COMPARING THE CONTRAST SENSITIVITY OF A MODIFIED PROLATE ANTERIOR SURFACE IOL AND OF TWO SPHERICAL IOLS

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ABSTRACT

Purpose: To compare the contrast sensitivity of an intraocular lens (IOL) with a modified prolate anterior surface (Tecnis Z9000, Pfizer), with 2 standard spherical IOLs (Sensar® AR40e Opti-Edge IOL, AMO and AcrySof® Natural SN60AT IOL, Alcon).

Methods: In this prospective study, 98 eyes of 71 patients received 1 of 3 IOLs at random. After 6 months, best corrected visual acuity, pupil size and contrast sensitivity under mesopic and photopic conditions were measured.

Results: No statistically significant differences in preoperative and postoperative refractive error and best corrected visual acuity existed between the groups. When comparing the Tecnis IOL with the AR40e IOL, contrast sensitivity testing showed significantly better results in the Tecnis group at 3 and 12 cpd in photopic conditions; at 3, 12 and 18 cpd in photopic with glare; at 3, 12 and 18 cpd in mesopic and at 12 and 18 cpd in mesopic with glare. The Tecnis IOL provided significantly better contrast sensitivity at almost all spatial frequencies in any lighting condition in comparison with the SN60AT IOL.

Conclusion: Implantation of a modified prolate IOL may improve quality of vision as demonstrated by our clinical results of contrast sensitivity testing. In this study, we found a better performance of the Tecnis IOL under both photopic and mesopic conditions, compared to the results of the AR40e and the SN60AT IOL.

SAMENVATTING

Doel: Vergelijking van de contrastgevoeligheid van een intraoculaire lens (IOL) met een prolate voorvlakte (Tecnis Z9000, Pfizer), met 2 sferische IOLs (Sensar® AR40e Opti-Edge IOL, AMO en AcrySof® Natural SN60AT IOL, Alcon).

Methoden: In deze prospectieve studie werd bij 98 ogen van 71 patiënten willekeurig 1 van deze 3 lenzen geïmplanteerd. Na 6 maanden werden de best gecorrigeerde visus, pupildiameter en contrastgevoeligheid onder mesopische en fotopische omstandigheden gemeten.

Resultaten: Er was geen statistisch significant verschil in preoperatieve en postoperatieve refractieve afwijking en in best gecorrigeerde visus tussen de groepen. Bij de vergelijking van de contrastgevoeligheid van de Tecnis IOL met de AR40e IOL, stelden we vast dat er significant betere resultaten waren in de Tecnis groep bij 3 en 12 cpd in fotopische belichting; bij 3, 12 en 18 cpd in fotopische belichting met verblinding; bij 3, 12 en18 cpd in mesopische belichting en bij 12 en 18 cpd in mesopische belichting met verblinding. In alle lichtomstandigheden vonden we bij bijna alle spatiale frequenties een significant betere contastgevoeligheid van de Tecnis IOL in vergelijking met de SN60AT IOL.

Besluit: Implantatie van een IOL met een prolate voorvlakte kan de visuskwaliteit verbeteren, zoals aangetoond in onze klinische testen van de contrastgevoeligheid. In deze studie vonden we zowel onder fotopische als mesopische belichting betere resultaten bij de Tecnis IOL dan bij de AR40e en SN60AT IOL.

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RÉSUMÉ

But: La comparaison de la sensibilité au contraste d'une lentille intraoculaire (LIO) avec la surface antérieure prolate (Tecnis Z9000, Pfizer) avec 2 lentilles standards sphériques (Sensar® AR40e Opti-Edge IOL, AMO et AcrySof® Natural SN60AT IOL, Alcon).

Méthodes: Dans cette étude prospective, 98 yeux de 71 patients ont eu arbitrairement une implantation d'une de ces 3 LIOs. La meilleure acuité visuelle corrigée, le diamètre de la pupille et la sensibilité aux contrastes en conditions mésopiques et photopiques ont été mesurés après 6 mois.

Résultats: Il n'y avait pas de différence statistique significative en erreur réfractive préopératoire et postopératoire et en meilleure acuité visuelle corrigée entre les groupes. La comparaison de la sensibilité au contraste de la LIO Tecnis avec la LIO AR40e, montrait des meilleurs résultats statistiques significatifs dans le groupe de Tecnis à 3 et12 cpd en conditions photopiques; à 3, 12 et 18 cpd en conditions photopiques avec éblouissement; à 3, 12 et 18 cpd en conditions mésopiques et à 12 et 18 cpd en conditions mésopiques avec éblouissement. A presque toutes les fréquences spatiales, la LIO Tecnis produisait une meilleure sensibilité significative au contraste en toutes conditions d'éclairage, que la LIO SN60AT.

Conclusion: L'implantation d'une LIO à surface antérieure prolate, peut améliorer la qualité de la vision, comme démontré par nos tests cliniques de la sensibilité aux contrastes. Dans cette étude, la LIO Tecnis produisait des meilleurs résultats en conditions mésopiques et photopiques, en comparaison avec la LIO AR40e et la LIO SN60AT IOL.

KEY WORDS

Contrast sensitivity - aspheric IOL - cataract.

MOTS-CLÉS

Sensibilité aux contrastes - LIO asphérique - cataracte.

INTRODUCTION

Even in healthy subjects, there is a decrease in retinal image quality and contrast sensitivity with age, starting around the age of 50 years (11,17,20). Guirao et al. (12) found a slightly larger spherical aberration in middle-aged and older corneas, while Oshika et al. (19) found an increase in total corneal aberrations with age, but no correlation between corneal spherical aberrations and age. The results of both studies indicated that the increase in *corneal* aberrations was too small to account for the measured reduction of retinal image quality with age.

In the *young* human eye, the positive spherical aberration introduced by the cornea is partially compensated by the negative spherical aberration of the youthful lens (2,3,4,6,7). As the eye gets *older*, the aberrations of these ocular components decouple, since the positive spherical aberration of the cornea changes little with age (12,19), while alterations in the lens cause an increase in spherical aberration, becoming also positive with age (10). This loss of balance leads to an increase in total ocular aberrations and explains the degradation of the ocular optics in older persons (2,4). Also, it helps to understand why the contrast sensitivity after implantation with a spherical IOL is similar or lower than in normal phakic eyes of the same age, even though these IOLs are optically superior to the natural crystalline lens (1,5). Since a spherical IOL has an inherent positive spherical aberration, again there is no correction of the positive spherical aberration of the cornea.

These findings have lead to the development of an IOL, the Tecnis Z9000 (Pfizer), to compensate for the corneal spherical aberration. Corneal topography measurements and determination of the wavefront aberration in 71 patients presenting for cataract surgery resulted in the design of an IOL with a modified prolate front surface (flatter curve in the periphery), producing an amount of negative spherical aberration similar to that of the young crystalline lens. This approximates the optical system of the youthful eye (13).

In this study, we compared the contrast sensitivity in patients implanted with the Tecnis Z9000 IOL (Pfizer), Sensar® AR40e Opti-Edge IOL (AMO) or AcrySof® Natural SN60AT IOL

(Alcon) to determine whether implantation of a modified prolate IOL results in measurably improved visual quality.

PATIENTS AND METHODS

This prospective randomized study was conducted at 1 center. Patients requiring cataract surgery were randomized to receive 1 of three IOL types: Tecnis Z9000 IOL (Pfizer), Sensar® AR40e Opti-Edge IOL (AMO) or AcrySof® Natural SN60AT IOL (Alcon). The Tecnis Z9000 is a silicone lens with a modified prolate anterior surface; the two others are acrylic spherical IOLs. The SN60AT has a covalently bonded yellow chromophore to absorb blue light. Detailed data on the lenses are shown in Table 1. Patients with cataract in both eyes received the same IOL in the fellow eye about one month after the first operation.

The study consisted of patients from 55 to 85 years of age who had clinically significant cataract. Patients with ocular pathology other than cataract, neurologic or other disease known to affect contrast sensitivity e.g.: high hyperopia (> +6.0 D), high myopia (> – 6.0 D), keratometric cylinder greater than 1.5 D, intraoperative or postoperative complications and posterior capsule opacification were excluded.

Preoperative evaluation included measurement of refraction and best spectacle corrected visual acuity (BSCVA), tonometry, visual field, slitlamp and dilated fundus examination. Keratometry was performed with a Haag-Streit keratometer. Axial length was measured by immersion ultrasonography (Axis II, Quantel).

Surgery was performed by a single surgeon (M.H.). After topical anesthesia with oxybuprocaïnehydrochloride 0.4 % (Oxybuprocaïne Minims®), a 1 mm paracenthesis was made and the anterior chamber was filled with 3% sodium hyaluronate/4% chondroitin sulfate (Viscoat®) and 1% sodium hyaluronate (Provisc®). A 3 mm clear corneal temporal incision was followed by a continuous curvilinear capsulorhexis, hydrodissection and phacoemulsification (chop technique) using the Alcon Legacy 20000 unit. After filling the capsular bag with Provisc®, the IOL was implanted in the bag and the viscoelastic was removed. Postoperatively, the eyes were treated with indomethacine (Indocollyre®) and tobramycin-dexamethasone (TobraDex®) on a tapering schedule.

All patients were examined at 1 day, 1 week and 1 month postoperatively. After 6 months, measurement of refraction and visual acuity, contrast sensitivity, pupil size, tonometry and slitlamp examination were performed by one examiner (H.K.). Pupil diameter was measured with the Procyon P2000D pupillometer under

Table 1. *Intraocular lens specifications.*

Characteristic	SN60AT	AR40e	Tecnis
Lens type	single-piece	3-piece	3-piece
Overall length (mm)	13.0	13.0	12.0
Optic diameter (mm)	6.0	6.0	6.0
Optic shape	Biconvex	biconvex	equi-biconvex, aspheric anterior surface
Haptic shape	L	modified C	capsular C
Haptic angulation (°)	0	5	6
Optic material	acrylate/methacrylate copolymer, covalently bonded yellow chromophore	hydrophobic acrylic	polysiloxane
UV filter	Yes	yes	yes
Blue light filter	Yes	no	no
Refractive index	1.55	1.47	1.46
Haptic material	idem optic	blue core PMMA monofilament	polyvinylidene fluoride
Suggested A-constant	118.4	118.4	119.0
Diopter range	+6.0 to +34.0	+6 to +30.0	+16.0 to +24

mesopic low (0.4 lux) and mesopic high (4 lux) conditions.

Best spectacle corrected visual acuity (BSCVA) was measured under photopic lighting conditions (160 lux) using a projected Snellen chart. Contrast sensitivity was measured using the Functional Acuity Contrast Test (FACT) chart (Vision Sciences Research) in the Stereo Optical VT1800 Digital Contrast Sensitivity Tester. The FACT chart uses Gaussian sine-wave gratings to measure contrast sensitivity at 5 standard spatial frequencies (1.5, 3, 6,12 and 18 cycles per degree [cpd]). This test involves performing a 3-alternative, forced-choice task. The patient was asked to look at the chart and choose the orientation of the sine-wave grating pattern in each patch (straight up and down or tilted right or left). Each test was repeated twice for each patient. Measurements were obtained with best spectacle correction under mesopic (6 candelas/m^2 [cd/m^2]) and photopic (85 cd/m^2) luminance levels, with and without a glare source (35 lux).

The 3 IOLs were compared interindividually. The contrast sensitivity values were compared using the 2-sided *t* test. A *P* value less than 0.05 was considered statistically significant.

RESULTS

Results included a total of 98 eyes of 71 patients. The SN60AT IOL was implanted in 32 eyes of 22 patients, the AR40e was implanted in 33 eyes of 26 patients, and the Tecnis IOL was implanted in 33 eyes of 23 patients.

Table 2 shows mean age and standard deviation of the 3 groups. No statistically significant differences in age distribution was present between the groups ($P > 0.05$).

The mean preoperative best spectacle corrected visual acuity (BSCVA) was 0.38 in the SN60AT and Tecnis groups and 0.4 in the AR40e group (Table 2); there was no statistically significant difference between the groups ($P > 0.3$). The mean preoperative refractive error is given in Table 2. The mean preoperative spherical equivalent was +0.17, +0.17 and -0.56 in the SN60AT, AR40e and Tecnis groups respectively. Preoperative refractive error did not differ significantly between the groups ($P > 0.25$).

Postoperatively, the eyes in the SN60AT, AR40e and Tecnis groups achieved BSCVA of 0.99, 0.97 and 1.00 respectively (Table 3). The difference in BSCVA between the three study groups was statistically not significant ($P > 0.35$). Also there were no statistically significant differences in postoperative refractive error between the groups ($P > 0.3$) (Table 3). The mean postoperative spherical equivalent was -0.15, -0.21 and -0.18 in the SN60AT, AR40e and Tecnis groups respectively (Table 3). The mean postoperative mesopic pupil size was 4.21, 4.35 and 4.34 mm (mesopic low) and 3.40, 3.46 and 3.46 (mesopic high) in the SN60AT, AR40e and Tecnis groups respectively. No statistically significant differences in mesopic low or mesopic high pupil diameters existed between the 3 groups ($P > 0.4$).

Postoperative contrast sensitivity testing revealed significant differences between the groups (Table 4, Figs. 1-4). Comparison of the Tecnis and the AR40e IOL showed statistically significant differences in photopic lighting conditions at 2 spatial frequencies: 3 and 12 cpd. When glare was added under photopic conditions, differences in contrast sensitivity at 18 cpd became statistically significant as well. Mesopic

Table 2. *Age distribution, mean preoperative refractive error and BSCVA*.*

	SN60AT	AR40e	Tecnis
n**	32	33	33
BSCVA*	0.38 ± 0.16	0.40 ± 0.11	0.38 ± 0.10
Mean age ± SD	71.8 ± 7.0	74.7 ± 5.7	74.9 ± 5.2
Mean refractive error			
Mean sphere ± SD	+0.37 ± 2.43	+0.39 ± 2.33	– 0.31 ± 2.77
Mean cylinder ± SD	– 0.40 ± 0.51	– 0.44 ± 0.50	– 0.51 ± 0.51
Mean SE⁂ ± SD	+0.17 ± 2.49	+0.17 ± 2.35	– 0.56 ± 2.78

* BSCVA: best spectacle corrected visual acuity
** n: number of eyes
⁂ SE: spherical equivalent

Table 3. *Mean postoperative refractive error and BSCVA*.*

	SN60AT	AR40e	Tecnis
BSCVA*	0.99 ± 0.13	0.97 ± 0.12	1.00 ± 0.13
Mean refractive error			
Mean sphere ± SD	+0.05 ± 0.99	+0.04 ± 0.94	+0.08 ± 0.91
Mean cylinder ± SD	– 0.41 ± 0.36	– 0.49 ± 0.47	– 0.51 ± 0.46
Mean SE** ± SD	– 0.15 ± 1.02	– 0.21 ± 0.96	– 0.18 ± 0.86

* BSCVA: best spectacle corrected visual acuity
** SE: spherical equivalent

Table 4. *Mean postoperative contrast sensitivity at each spatial frequency for each IOL group under photopic and mesopic conditions, with and without glare.*

Spatial Frequency (cpd)	SN60AT	AR40e	Tecnis
	Photopic contrast sensitivity (without glare)		
1.5	51.8*	53.5	59.6
3	82.5**	87.6*	98.1
6	82.5*	93.1	95.3
12	37.5⁂	42.3*	50.1
18	13.8⁂	18.6	22.4
	Mesopic contrast sensitivity (without glare)		
1.5	48.2*	49.2*	56.3
3	63.0**	69.1	74.9
6	48.4**	57.6	63.1
12	17.0⁂	20.2**	25.3
18	4.1⁂	5.4**	8.0
	Photopic contrast sensitivity (with glare)		
1.5	50.7*	53.6	57.8
3	73.7⁂	79.6*	91.2
6	77.4*	86.6	89.3
12	34.0⁂	39.5*	48.3
18	13.0⁂	16.0**	23.3
	Mesopic contrast sensitivity (with glare)		
1.5	50.3	50.7	53.5
3	62.2**	67.0	74.8
6	49.0**	55.1	61.8
12	16.8⁂	18.5**	23.5
18	4.3⁂	5.5⁂	8.5*

*$P < 0.05$
**$P < 0.01$
⁂$P < 0.001$
(P values after comparison of SN60AT versus Tecnis, and AR40e versus Tecnis, using 2-sided t-test)

contrast sensitivity values reached statistically significant difference at 1 additional spatial frequency when compared to photopic measurements: at 1.5, 12 and 18 cpd. Addition of glare in mesopic circumstances only revealed significant difference at 12 and 18 cpd, but the difference at 18 cpd was more significant ($P < 0.001$ versus $P < 0.01$ in photopic with glare).

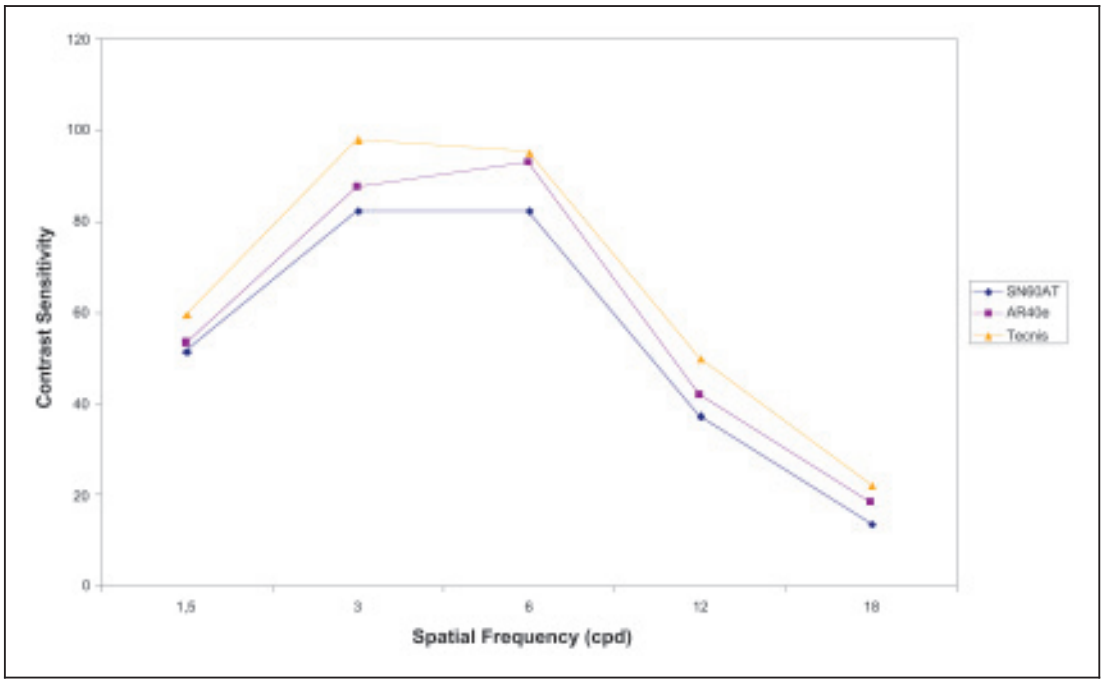

Fig 1. Photopic contrast sensitivity (without glare)

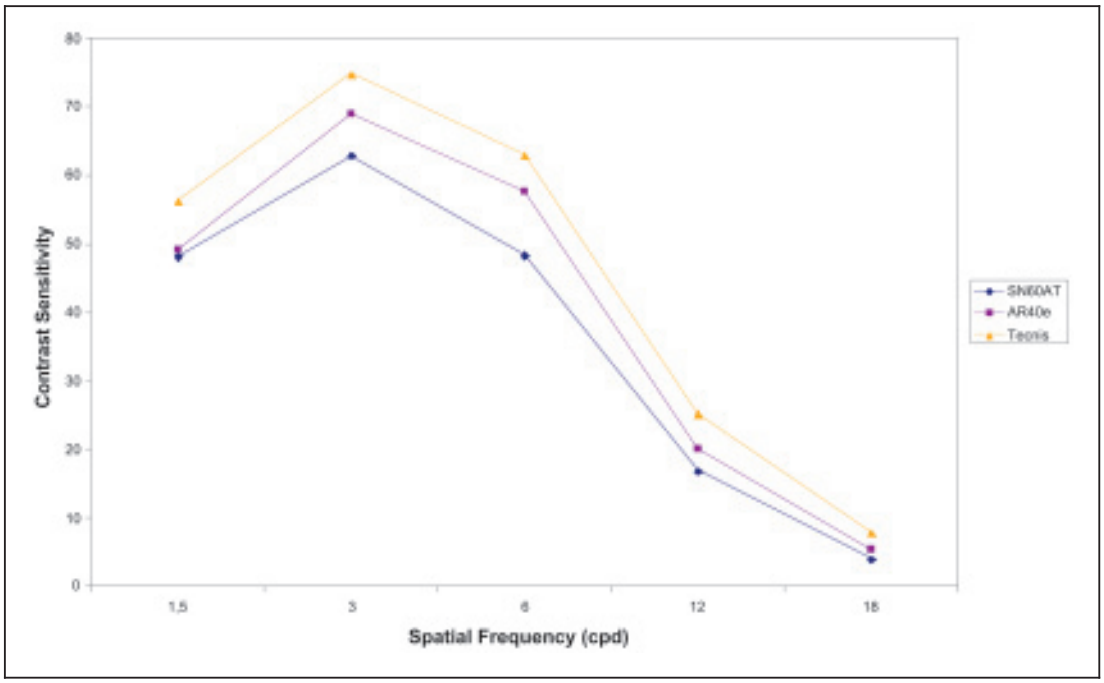

Fig 2. Mesopic contrast sensitivity (without glare)

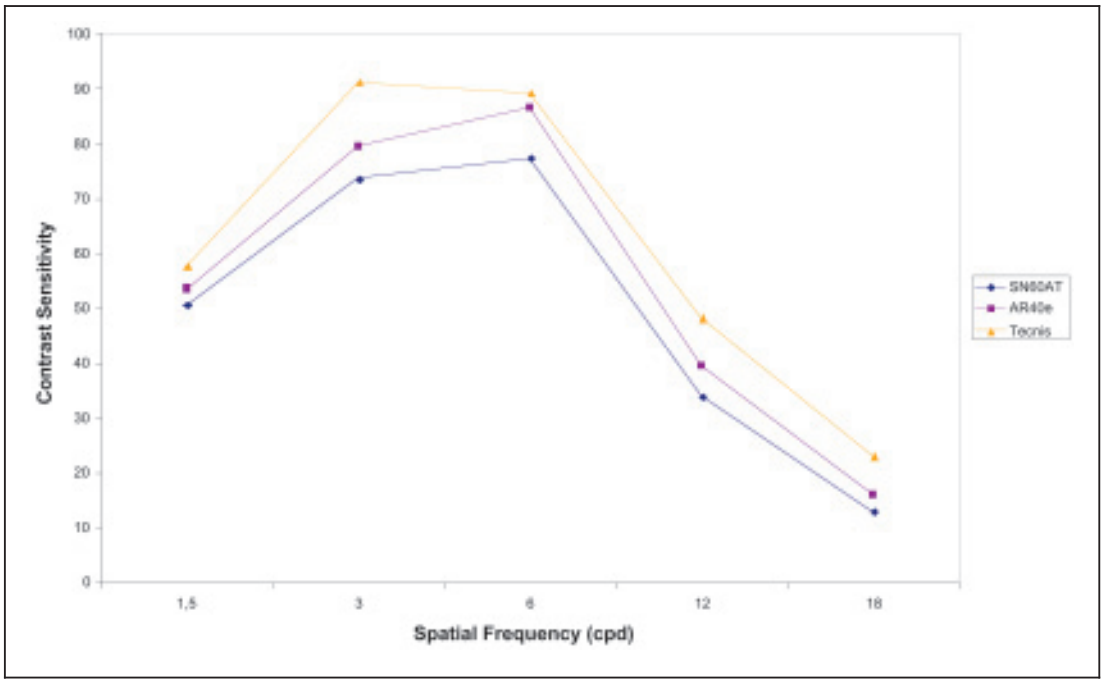

Fig 3. Photopic contrast sensitivity (with glare)

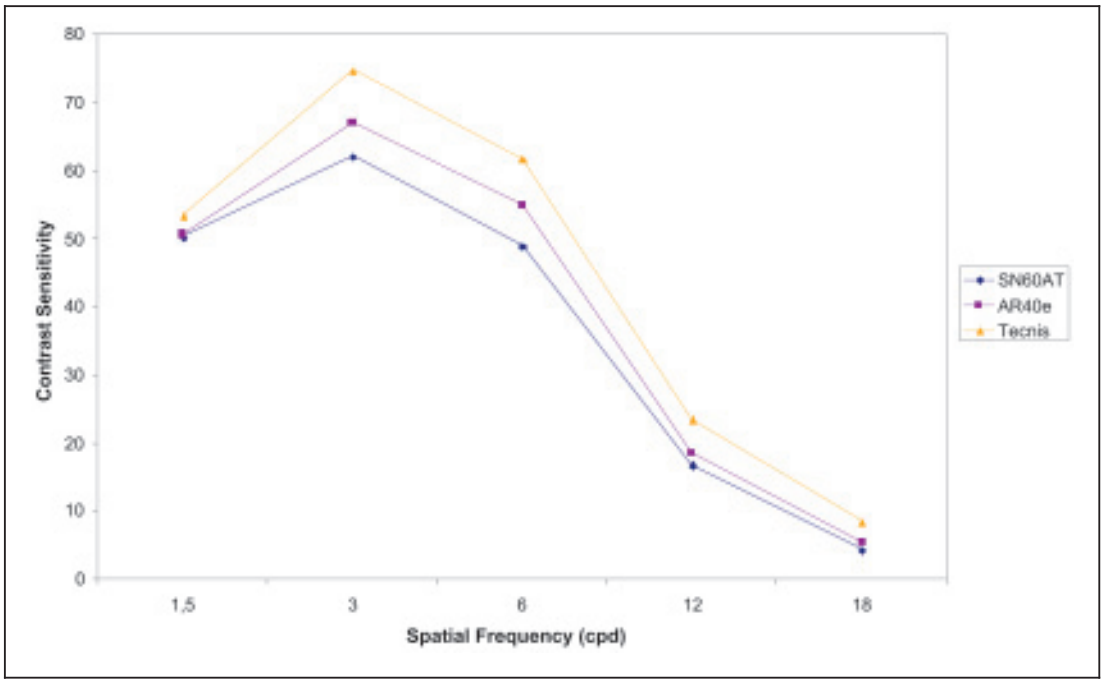

Fig 4. Mesopic contrast sensitivity (with glare)

When we compared the Tecnis and the SN60AT, we found statistically significant differences at almost all spatial frequencies in any lighting condition. Only at 1.5 cpd in mesopic lighting with glare there was no statistically significant difference.

Differences in contrast sensitivity did not reach statistical significance when comparing the SN60AT with the AR40e IOL, except in two circumstances. The AR40e IOL performed better than the SN60AT at 6 cpd in mesopic lighting conditions ($P < 0.05$) and at 18 cpd in photopic lighting conditions ($P < 0.05$), both without glare. *P* values of the comparison of these 2 IOLs are not given in table 4 for the sake of clarity.

DISCUSSION

Postoperative contrast sensitivity testing revealed significant differences between the 3 study groups, indicating a better performance of the Tecnis IOL under both photopic and mesopic conditions at some spatial frequencies when comparing to the AR40e IOL and at almost all spatial frequencies in comparison with the SN60AT IOL. Differences in contrast sensitivity between the Tecnis and the 2 other IOLs were most pronounced at the highest spatial frequencies (lowest *P* values). No statistically significant differences between the 2 acrylic spherical IOLs were found in almost all testing circumstances.

Also in other studies, the Tecnis IOL has been shown to provide a better contrast sensitivity than other IOLs. Packer et al. (22, 23) found statistically significant differences in contrast sensitivity between the Tecnis and AR40e IOL. Kershner et al. (14) compared the Tecnis IOL with a conventional spherical silicone (AA4207VF, Staar®) and acrylic (AcrySof® SA60AT, Alcon) IOL. The Tecnis IOL provided a significant improvement in functional acuity contrast testing. Mester et al. (16) carried out an intraindividual randomized study comparing the Tecnis Z9000 lens with the SI-40 IOL (AMO). Contrast sensitivity was significantly better in the Tecnis eyes than in the SI-40 eyes.

To our knowledge, so far no studies about the contrast sensitivity in patients with an AcrySof Natural SN60AT IOL have been published. This lens has a yellow colour since a yellow chromophore is covalently bonded to provide filtration of blue light. Niwa et al. (18) compared an ultraviolet-absorbing IOL and a noncyanopsia yellow-tinted IOL, which was designed to absorb light below a wavelength of 500 nm. The implanted yellow-tinted IOL showed improved contrast sensitivity in the middle spatial frequencies of 6 and 12 cpd in photopic and mesopic vision. However in our study, patients implanted with the yellow SN60AT had the lowest contrast sensitivity measurements of the 3 compared IOLs. Kershner et al. (14) found that the Tecnis performed better than the SA60AT, an IOL that does not differ in design from the SN60AT, except that it is not tinted.

Because we were especially interested in the clinical efficacy of the aspheric IOL, we only measured a subjective parameter (contrast sensitivity) and we did not carry out objective measurements of aberration.

Although we used interindividual comparisons instead of intraindividual comparisons, the 3 study groups are comparable. They are not significantly different in pre- and postoperative best spectacle corrected visual acuity, refractive error, age distribution and postoperative mesopic pupil size.

Loss of contrast sensitivity has an impact on several aspects of daily life and therefore deserves more attention. Contrast sensitivity impairment elevates the risk of crash involvement among older drivers (21) and there is a significant relationship between contrast sensitivity and highway sign discrimination distance (8). In a study by Ginsburg et al. (9), contrast sensitivity was found to be better than visual acuity for predicting a pilot's ability to detect a small air-to-ground target. Furthermore, contrast sensitivity is one of the predictors for self-reported difficulty with everyday visual tasks (24) and it is one of the strongest risk factors for falls in older people (15).

When patients who already suffer from contrast sensitivity loss caused by certain conditions (e.g. glaucoma and other optic neuropathies, macular and retinal diseases, cerebral disease) require cataract surgery, implantation of a spherical IOL may not be the first choice, since this cannot improve contrast sensitivity (1,5). On the other hand, implanting an IOL with an aspheric design reduces the spherical

aberration of the eye (13,16). Therefore at least there will be no additional factor of contrast sensitivity loss caused by the pseudophakia itself and visual impairment of these patients will be further reduced. Also, patients without other ocular pathology will be more satisfied after implantation with an aspheric IOL because they will gain a better contrast sensitivity, as shown by our study, and thus a better quality of vision.

CONCLUSION

The Tecnis IOL is a modified prolate intraocular lens designed to correct spherical aberration in the human eye. Implantation of this IOL improves quality of vision as confirmed by our clinical results of contrast sensitivity testing. In this study, we found a better performance of the Tecnis IOL under both photopic and mesopic conditions, compared to the results of the AR40e and the SN60AT IOL.

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