthalmol 2004;137:988–992.
20. Roorda A and Glasser A. Wave aberrations of the isolated crystalline lens. J Vis 2004;4:250–261.
21. Sachdev N, Ormonde SE, Sherwin T, McGhee CN. Higher-order aberrations of lenticular opacities. J Cataract Refract Surg 2004;30:1642–1648.
22. Vilarrodona L, Barrett GD, Johnson B. High-order aberrations in pseudophakia with different intraocular lenses. J Cataract Refract Surg 2004;30:571–575.
23. Uchio E, Ohno S, Kusakawa T. Spherical aberration and glare disability with intraocular lenses of different optical design. J Cataract Refract Surg 1995;21:690–696.
24. Werner L, Mamalis N. Wavefront corrections of intraocular lenses. Ophthalmol Clin North Am 2004;17:233–245.
25. 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:S579–S583.
26. Chalita MR, Krueger RR. Correlation of aberrations with visual acuity and symptoms. Ophthalmol Clin North Am 2004;17:135–142.
27. Marcos S, Barbero S, Jimenez-Alfaro I. Optical quality and depth-of-field of eyes implanted with spherical and aspheric intraocular lenses. J Refract Surg 2005;21:223–235.
28. Guirao A, Tejedor J, Artal P. Corneal aberrations before and after small-incision cataract surgery. Invest Ophthalmol Vis Sci 2004;45:4312–4319.
29. Packer M, Fine IH, Hoffman RS, Piers PA. Prospective randomized trial of an anterior surface modified prolate intraocular lens. J Refract Surg 2002;18:692–696.
30. Aggarwal A, Khurana AK, Nada M. Contrast sensitivity function in pseudophakics and aphakics. Acta Ophthalmol Scand 1999;77:441–443.
31. Nio YK, Jansonius NM, Geraghty E, Norrby S, Kooijman AC. Effect of intraocular lens implantation on visual acuity,

contrast sensitivity, and depth of focus. J Cataract Refract Surg 2003;29:2073–2081.
32. Elliott DB, Whitaker D. Clinical contrast sensitivity chart evaluation. Ophthalmol Physiol Opt 1992;12:275–280.
33. Atchison DA. Design of aspheric intraocular lenses. Ophthalmol Physiol Opt 1991;11:137–146.
34. Altmann GE, Nichamin LD, Lane SS, Pepose JS. Optical performance of 3 intraocular lens designs in the presence of decentration. J Cataract Refract Surg 2005;31:574–585.
35. Sparrow JR, Miller AS, Zhou J. Blue light-absorbing intraocular lens and retinal pigment epithelium protection in vitro. J Cataract Refract Surg 2004;30:873–878.
36. Leibovitch I, Lai T, Porter N, Pietris G, Newland H, Selva D. Visual outcomes with the yellow intraocular lens. Acta Ophthalmol Scand 2006;84:95–99.

REPORTING VISUAL ACUITIES

The AJO encourages authors to report the visual acuity in the manuscript using the same nomenclature that was used in gathering the data provided they were recorded in one of the methods listed here. This table of equivalent visual acuities is provided to the readers as an aid to interpret visual acuity findings in familiar units.

Table of Equivalent Visual Acuity Measurements

Snellen Visual Acuities				
4 Meters	6 Meters	20 Feet	Decimal Fraction	LogMar
4/40	6/60	20/200	0.10	+1.0
4/32	6/48	20/160	0.125	+0.9
4/25	6/38	20/125	0.16	+0.8
4/20	6/30	20/100	0.20	+0.7
4/16	6/24	20/80	0.25	+0.6
4/12.6	6/20	20/63	0.32	+0.5
4/10	6/15	20/50	0.40	+0.4
4/8	6/12	20/40	0.50	+0.3
4/6.3	6/10	20/32	0.63	+0.2
4/5	6/7.5	20/25	0.80	+0.1
4/4	6/6	20/20	1.00	0.0
4/3.2	6/5	20/16	1.25	−0.1
4/2.5	6/3.75	20/12.5	1.60	−0.3
4/2	6/3	20/10	2.00	−0.3

From Ferris FL III, Kassoff A, Bresnick GH, Bailey I. New visual acuity charts for clinical research. Am J Ophthalmol 1982;94:91–96.

Biosketch

Karolinne Maia Rocha, MD, received her medical degree from University of Londrina in Paraná, Brazil. After obtaining her MD, she performed her Residence in Ophthalmology at Federal University of São Paulo and was certified by the Brazilian Council of Ophthalmology in 2005. Subsequently, she was a Fellow at the same University in Cataract and Glaucoma Service. At this moment, she is concluding her PhD in wavefront analysis of intraocular lenses.