13 Multifocal Intraocular Lenses: AT LISA tri 839 MP

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13.1 Introduction

The great prevalence of presbyopia and the importance of near and intermediate vision in modern society have resulted in the development of techniques to compensate this refractive condition. Moreover, as has been reported, the loss of reading skills can reduce the quality of life of presbyopic patients [1–4].

The use of multifocal lenses can improve near and distance uncorrected visual acuity reducing the spectacle dependence [5]. For this purpose, many designs have been developed by manufacturers of intraocular lenses (IOLs). The main types of multifocal IOLs available are refractive, diffractive, refractive–diffractive, and accommodative.

Each model has its own advantages and disadvantages, but in mean terms, all of them can improve near and distance uncorrected vision. However, IOLs are still far from be perfect, and collateral effects such as halos, glare, and loss of contrast sensitivity [6–9] have been reported after their implantation. Moreover, the results achieved in intermediate distance vision are not satisfactory in a great number of cases. Therefore, the improvement in intermediate vision is nowadays one of the most important challenges in this field. In this sense, the achievement of an intermediate focus in IOLs could be interesting to solve this problem.

As will be seen along the chapter, the AT LISA tri is one of existing trifocal IOLs [10–13], and what is more important, it has shown unbeatable results in improving near, intermediate, and distance visual acuity in presbyopic patients [14, 15].

13.2 Intraocular Lens

This lens is the first premium preloaded intraocular lens with 6.0 mm biconvex optic and overall length of 11.0 mm. It is made of foldable hydrophilic acrylate with a water content of 25%, hydrophobic surface properties and a refractive index of 1.46. It smooths diffractive structure covering the entire anterior optical surface. Aspheric optic corrects spherical aberration of typical cornea, and the asphericity of this lens is –0.18 um. It has a four-haptic design with an angulation of 0° and a new 360-degree square edge to prevent posterior capsule opacification. The

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lens is available from spherical power of 0.0 D to +32.0 D in 0.5 increments and is implanted with a single-use injector BLUEMIXS 180 through an incision less than 1.8 mm. The company labeled A-constant for this lens is 118.6.

The AT LISA tri is trifocal within a lens diameter of 4.3 mm, and between 4.3 and 6 mm diameter it is bifocal. The add powers within the 4.3 mm diameter are 1.66 to intermediate and 3.33 diopters to near distance. In Fig. 13.8, the add power between the 4.3 and 6 mm diameter is 3.75 diopters (equal to the AT LISA) (Fig. 13.1). For large pupils (e.g., 6 mm), the adds of 3.33 diopters and 3.75 diopters, respectively, blend to result in a depth of focus in the near power. The relative intensity distribution is practically constant up to a diameter of 4.3 mm, with 50% relative intensity for distance, 30% for near, and 20% for intermediate. For pupils larger than 4.3 mm, the distance intensity increases, and the intermediate intensity decreases, while the near intensity remains constant (Fig. 13.2). Total usable light intensity is 87%, an amount which compares favorably with bifocal diffractive lenses with equal light distribution between distance and near, where it is 81% (Fig. 13.3).

The trifocality is achieved exclusively by a modification of the main and the phase zones of the AT LISA. Unlike AT LISA, AT LISA tri consists of different phase zones in even and uneven zones (Fig. 13.4). Thus, the AT LISA tri does not require any additional lens zones. This modification is the result of advanced analysis of diffractive lenses. With fewer rings on the optical surface (29 diffractive steps for 0.0 D and 21 steps for +32.0 D IOLs), the AT LISA tri reduces the risk of visual disturbances.

The AT LISA tri allows distance, intermediate, and near vision in practical independence of pupil size. The images produced by the lens are in high resolution at every distance in all light conditions (Figs. 13.5 and 13.6).

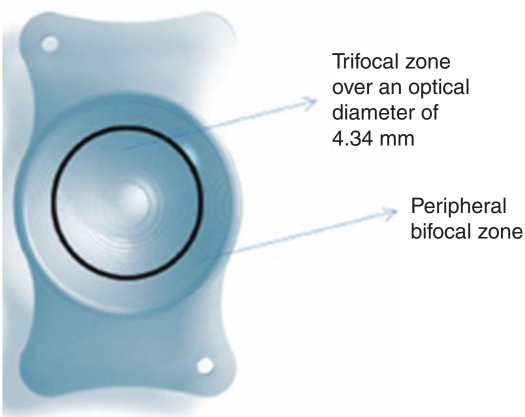

Fig. 13.1 Optics of AT LISA tri consists of two parts, central, 4.34 mm trifocal zone and peripheral bifocal (like AT LISA)

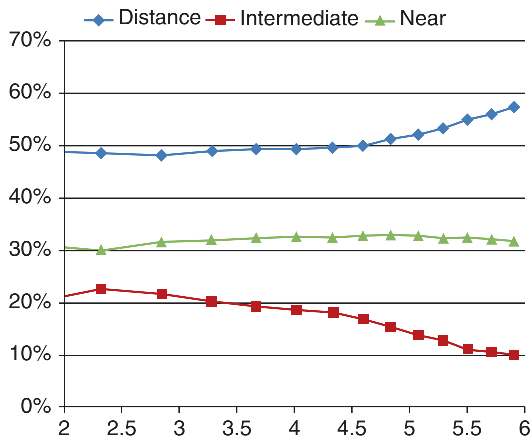

Fig. 13.2 Relative light distribution of the AT LISA tri for far, intermediate, and near focus and sum of light intensities as absolute value in %

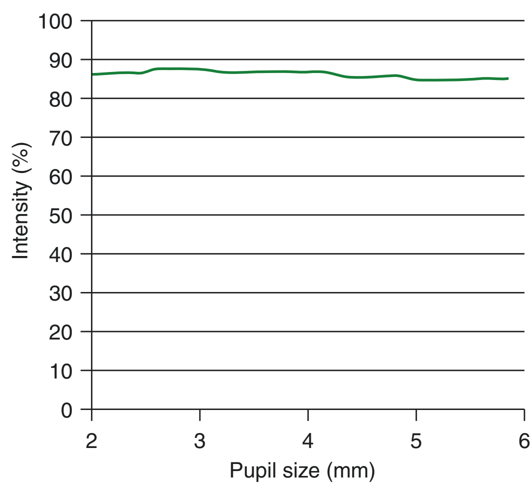

Fig. 13.3 Global light transmittance is close to 90%

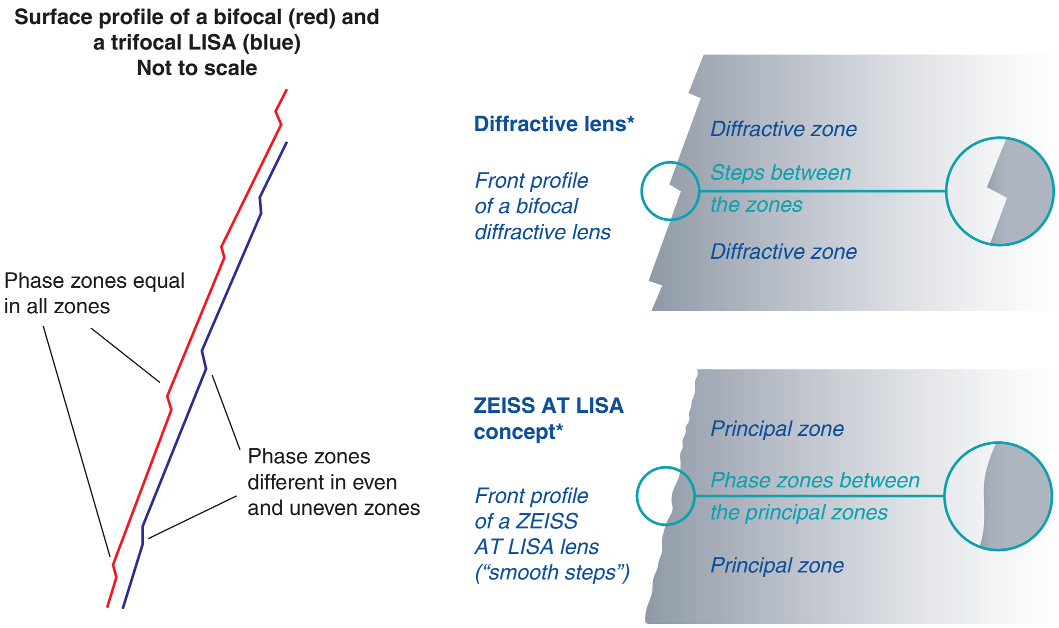

Fig. 13.4 Comparison of diffractive pattern of the bifocal and trifocal AT LISA

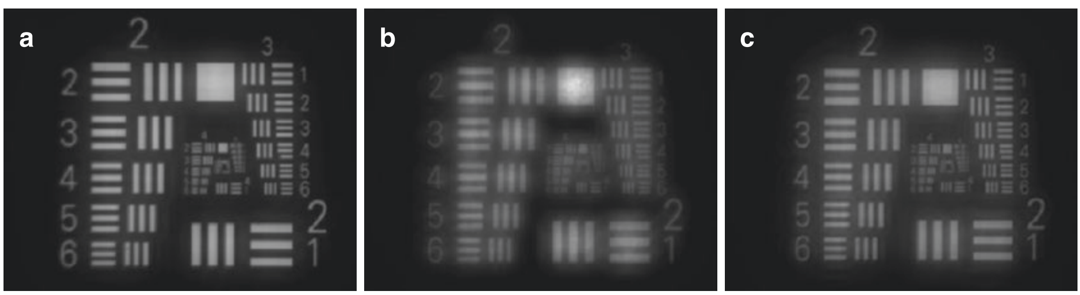

Fig. 13.5 US Air Force Resolution Target Test (AFT). AT LISA tri at far (**a**), intermediate (**b**), and near (**c**) vision under photopic condition

13.3 Preoperative and Postoperative Examination

The study enrolled 120 eyes of 60 patients included were patients with cataract or presbyopic or pre-presbyopic eyes suitable for refractive lens exchange who were seeking spectacle independence and had preexisting corneal astigmatism of less than 1.25 diopters (D). Exclusion criteria were a history of glaucoma or retinal detachment, corneal disease, irregular corneal astigmatism, abnormal iris, macular degeneration or retinopathy, neuro-ophthalmic disease, ocular inflammation, or ocular surgery. Before surgery, a complete ophthalmologic examination was performed including manifest refraction, keratometry, measurement of monocular uncorrected (UDVA) and corrected (CDVA) distance visual acuity using the Early Treatment Diabetic Retinopathy Study (ETDRS) charts, measurement of monocular uncorrected (UIVA) and corrected (CIVA) intermediate visual acuity at 66 cm (modified ETDRS for European-wide use for near and intermediate distance recordings, Precision Vision) and 80 cm (Logarithmic

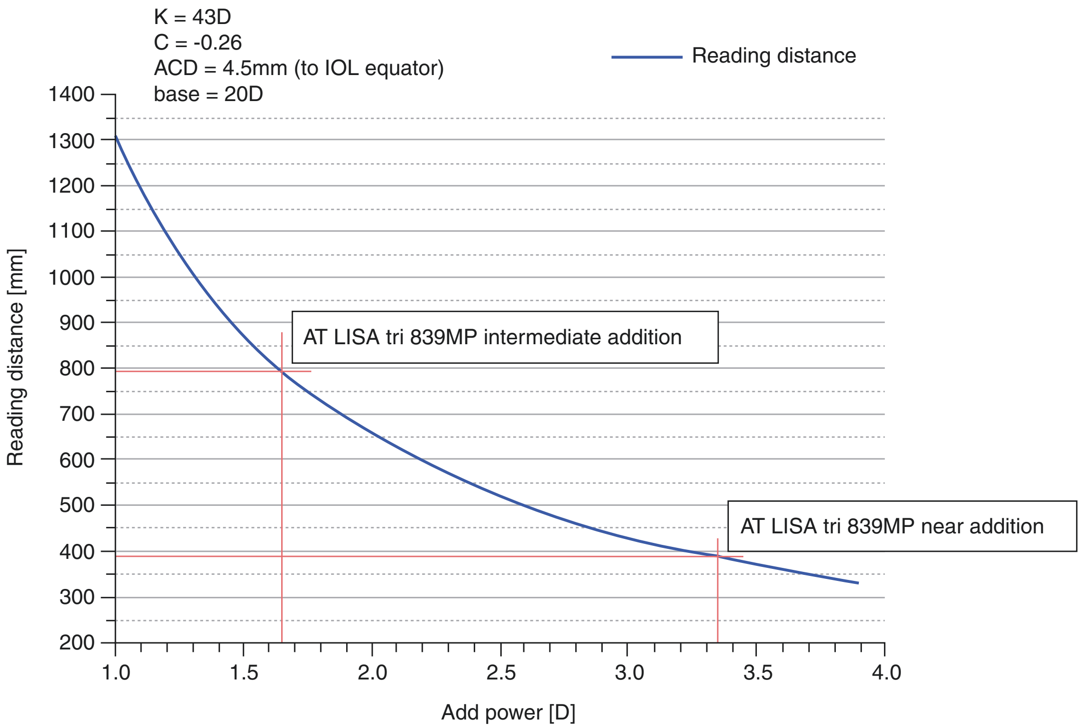

Fig. 13.6 Average reading distance for intermediate and near vision based on optical ray trace calculation for the average eye. Relationship between reading distance and additions

Visual Acuity Charts, calibrated for testing at 80 cm, Precision Vision), measurement of monocular uncorrected (UNVA) and corrected (CNVA) near visual acuity at 33 cm (modified ETDRS for European-wide use for near and intermediate distance recordings, Precision Vision) and 40 cm (Logarithmic Visual Acuity Chart, ETDRS 2000, calibrated for testing at 40 cm, Precision Vision), measurement of monocular distance-corrected near (DCNVA) (33 and 40 cm) and intermediate (DCIVA) visual acuity (66 and 80 cm), Goldmann applanation tonometry, slitlamp examination, ocular aberrometry, and corneal topography (both OPD Scan III, Nidek Co., Ltd.), biometry (IOLMaster version 4.3, Carl Zeiss Meditec AG), and fundoscopy. The analysis of optical aberrations was performed under pupil dilation and considering a pupil aperture of analysis of 5.0 mm. The following parameters were calculated and recorded for the corneal, internal, and ocular optics: coma Z(3,−1) and Z(3,1), higher-order aberrations (HOAs) root mean square (RMS), and the Zernike coefficient for spherical aberration Z(4,0). Postoperatively, patients were evaluated at 1 day and 1, 3, 6, and 12 months. The postoperative examination protocol was identical to the preoperative protocol, but with these additional tests at the 12-month visit: evaluation of the defocus curve to evaluate the range of functional function, contrast sensitivity measurement under photopic (85 candelas [cd]/m^2) and mesopic conditions (3 cd/m2) (CSV-1000, VectorVision), and evaluation of the level of posterior capsule opacification (PCO) in the central 4.3 mm zone (Evaluation of Posterior Capsule Opacification [EPCO] 2000 software). For the evaluation of the defocus curve, patients wore the correction providing the distance visual acuity in both eyes and the ETDRS charts were used at a distance of 4 m. Different levels of defocus were introduced in 0.5 D steps from +1.00 D to −4.00 D, and visual acuity values were recorded. All these data were then represented in a Cartesian graphic display, with the x-axis showing the levels of defocus and the y-axis the visual acuity achieved [15].

13.4 Surgical Technique

All incisions were made at the temporal area, using a standard technique of sutureless 1.6 mm microincision phacoemulsification. Topical anesthesia and mydriatic drops were instilled in all cases before the surgical procedure. After capsulorhexis creation and phacoemulsification, the IOLs were inserted into the capsular bag using the Bluemixs 180 injector (Carl Zeiss Meditec AG) through the main incision.

13.5 Visual Acuity and Refraction

Table 13.1 shows the visual outcomes during the follow-up. At 12 months, there was statistically significant improvement in UDVA, UNVA at 33 cm and 40 cm, UIVA at 66 and 80 cm, DCNVA at 33 cm and 40 cm, and DCIVA at 66 cm and 80 cm ($p < 0.001$). In contrast, no statistically significant changes were observed at 12 months in CDVA, CNVA, and CIVA ($p \geq 0.087$). One

Table 13.1 Preoperative and postoperative monocular visual acuities

Acuity (LogMAR)	Preoperative	1 month	3 months	6 months	12 months	P value[a]
UDVA						<0.001
Mean +/SD Median (range)	0.55 +/ 0.42 0.40 (0.00, 2.00)	−0.01 +/ 0.09 0.00 (−0.20, 0.20)	−0.02 +/ 0.10 0.00 (−0.20, 0.30)	−0.02 +/ 0.09 0.00 (−0.20, 0.20)	0.03 +/ 0.13 0.00 (−0.20, 0.50)	
CDVA						0.104
Mean +/SD Median (range)	0.02 +/ 0.25 0.00 (−0.30, 2.00)	−0.03 +/ 0.08 0.00 (−0.20, 0.20)	−0.03 +/ 0.09 0.00 (−0.20, 0.20)	−0.03 +/ 0.08 0.00 (−0.20, 0.20)	0.01 +/ 0.11 0.02 0.00 (−0.20, 0.50)	
UNVA, 33 cm						<0.001
Mean +/SD Median (range)	0.86 +/ 0.26 0.90 (0.10, 1.40)	0.17 +/ 0.12 0.20 (−0.10, 0.50)	0.16 +/ 0.12 0.10 (−0.10, 0.50)	0.18 +/ 0.12 0.20 (−0.10, 0.50)	0.23 +/ 0.15 0.20 (0.00, 0.70)	
CNVA, 33 cm						0.872
Mean +/SD Median (range)	0.13 +/ 0.17 0.10 (−0.20, 0.90)	0.15 +/ 0.11 0.10 (0.00, 0.50)	0.11 +/ 0.09 0.10 (−0.10, 0.30)	0.11 +/ 0.09 0.10 (−0.10, 0.40)	0.12 +/ 0.09 0.10 (0.00, 0.40)	
DCNVA, 33 cm						<0.001
Mean +/SD Median (range)	0.63 +/ 0.20 0.60 (0.10, 1.00)	0.17 +/ 0.11 0.20 (0.00, 0.50)	0.15 +/ 0.11 0.10 (−0.10, 0.40)	0.16 +/1 0.11 0.20 (−0.10, 0.40)	0.21 +/ 0.14 0.20 (0.00, 0.70)	
UNVA, 40 cm						<0.001
Mean +/SD Median (range)	0.86 +/ 0.26 0.90 (0.10, 1.40)	0.22 +/ 0.11 0.20 (0.00, 0.60)	0.23 +/ 0.11 0.20 (0.00, 0.50)	0.22 +/ 0.10 0.20 (0.00, 0.50)	0.27 (0.15) 0.20 (0.00, 0.70)	
CNVA, 40 cm						0.087
Mean +/SD Median (range)	0.14 +/1 0.18 0.10 (−0.20, 1.00)	0.18 +/– 0.10 0.20 (0.00, 0.40)	0.18 +/ 0.10 0.20 (0.00, 0.40)	0.16 +/ 0.09 0.20 (0.00, 0.30)	0.16 +/ 0.09 0.10 (0.00, 0.50)	
DCNVA, 40 cm						<0.001
Mean +/SD Median (range)	0.63 +/ 0.20 0.60 (0.10, 1.20)	0.22 +/ 0.12 0.20 (0.00, 0.60)	0.23 +/ 0.12 0.20 (0.00, 0.50)	0.22 +/ 0.10 0.20 (0.00, 0.50)	0.25 +/ 0.14 0.20 (0.00, 0.70)	

(continued)

Table 13.1 (continued)

Acuity (LogMAR)	Preoperative	1 month	3 months	6 months	12 months	*P* value[a]
UIVA, 66 cm						<0.001
Mean +/SD Median (range)	0.73 +/ 0.28 0.70 (0.10, 1.40)	0.08 +/ 0.10 0.10 (−0.10, 0.40)	0.09 +/ 0.09 0.10 (−0.10, 0.40)	0.08 +/ 0.09 0.10 (−0.10, 0.40)	0.12 +/ 0.13 0.10 (−0.10, 0.50)	
CIVA, 66 cm						0.209
Mean +/SD Median (range)	0.07 +/ 0.20 0.00 (−0.20, 0.80)	0.07 +/ 0.10 0.10 (−0.10, 0.40)	0.07 +/ 0.09 0.10 (−0.10, 0.30)	0.06 +/ 0.09 0.05 (−0.10, 0.40)	0.08 +/ 0.09 0.10 (−0.10, 0.30)	
DCIVA, 66 cm						<0.001
Mean +/SD Median (range)	0.36 +/ 0.25 0.30 (−0.10, 1.10)	0.08 +/ 0.10 0.10 (−0.10, 0.40)	0.09 +/ 0.09 0.10 (−0.10 0.40)	0.08 +/ 0.10 0.10 (−0.10, 0.40)	0.11 +/ 0.12 0.10 (−0.10, 0.50)	
UIVA, 80 cm						<0.001
Mean +/SD Median (range)	0.71 +/ 0.27 0.70 (0.10, 1.40)	0.07 +/ 0.09 0.10 (−0.10, 0.30)	0.07 +/ 0.09 0.10 (−0.20, 0.30)	0.07 +/ 0.08 0.10 (−0.20, 0.30)	0.11 +/ 0.13 0.10 (−0.10, 0.40)	
CIVA, 80 cm						0.819
Mean +/SD Median (range)	0.08 +/ 0.19 0.00 (−0.20, 0.80)	0.05 +/ 0.10 0.00 (−0.10, 0.30)	0.06 +/ 0.09 0.10 (−0.20, 0.30)	0.05 +/ 0.08 0.00 (−0.20, 0.30)	0.07 +/ 0.10 0.10 (−0.10, 0.40)	
DCIVA, 80 cm						<0.001
Mean +/SD Median (range)	0.33 +/ 0.26 0.30 (−0.10, 1.10)	0.07 +/ 0.09 0.10 (−0.10, 0.30)	0.07 +/0.09 0.10 (−0.20, 0.30)	0.07 +/ 0.08 0.10 (−0.20, 0.30)	0.11 +/ 0.13 0.10 (−0.10, 0.50)	

CDVA corrected distance visual acuity, *CNVA* corrected near visual acuity, *DCIVA* distance-corrected intermediate visual acuity, *DCNVA* distance-corrected near visual acuity, *UDVA* uncorrected distance visual acuity, *UIVA* uncorrected intermediate visual acuity, *UNVA* uncorrected near visual acuity

[a]Preoperative to 12 months

month postoperatively, an improvement was observed in all visual parameters ($p \leq 0.03$) except CNVA at 33 cm ($p = 0.05$) and CIVA at 66 cm ($p = 0.24$) and 80 cm ($p = 0.25$). From 1 to 12 months postoperatively, small but statistically significant changes were observed in UDVA ($p < 0.001$), CDVA ($p < 0.001$), UNVA at 33 cm ($p = 0.03$) and 40 cm ($p < 0.001$), CNVA at 33 cm ($p = 0.03$), DCNVA at 33 cm ($p = 0.001$), UIVA at 66 cm ($p = 0.01$) and 80 cm ($p = 0.001$), and DCIVA at 66 cm ($p = 0.04$). In contrast, changes during this period in CNVA at 40 cm ($p = 0.05$), DCNVA at 40 cm ($p = 0.05$), CIVA at 66 ($p = 0.90$) and 80 cm ($p = 0.09$), and DCIVA at 80 cm ($p = 0.12$) were not statistically significant. At 12 months, the UNVA, CNVA, and DCNVA were statistically significantly better at 33 cm than at 40 cm (all $p < 0.001$). However, no statistically significant differences were found among UIVA ($p = 0.23$), CIVA ($p = 0.14$), and DCIVA ($p = 0.34$) at 66 cm and 80 cm. During the 12-month follow-up, minimal but statistically significant changes in the visual outcomes were observed. Specifically, a worsening of half of a line of logMAR visual acuity or less was observed from 1 to 12 months postoperatively in the UDVA, CDVA, and UNVA measured at 33 cm and 40 cm, DCNVA at 33 cm, UIVA at 66 cm and 80 cm, and DCIVA at 66 cm. This visual worsening was consistent with a small but also statistically significant increase in the level of ocular and internal HOAs, without specific changes in the level of primary coma. One potential explanation for this visual worsening might be the development of some degree of PCO deteriorating the level of visual acuity and quality provided by the trifocal IOL.

The predictability of the refractive correction was excellent, with a mean postoperative spherical equivalent (SE) of 0.30 ± 0.42 D at

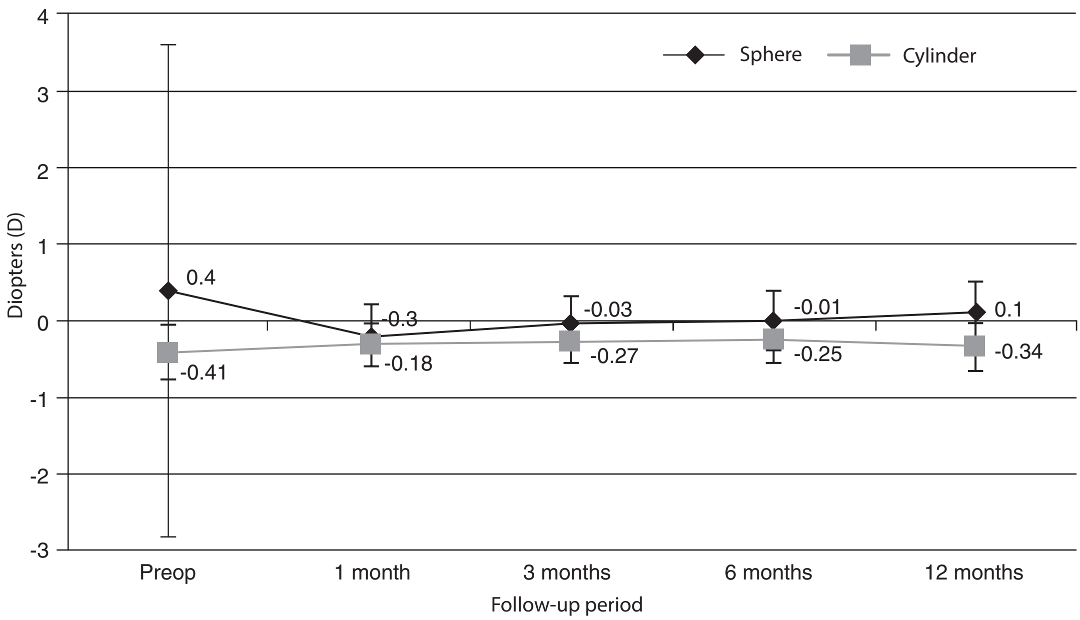

Fig. 13.7 Changes in manifest sphere and cylinder at the 12-month follow-up

1 month and 0.08 ± 0.39 D at 12 months and with 90.8% of eyes having an SE within ±0.50 D at 12 months. This confirms the refractive precision of the correction achieved with the evaluated IOL, suggesting that the constant defined for the power calculations with this IOL was appropriate. Figure 13.7 shows the evolution of the manifest sphere and cylinder during the follow-up. Changes in manifest sphere ($p = 0.001$) and cylinder ($p = 0.003$) were statistically significant at 1 month. From 1 to 12 months, statistically significant changes were observed in sphere ($p < 0.001$) but not in manifest cylinder ($p = 0.093$).

13.6 Defocus Curve

Defocus curve provides an objective measurement of expected vision at different distances; in simple words, it shows how the lens works in reality. As can be seen from Fig. 13.8 for high values of the defocus (positive or negative), the visual acuity decreases as expected if the patients are properly refracted. This fact is compatible with the results found in the refractive analysis, with 100% of the patients within the interval + 1.00 to −1.00 D. The defocus interval between 0.00 and − 3.00 D corresponds to distances from infinite to 33.33 cm. This is the most interesting zone of the defocus curve to evaluate the IOL efficacy for different tasks depending on the distance. Figure 13.8 shows a display of the mean defocus curve obtained binocularly at the end of the follow-up. No statistically significant differences were found between the visual acuities obtained for defocus levels of 1.0 D and 2.0 D ($p = 0.22$); however, the visual acuity for the defocus of 1.5 D was statistically significantly better than that corresponding to a level of defocus of 3.0 D ($p < 0.001$). Our defocus curve showed a maximum of visual acuity for zero defocus (distance vision), with a slight drop afterward but maintaining a functional range of visual acuity with values of 0.1 logMAR or better, for defocus levels between 0 D and 2.5 D. Therefore, effective restoration of the distance, intermediate, and near visual function was with the evaluated IOL. This functional visual restoration was accompanied by the achievement of a good contrast sensitivity outcome and a reduction in the level of ocular spherical aberration, reaching values of almost

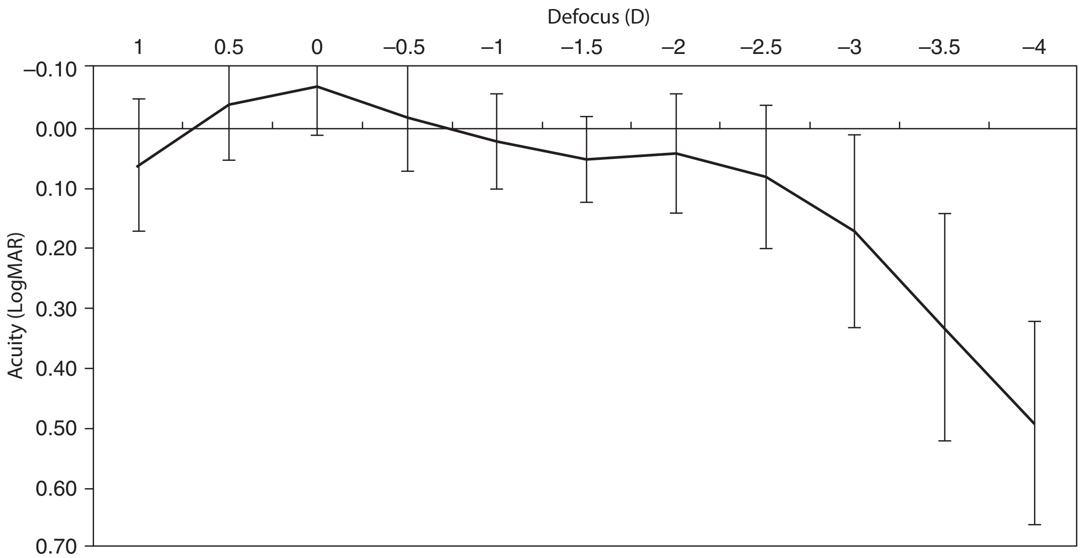

Fig. 13.8 Mean defocus curve 12 months postoperatively

zero in almost all patients, as in a previous series evaluating the same type of trifocal IOL [14, 15].

13.7 IOL Centration and Angle Kappa

Proper centration of MIOL is crucial point to achieve perfect visual performance. Cataract surgeons usually center the lens in the middle of dilated pupil. Some surgeons recommend intraoperative instillation of miochol to induce miosis. This is simple and effective method in patient with small angle kappa, where the visual axis is very close or identical with pupillary axis. Angle kappa describes the distance between pupillary axis (center of pupil) and visual axis. However, centration on pupil center in patient with large angle kappa could lead to postoperative dissatisfaction. In this case, primary path of light passes through multifocal rings instead of pupillary center inducing coma and glare. Unfortunately, the surgeon is not able to influence angle kappa. In preoperative measurement, the angle kappa should be identified. In our previous study of 30 patients, 60 eyes, we measured the mean angle kappa in myopes (10 eyes) of 0.2 ± 0.10 under photopic condition and 0.21 ± 0.10 under mesopic condition, in emmetropes (6 eyes) 0.34 ± 0.12 and 0.37 ± 0.13, and hypermetropes (42 eyes) 0.43 ± 0.18 and 0.41 ± 0.15, respectively. In all cases, AT LISA tri were implanted. One of very nice things about this lens is central optical zone of 1.04 mm and it could be implanted even in patient with large angle kappa (Fig. 13.9). It is hypothesized that central optical zone should be half diameter greater than angle kappa. In addition, AT LISA tri is independent of pupil size resulting in very high postoperative satisfaction under mesopic condition and reducing visual phenomena.

The best location for MIOL centration is first Purkinje image. This point is very close to visual axis. Intraoperatively, coaxial light of microscopes is helpful in identifying the correct position (first Purkinje image) for lens centration.

13.8 Posterior Capsule Opacification (PCO)

One of the main drawbacks of MIOLs is higher rate of YAG laser capsulotomy comparing with monofocal lenses. It has been shown that even

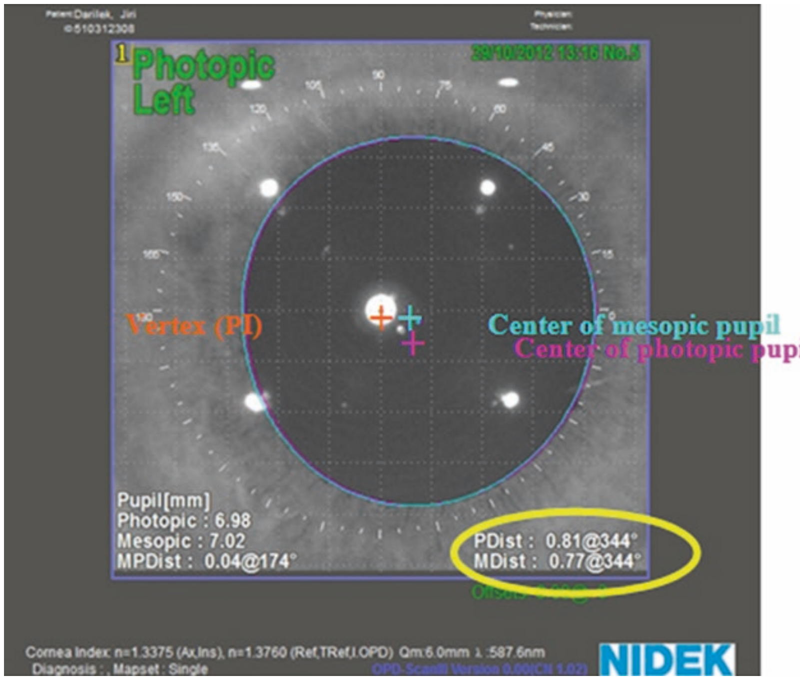

Fig. 13.9 Preoperative measurement of patients with high angle kappa with AT LISA tri

low grade of PCO impairs significantly visual acuity. Trifocal lens splits incoming light among three focuses, far, intermediate, and near. It delicate optic is very sensitive to any capsular changes, especially in the central 4.34 trifocal zone, leading to deterioration of visual performance as well as to enhancement of disturbing visual phenomena such as halos and glare. PCO is caused by epithelial cells proliferation and migration to the posterior capsule. It is classified into two forms: proliferative (Elschnig pearls) and non-proliferative (fibrosis). Proliferative PCO could be successfully treated using bimanual irrigation/aspiration cannulas. (Figs. 13.10 and 13.11). Studies have shown that acrylic material, polishing of anterior and posterior capsule, and square edge are associated with lower PCO rate. A new 360-degree square edge and hydrophobic surface of trifocal lens prevent early PCO formation.

Fibrosis of posterior capsule should be treated with YAG laser capsulotomy to create opening in the posterior capsule. Although it is very effective and safe procedure, complications such as vitreous opacities, cystoid macular oedema, or retinal detachment were reported. During the 12-month follow-up, in 120 eyes, neodymium:YAG (Nd:YAG) capsulotomy was required in four eyes (3.3%) because of the presence of significant levels of PCO. Likewise, 15 eyes (12.5%) had surgical aspiration of proliferative forms (Elschnig pearls). Therefore, significant PCO was found in 19 eyes (15.8%). The mean EPCO score 12 months postoperatively was 0.32 ± 0.44 (median 0.11; range from 0.00 to 2.11) (Fig. 13.12).

13.9 Contrast Sensitivity Curve

The benefit of trifocal lens is improvement of intermediate vision. However, one major problem of any multifocal lens is impaired contrast sensitivity. Figure 13.13 shows the mean postoperative contrast sensitivity function under photopic and mesopic conditions in the two groups. Photopic contrast sensitivity was statistically significantly better than that measured under mesopic conditions at all spatial frequencies evaluated ($P < 001$).

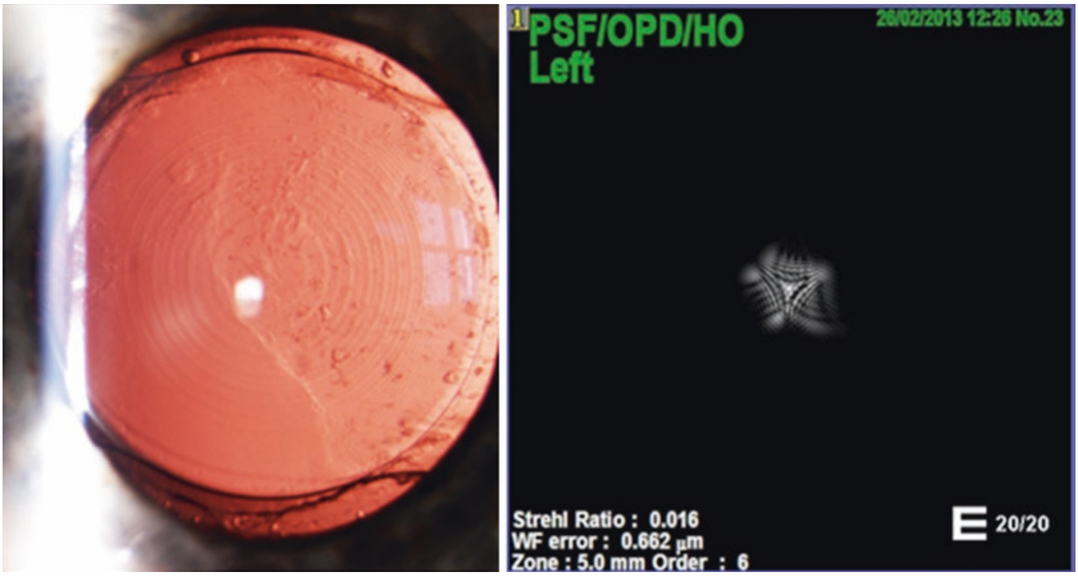

Fig. 13.10 Patients 14 months after AT LISA tri implantation. Left: Elschnig pearls in central zone, Right very low Strehl ratio in 5.0 mm pupil

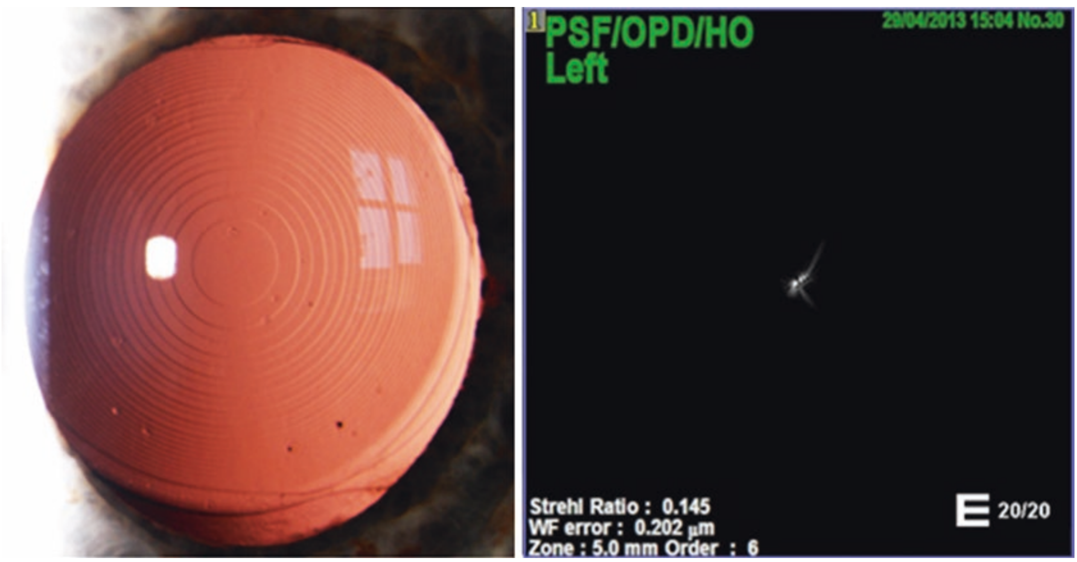

Fig. 13.11 The same patient after successful aspiration of Elschnig pearls (very clean posterior capsule) and significant improvement of Strehl ratio and visual acuity

13.10 Optical Quality

Aim of multifocal lens exchange is offering some degree of spectacle independence and to improve image quality. Emmetropic eye with the pupil less than 3 mm is aberrations free and providing high image quality. However, when the pupil size increases, optical aberrations increase resulting in loss of optical image quality. (Fig. 13.14). Modulation transfer function (MTF) is quantitative measurement of image quality. It measures loss of contrast sensitivity and image sharpness

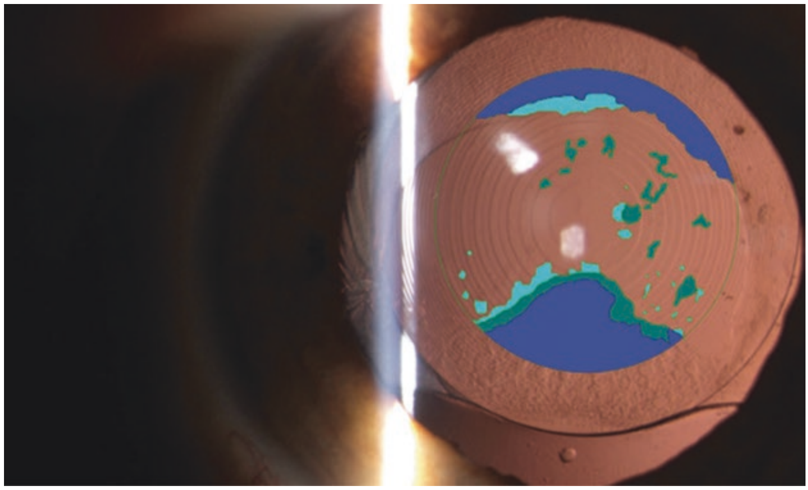

Fig. 13.12 EPCO 2000 evaluation report 12 months after surgery. Areas with low PCO density are marked with lighter color and areas with higher PCO density with darker color

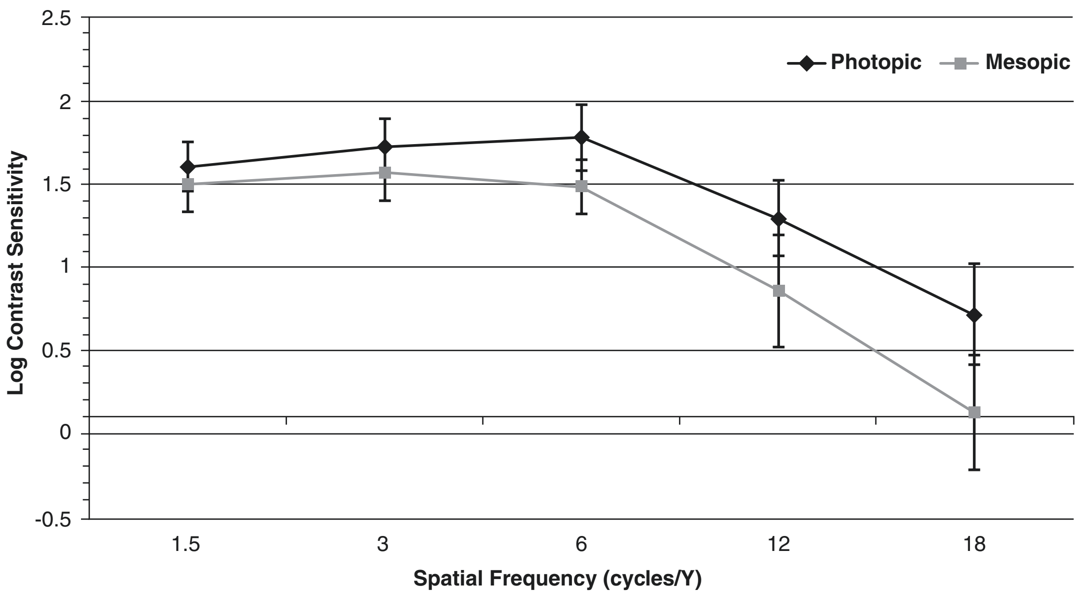

Fig. 13.13 Mean 12-month postoperative contrast sensitivity function measured under photopic and mesopic conditions

when light passes through the optical system. MTF is very sensitive to image degradation. Perfect optical system is defined as an ability of the eye to produce a point image on the retina while watching at the point object. Point spread function (PSF) should be a highly localized bright spot, and its mathematical expression is Strehl ratio. It should be as close as possible to 1 which represents the ideal or perfect optical system. Strehl ratio and MTF cutoff frequency were evaluated in pupil under cycloplegia with a minimum diameter of 5 mm. All measures correspond to a 5 mm pupil. There was a significant improvement in the Strehl ratio from 0.01 ± 0.01 preoperatively to 0.07 ± 0.03 6 months after the surgery, and an improvement in the cut-off frequency of the MTF ($p < 0.001$) from 25.61 ± 11.36 to 57.82 ± 12.00 cpd. However, photic phenomena such as halos and glare were mentioned by the patients as reported in previous studies of diffractive multifocal IOLs. Three patients (10%) complained of significant halos,

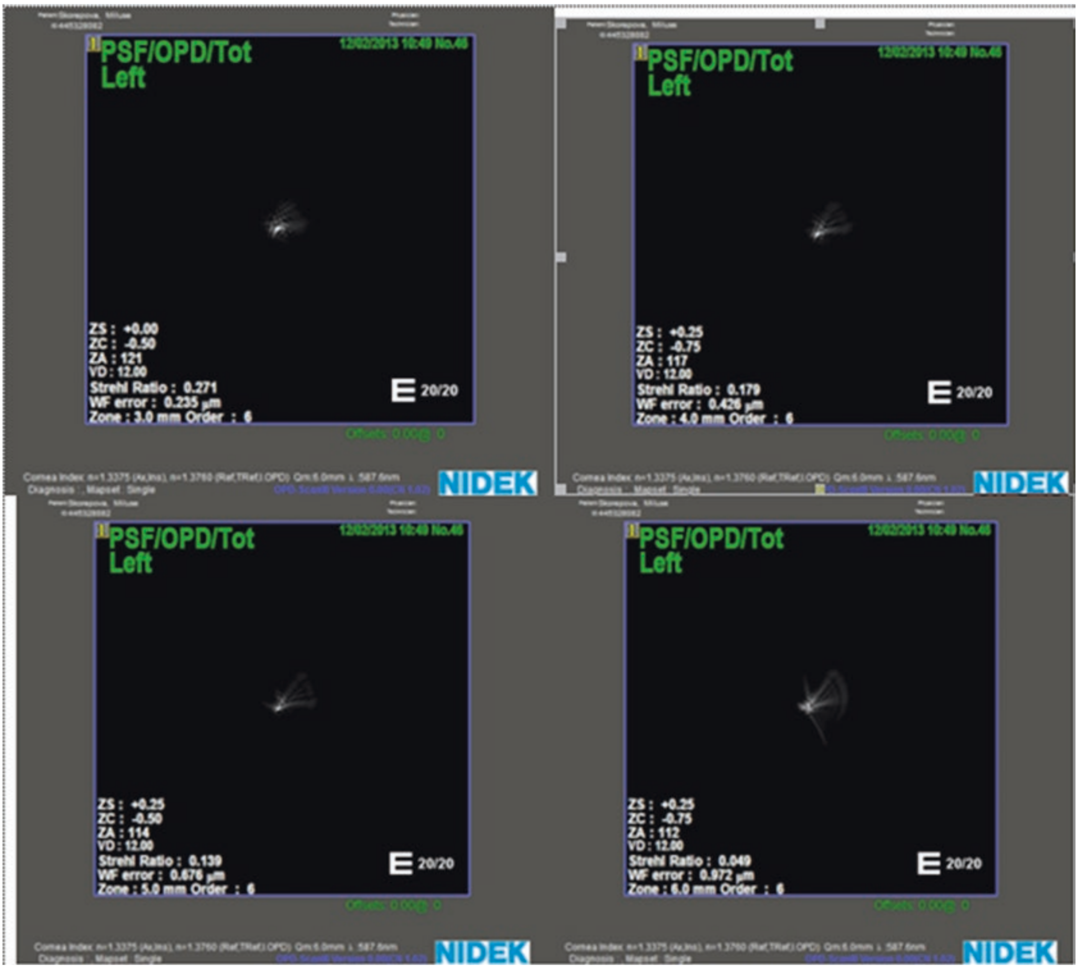

Fig. 13.14 Optical image quality in patient with AT LISA tri in 3, 4, 5, and 6 mm pupil

and three patients complained of glare. Three patients also referred color distortion (one of them occasionally) for greens but not disturbing and only temporary. During the follow-up period, the patients complaining of severe halos reported a significant improvement and overall satisfaction with the implantation.

13.11 Aberrometry

Figure 13.15 shows the preoperative, 6-month, and 12-month postoperative aberrometric data for internal and global ocular optics in the evaluated sample. No statistically significant changes were observed in ocular HOAs ($p = 0.967$) or coma RMS ($p = 0.871$) at 6 months; however, the RMS of the ocular HOAs increased significantly from 6 to 12 months postoperatively ($p < 0.001$), with no statistically significant changes in coma RMS ($p = 0.247$). The level of ocular spherical aberration decreased statistically significantly at 6 months ($p < 0.001$), with no statistically significant changes afterward ($p = 0.306$). A statistically significant change in internal aberrations was observed in HOAs ($p = 0.017$) and in coma RMS ($p < 0.001$), as well as in the Zernike term corresponding to primary spherical aberration at 6 months ($p < 0.001$). From 6 to 12 months postoperatively, a statistically significant change was observed in HOA RMS ($p = 0.013$), but not in the levels of coma ($p = 0.816$) or spherical aberration ($p = 0.410$).

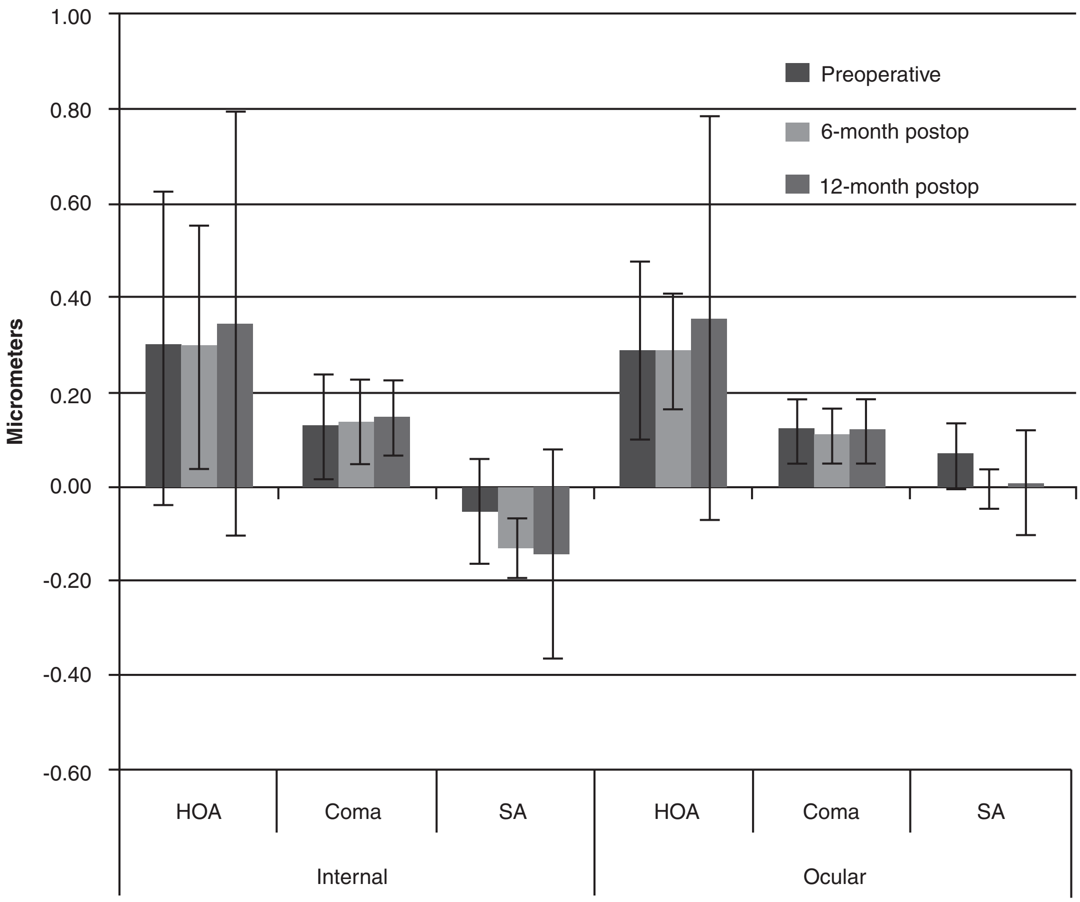

Fig. 13.15 Distribution of preoperative and 6-month and 12-month postoperative ocular and internal aberrometric data. (HOA higher-order aberration, SA spherical aberration)

13.12 Patient Satisfaction

All patients were asked about their degree of satisfaction in different tasks. A clinician registered the scores to the following question: "describe, using a number, the quality of vision for these different tasks." Tasks evaluated were TV, theater/concerts, at home, driving at daytime, driving at night (distance vision), and cooking, newspaper, computer, housework (intermediate and near vision). The possible scores were excellent (1), very good (2), good (3), not completely satisfied (4), dissatisfied (5), and very dissatisfied (6). As expected, the worst result was achieved in driving at night (2.57) in Table 13.2. Correlations between these scores and visual outcomes were also investigated.

Table 13.2 Satisfaction of the patients with working distances

Task	Score[a]
Television	
Mean +/ SD	1.13 +/ 0.35
Range	1, 2
Theater/concert	
Mean +/ SD	1.23 +/ 0.43
Range	1, 2
Driving at daytime	
Mean +/ SD	1.33 +/ 0.48
Range	1, 2
At home	
Mean +/ SD	1.17 +/ 0.38
Range	1, 2
Driving at night	
Mean +/ SD	2.57 +/ 0.77
Range	1, 4

(continued)

Table 13.2 (continued)

Task	Score[a]
Cooking	
Mean +/ SD	1.13 +/ 0.35
Range	1, 2
Newspaper	
Mean +/ SD	1.67 +/ 0.71
Range	1, 3
Computer	
Mean +/ SD	1.67 +/ 0.80
Range	1, 4
Homework	
Mean +/ SD	1.10 +/ 0.31
Range	1, 2
Overall	
Mean +/ SD	1.43 +/ 0.57
Range	1, 2

[a]Excellent (1); very good (2); good (3); not completely satisfied (4); dissatisfied (5); very dissatisfied (6)

The overall scores were highly correlated with the scores for the variable related to the household tasks ($r = 0.512$, $p < 0.001$). Overall scores were also strongly correlated with the scores obtained for "reading newspaper" ($r = 0.48$, $p < 0.001$) and "driving at night" ($r = 0.473$, $p < 0.001$). So, these three questions had an important weight in the overall score assigned by each patient. Some of the most interesting correlations between the scores and visual outcomes are present in Table 13.3**.** The results provided by the questions to evaluate patients' subjective satisfaction revealed the importance of contrast sensitivity to medium/high spatial frequencies for different visual tasks. The correlation is negative since the higher the contrast sensitivity, the lower the score (better results

Table 13.3 The most important correlations between visual and refractive variables and scores to question about degree of satisfaction in different visual tasks

Variable	Overall	At home	Reading newspaper	Driving at night	Cooking
CS at 3 cpd					
r value	–	–	–	–	−0.300
P value	–	–	–	–	0.020
CS at 6 cpd					
r value	–	–	–	–	−0.362
P value	–	–	–	–	0.004
CS at 12 cpd					
r value	−0.254	−0.274	−0.256	–	−0.345
P value.	0.050	0.034	0.049	–	0.007
CS at 18 cpd					
r value	−0.255	–	−0.357	–	−0.345
P value	0.050	–	0.005	–	0.007
SE					
r value	–	–	–	–	0.348
P value	–	–	–	–	0.006
HOA					
r value	–	–	–	0.291	–
P value	–	–	–	0.024	–
Strehl ratio					
r value	–	–	–	−0.246	–
P value	–	–	–	0.058	–
UNVA (33 cm)					
r value	–	0.317	0.297	–	–
P value	–	0.014	0.021	–	–
CNVA (33 cm)					
r value	–	–	0.278	–	–
P value	–	–	0.031	–	–

CS contrast sensitivity, *CNVA* corrected near visual acuity, *HOA* higher-order aberration, *SE* spherical equivalent, *UNVA* uncorrected near visual acuity correspond to lower scores). The positive correlation of higher order aberrations with the score achieved in the question "driving at night" explains the negative effect of HOAs on the retinal image quality, and its major importance at night when pupil size increases. Specifically, the primary spherical aberration (fourth order) has been identified to be an important source of alteration in quality of vision at night. The opinion of the users about this IOL implantation was very positive since all of them considered that the final result, as a whole, was excellent or very good (1 or 2 points). Moreover, all of them referred that they were comfortable in intermediate distance tasks. Two additional questions were made to the patients: "Would you choose the same lens again?", and "Would you recommend this lens to other person?". All the patients answered "yes". This result reflects the excellent visual results achieved with this multifocal IOL model.

13.13 Conclusion

Trifocal diffractive AT LISA tri provides effective distance, intermediate, and near visual restoration after cataract surgery with excellent levels of visual quality. Analysis of the defocus curve showed that this trifocal diffractive model can efficiently improve intermediate vision as well as near vision. This level of visual acuity restoration was accompanied by good levels of contrast sensitivity and physiologic levels of ocular aberrations. Internal aberrations analysis showed that this IOL model accurately compensates for the spherical aberration induced by the cornea in presbyopic patients.

Compliance with Ethical Requirements Peter Mojzis declares that he has no conflict of interest. All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study. No animal studies were carried out by the authors for this article.

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