

A More Natural Way of Seeing: Visual Performance of Three Presbyopia Correcting Intraocular Lenses

Amir Hamid, Arif Sokwala

Optimax and Ultralase Clinics, London, UK
Email: info@dramirhamid.com

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Abstract

Purpose: To compare the visual and refractive outcomes, patient satisfaction and spectacle independence between three novel designs of diffractive IOLs. **Method:** Prospective study including 150 patients with implantation of three IOLs: trifocal diffractive IOL AT LISA tri 839 MP (ATLISA, n = 50), trifocal diffractive IOL PhysiOL FineVision (FineVision, n = 50) and the extended range of vision IOL Tecnis Symphony ZRX00 (Symphony, n = 50). Patients were followed up for 6 months after surgery. Major parameters were monocular and binocular uncorrected (UDVA) and corrected (CDVA) distance, uncorrected (UIVA) and distance corrected (DCIVA) intermediate (80 cm), and uncorrected (UNVA) and distance corrected (DCNVA) near (40 cm) visual acuities (UNVA), contrast sensitivity (CS), defocus curve as well as patient satisfaction and spectacle use. **Results:** Mean postoperative decimal UDVA was 1.01 for Symphony, 0.96 for ATLISA and 0.95 for the FineVision IOL. Postoperative UIVA was 0.95 with Symphony, 0.72 with ATLISA and 0.85 with the FineVision IOL. Postoperative UNVA was 0.96 with the FineVision, 0.72 with the ATLISA and 0.63 with the Symphony IOL. The Symphony defocus curve showed the smoothest profile. Mean mesopic CS was 0.84 log units with the Symphony, 0.83 with the ATLISA (0.83) and 0.65 with the FineVision IOL. Mean photopic CS with the Symphony, ATLISA and FineVision was 1.05, 0.85 and 0.69 log units, respectively. Twenty percent of the patients with the ATLISA and FineVision IOLs and 5.6% of the Symphony patients reported halos and glare as troublesome or disabling. Reading glasses were frequently used by 5.6% of the Symphony patients. All patients with the trifocal IOLs reported to be spectacle-free for any distance. **Conclusion:** All 3 IOLs produce excellent results with high levels of spectacle independence. The Symphony produces better levels of distance and intermediate visual acuity, whereas the trifocal IOLs produced better near vision. Higher frequency of dysphotopsia was seen with the trifocal IOLs.

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Keywords

Extended Range of Vision, Tecnis Symphony, Trifocal, Defocus Curve, Visual Outcome

1. Introduction

Cataract surgery has evolved from a simple procedure of removing the opacified crystalline lens to a method that additionally aims to correct all refractive errors. In the past years, the major goal of the implantation of intraocular lenses (IOLs) was the achievement of emmetropia for distance. Currently, IOLs are able to compensate not only for spherical errors, but also for astigmatism and presbyopia, providing a complete restoration of the visual function with high levels of spectacle independence. Multifocal intraocular lenses (MIOLs) are designed to reduce spectacle dependence improving certain aspects related to quality of life. To date, there is scientific evidence of the significant improvement of uncorrected near visual acuity (UNVA) after the implantation of MIOLs compared to monofocal IOLs, without a significant decrease of uncorrected distance visual acuity (UDVA) [1]. However, there are some concerns regarding the visual quality provided by MIOLs, such as glare, halos or reduced contrast sensitivity (CS).

Earlier MIOL designs were bifocal, allowing the patient to obtain a postoperative functional distance and near visual acuity. Nowadays, the extended usage of computers and mobile devices has changed the preference of spectacle independence from near to intermediate distances. The latest generation of MIOLs based on diffractive platforms is able to distribute light in more than two different foci, the trifocal IOLs [2]-[4]. These three focal points can be generated in two ways, either by combining two bifocal diffractive profiles in one surface of the IOL [3] or by using a trifocal diffractive profile combined with a bifocal diffractive optic [2] [5]. Besides MIOLs, other new concepts have been developed on the basis of a diffractive optic pattern, such as the extended range of vision IOL Tecnis Symphony. We have recently conducted a study to compare the visual and refractive outcomes as well as patient satisfaction and spectacle independence between three novel designs of diffractive IOLs.

2. Patients and Methods

We conducted a prospective clinical study including 150 patients undergoing cataract surgery or clear lens extraction with implantation of three different IOLs: the trifocal diffractive IOL ATLISA tri 839MP (50 patients), the trifocal diffractive IOL PhysIOL FineVision (50 patients) and the extended range of vision IOL Tecnis Symphony ZRX00 (50 patients). The preoperative refractive and demographic characteristics of the evaluated sample are summarized in **Table 1**. Exclusion criteria comprised previous ocular surgery including corneal or refractive surgery, chronic or recurrent uveitis, acute ocular disease or external/internal infection, diabetes with retinal changes, glaucoma or intraocular pressure (IOP) equal or higher than 24 mmHg, pseudoexfoliation syndrome, pathological miosis, keratoconus, and corneal endothelial dystrophy. All patients were informed about the study and provided informed consent to undergo the clinical examinations in accordance with the tenets of the Declaration of Helsinki. The study was approved by an institutional review board.

Before surgery, all patients underwent a comprehensive preoperative ophthalmological examination that included measurement of monocular and binocular uncorrected distance (UDVA), intermediate (80 cm) (UIVA), and near (40 cm) visual acuity (UNVA), monocular and binocular corrected distance (CDVA), distance-corrected intermediate (DCIVA) and distance-corrected near visual acuity (DCNVA), optical biometry (IOL Master, Carl Zeiss Meditec AG, Germany), manifest refraction, biomicroscopy, Goldmann applanation tonometry, and dilated funduscopy. Patients were evaluated at 1 week and at 2, 3 and 6 months after surgery. Visual acuities, subjective refraction, contrast sensitivity function under mesopic and photopic conditions with the Thomson Charts (<http://www.thomson-software-solutions.com/test-chart-xpert-3di/>) and the defocus curve were assessed at each visit. In addition, at the end of the follow-up, patients were asked about the perception of photic phenomena or visual disturbances, such as glare or halos, as well as about their need for using spectacles for reading or intermediate distance. Specifically, the questionnaire consisted of various items that scored the perception of glare and halos. Each item was scored from none (minimum) to disabling (maximum). The overall satisfaction was scored on the basis of 3 items: choice of same multifocal IOL again, recommendation to friends and family, and the use of spectacles at far, near and intermediate distances.

Table 1. Preoperative refractive and demographic characteristics of patients implanted with each type of IOL. Abbreviations: M (male), F (female), SD (standard deviation), Pre-op (pre-operative), SEQ (spherical equivalent), Cyl (cylinder), Post-op (postoperative), D (diopters).

	Tecnis Symphony ZXR00	AT LISA tri	FineVision
Males/Females	1:2	1:2	1:2
Mean Age (SD)	57.8 ± 6.03	56.9 ± 7.01	58.2 ± 9.41
Age Range	34 - 74	39 - 73	50 - 75
Pre-op SEQ	0.6 ± 1.19	0.2 ± 1.36	-0.05 ± 0.78
Pre-op Sphere Range	-1.25 to 4.75 D	-3.75 to 4.25D	-6.25 to 0.25D
Pre-op Cyl Range	-1.25 to 0 D	-1.5 to 0 D	-0.50 to 0 D
Post-op SEQ	-0.1 ± 0.23	0.0 ± 0.19	0.0 ± 0.10

Statistical analysis was performed with the SPSS statistics software package version 15.0.1 for Windows (IBM, Armonk, NY, USA). Normality of data distribution was analysed with the Kolmogorov-Smirnov test. When parametric analysis was possible, the Student t test for paired data was used for all parameter comparisons between preoperative and postoperative examinations as well as between consecutive postoperative visits. Otherwise, when parametric analysis was not possible, the Wilcoxon Rank Sum test was applied to assess the significance of differences between consecutive examinations. In all cases, the same level of significance ($p < 0.05$) was considered.

3. Results

3.1. Visual Outcomes

The Tecnis Symphony IOL provided the best results for distance visual acuity. Mean postoperative UDVA was 1.01 (decimal scale), and CDVA changed from 1.08 preoperatively to 1.09 postoperatively. Likewise, the AT LISA tri IOL also provided good distance visual results, with a mean postoperative UDVA of 0.96 and a CDVA not changing significantly with surgery from 1.04 to 1.03. In contrast, the FineVision IOL showed the lowest mean postoperative value of UDVA (0.95), but with a significant increase in CDVA (from 1.05 to 1.10). The differences in UDVA between Tecnis Symphony and ATLISA tri ($p = 0.048$) as well as Tecnis Symphony and FineVision ($p = 0.006$) were statistically significant.

Regarding intermediate distance, the Symphony IOL was again the best option. With this IOL, a postoperative UIVA of 0.95 was achieved while mean values of 0.72 and 0.85 were obtained with the ATLISA and FineVision IOLs, respectively. The differences between the Symphony IOL and the other two lens models were statistically significant ($p = 0.0018$ vs AT LISA; $p = 0.021$ vs FineVision).

In our sample, a mean UNVA of 0.96 was obtained with the FineVision IOL while a mean value of 0.72 was obtained with the AT LISA tri IOL. A statistically significant difference was observed when these trifocal IOLs were compared with the Symphony IOL (0.63; $p = 0.03$ vs AT LISA; $p = 0.033$ vs FineVision) (**Figure 1**).

3.2. Defocus Curve

The Symphony IOL provided the smoother profile along the whole defocus curve, with a more progressive visual acuity decrease to the higher levels of defocus, while both diffractive trifocal IOL models showed some distinct peaks based on their optic designs. Specifically, the Symphony IOL was clearly superior to the trifocal IOLs at defocus levels of -1 D and -1.50 D that correspond with the vergence demands required for intermediate distance (**Figure 2**).

3.3. Contrast Sensitivity Outcomes

A mean mesopic CS of 0.84 log units was achieved with the Symphony IOL, a significantly higher level than that obtained with the AT LISA IOL (0.83; $p = 0.017$) and the FineVision trifocal IOL (0.65; $p = 0.02$). Under

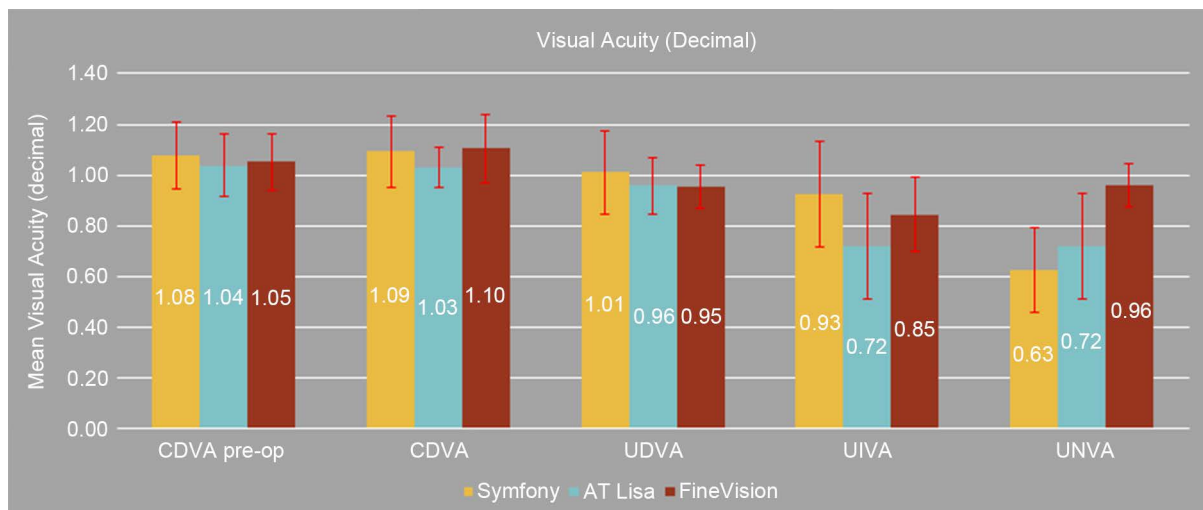


Figure 1. Mean postoperative visual acuities in the three IOL subgroups. Abbreviations: Preop (preoperative); CDVA (corrected distance visual acuity); UDVA (uncorrected distance visual acuity); UIVA (uncorrected intermediate visual acuity); UNVA (uncorrected near visual acuity); DCNVA (distance corrected near visual acuity).

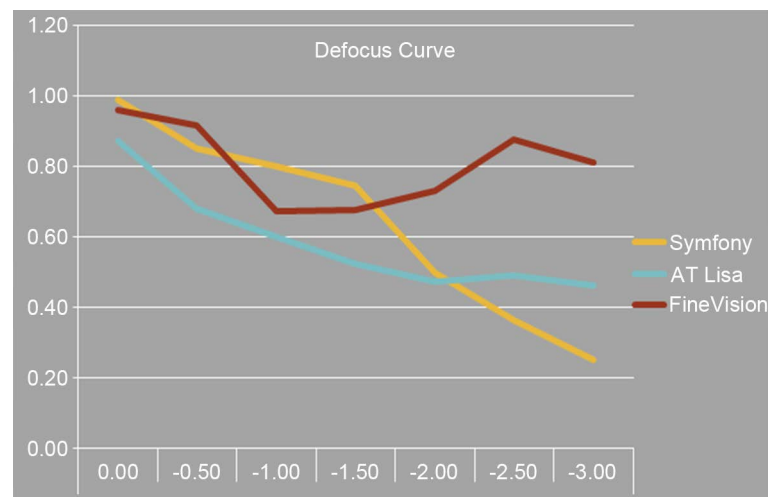


Figure 2. Defocus curves for different defocus levels from 0 to -3 D in the three IOL subgroups.

photopic conditions, the Symfony IOL provided significantly higher levels of CS (1.05 log units), with clearly inferior CS values for the Fine Vision and AT LISA tri IOLs (0.69 log units; $p = 0.03$ and 0.85 log units; $p = 0.02$) respectively) (**Figure 3**).

3.4. Photic Phenomena and Patient Satisfaction

In our series, 20% of patients with the AT LISA and FineVision IOLs reported each, halos and glare as troublesome or even disabling (**Figure 4**). Only 5.6% of the patients with the extended range of vision IOL, Symfony, rated halos and glare as troublesome and none of the patients felt disabled by these photic phenomena.

A total of 94.4% of patients implanted with the Symfony IOL would choose the same IOL again and would recommend this IOL model to their friends and family. Likewise, a patient satisfaction rate of 93.3% was obtained with the ATLISA IOL, whereas a dissatisfaction rate of 20% was obtained with the FineVision IOL. Almost 95% of patients did not need spectacles at any distance after the implantation of the Symfony IOL. Only 5.6% needed reading glasses frequently (**Figure 5**). All patients with the trifocal IOLs reported that they did not need spectacles for any distance.

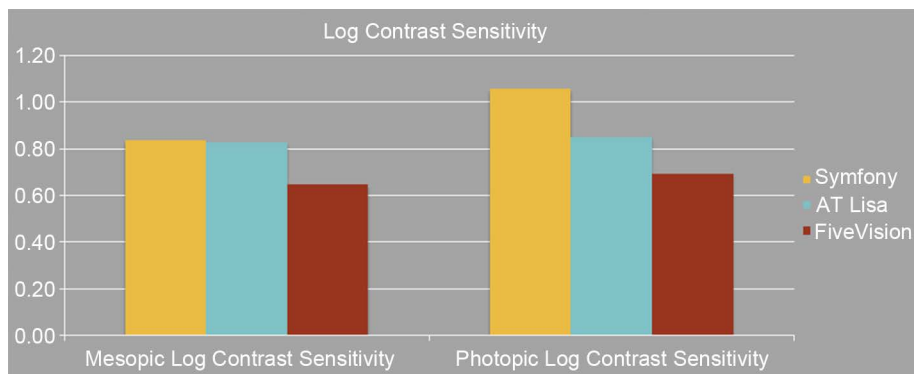


Figure 3. Contrast sensitivity values under photopic and mesopic conditions in the three IOL subgroups.

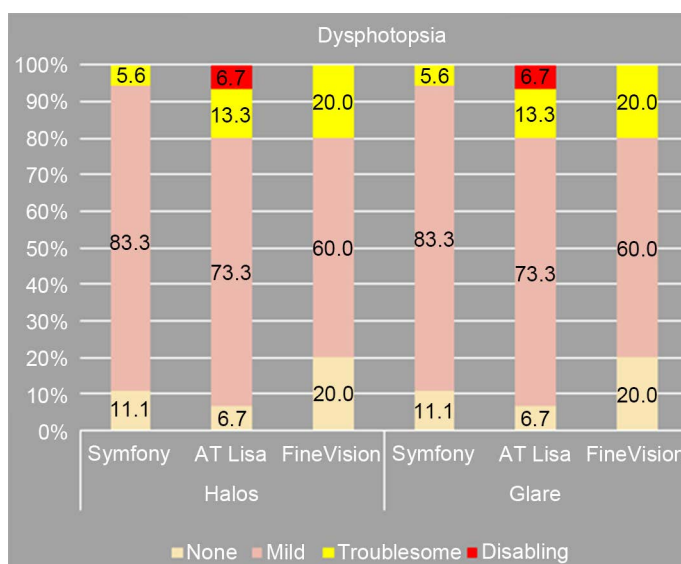


Figure 4. Rates of photic phenomena (halos and glare) in the three IOL subgroups.

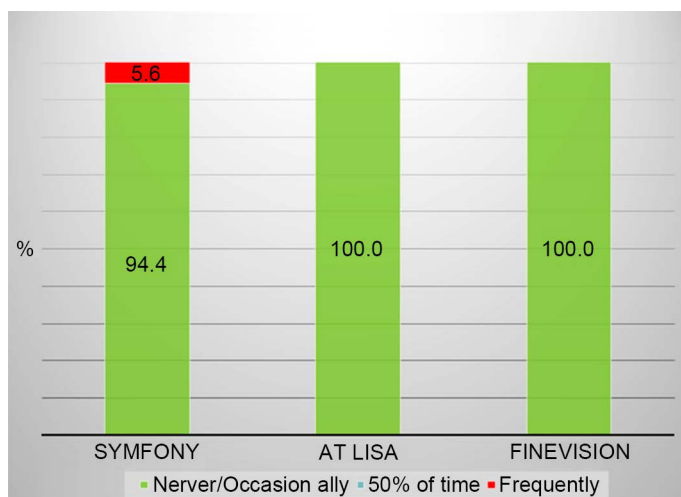


Figure 5. Spectacle independence rates for near vision in the three IOL subgroups.

4. Discussion

The Tecnis Symphony IOL is a new promising alternative to provide an extended effective and continuous range of optimum vision from far to near distances after cataract surgery or refractive lens exchange. This IOL is based on a new echelette optic design and combines the compensation for chromatic aberration and primary spherical aberration [6] [7]. Although there is still a lack of clinical studies reporting the clinical outcomes of this IOL, in-vitro studies have shown its ability to provide an enlarged depth of focus [8]. Likewise, experimental studies have revealed that the modulation transfer function (MTF) of the Tecnis Symphony IOL for intermediate distances is comparable to that achieved with trifocal IOLs [9]. This is consistent with the results obtained in our study.

Distance visual outcomes were excellent with all studied IOLs. This confirms the ability of the lenses to successfully restore the distance visual function, as also shown for different models of multifocal IOLs [5] [10]-[25]. A mean monocular UDVA of 0.05 ± 0.07 logMAR (decimal 0.89) was reported by Law *et al.* [14] in patients bilaterally implanted with the ATLISA trifocal IOL. Kohnen *et al.* [24] found a mean binocular UDVA of -0.06 ± 0.10 logMAR (decimal 1.16) after implantation of the same lens model. With the FineVision IOL, mean monocular 2-month and 6-month postoperative logMAR UDVA values of 0.19 ± 0.09 (decimal 0.65) and 0.18 ± 0.13 (decimal 0.66) were reported by Sheppard *et al.* [18] and Alió *et al.* [17], respectively. Jonker *et al.* found binocular UDVA values of 0.01 ± 0.11 (decimal 0.98) logMAR after bilateral implantation of the FineVision IOL [25].

The Symphony IOL showed the best UIVA values in our study with 0.95, compared to 0.72 and 0.85 for the ATLISA and FineVision IOLs, respectively. Mean logMAR UIVA values of 0.08 ± 0.10 (decimal 0.83; measured at 66 cm) and 0.03 ± 0.08 (decimal 0.93; measured at 80 cm) have been reported by Mojzis *et al.* in two case series with the ATLISA trifocal IOL [5] [15]. Kohnen *et al.* [24] found binocular UIVA values of 0.00 ± 0.12 (decimal 1.0) with this lens model. Two separate studies reported mean logMAR UIVA values of 0.08 ± 0.12 (decimal 0.83; measured at 65 cm) [13] and 0.05 ± 0.19 (decimal 0.89; measured at 70 cm) [19]. Mean UIVA values of 0.20 ± 0.11 logMAR (decimal 0.63; measured at 80 cm) and 0.32 ± 0.15 logMAR (decimal 0.48; measured at 70 cm) were obtained in two studies evaluating the same type of trifocal IOL [17] [25].

As expected, near visual acuity outcomes improved with increasing near addition of the IOL, with the FineVision IOL showing the best results, followed by ATLISA and Symphony. Law *et al.* [1] reported a mean binocular UNVA value of 0.16 ± 0.07 logRAD (decimal 0.69; measured at 40 cm) in a group of eyes implanted with the ATLISA trifocal IOL, Kohnen *et al.* [24] reported bilateral UNVA values of 0.04 ± 0.10 (decimal 0.91) and Mojzis [5] found a monocular mean UNVA of 0.20 ± 0.12 logMAR (decimal 0.63; measured at 33 cm) with the same lens model. With the FineVision trifocal IOL, Alió *et al.* [17] reported a mean monocular UNVA of 0.26 ± 0.15 (decimal 0.55; measured at 40 cm) and Jonker *et al.* [25] 0.15 ± 0.13 logMAR (decimal 0.71). Mean logMAR UNVA values of 0.11 ± 0.12 (decimal 0.11; measured at 35 cm) and 0.01 ± 0.06 (decimal 0.98; measured at 35 cm) have been reported by Vryghem and Heireman [19] and Cochener *et al.* [13].

The perception of visual disturbances is a common occurrence after the implantation of diffractive multifocal IOLs. Although the rate of severe symptoms is usually low, a significant percentage of patients may consider them as disabling, leading to dissatisfaction. Those symptoms usually decrease with time, probably as a result of a neuro-adaptive mechanism. In our series, patients with the Symphony IOL reported less troublesome photic phenomena than patients implanted with the trifocal lenses. None of the Symphony patients felt disabled by these symptoms. Law *et al.* [14] found that 80% of patients reported difficulties associated to halo perception at 1 month after implantation of the ATLISA trifocal IOL. This percentage decreased to 40% at 6 months after surgery [14]. In another study with the same lens model, the most common visual symptom was halos, which were reported by 60% of the patients, followed by glare in 28% and starburst in 8% of the patients [24]. In a retrospective study, Kamiya *et al.* [26] found that disabling photic phenomena were one of the main causes for multifocal IOL explantation. The optic lens design of the Symphony IOL with the elongated focus instead of distinct focal points might have contributed to the low level of photic phenomena.

In our sample, the Symphony IOL provided the best performance in terms of CS when compared with the trifocal IOLs. Under mesopic conditions, Symphony and ATLISA showed comparable results, whereas CS with the FineVision was significantly worse. Under photopic conditions Symphony was significantly better than both trifocal IOLs. Marques and Ferreira [27] reported no significant differences in contrast sensitivity between eyes with the FineVision and eyes with the ATLISA IOL. Law *et al.* [14] used the Pelli Robson test to measure CS in

patients with the ATLISA IOL and found no differences between mesopic and photopic results. Also, the light distribution of the Symphony IOL between its best vision foci has been demonstrated to be more homogeneous and less vergence dependent under dim conditions compared to multifocal IOLs [28].

The defocus curve of the Symphony IOL showed the smoothest profile, and was superior to the trifocal IOLs at defocus levels of -1 D and -1.50 D which are important for intermediate vision. In another study by Mojzis *et al.* [5] the defocus curve of the ATLISA trifocal IOL showed a maximum of visual acuity at a defocus of zero and a slight drop with increasing defocus but a functional range of visual acuity with values of 0.1 logMAR or better at defocus levels between 0 D and 2.5 D.

None of the patients with trifocal IOLs in our series reported to need glasses for any distance. Despite the lower near addition, only 5.6% of the Symphony patients needed reading glasses frequently. Kohnen *et al.* [24] found in his study with the ATLISA trifocal IOL that 100% of the patients were independent of spectacles for distance and intermediate vision and 12% needed occasional near correction. Law *et al.* [14] reported that a limited percentage of patients implanted with the same IOL had some difficulties to perform near and intermediate visual tasks without glasses, such as reading the newspaper or working with the computer [14]. In a study with the FineVision IOL, 80% of the patients were reported to be completely spectacle independent [25].

Patient satisfaction was very high in our series with 94.4% of the Symphony patients and 93.3% of the ATLISA patients who would choose the same IOL again and would recommend this IOL model to their friends and family. The dissatisfaction rate was higher in the FineVision group with 20% of the patients reporting that they would not choose the same lens again or recommend the lens.

5. Conclusion

In summary, the Tecnis Symphony IOL, designed to restore visual function after extraction of the crystalline lens, provides excellent efficacy outcomes regarding visual acuity at far and intermediate distances. Only a very low percentage of patients need spectacles for near distances. The rate of halos and glare is significantly lower compared to the trifocal diffractive IOL models. Therefore, the combination of the good visual outcome based on the extended range of vision, the high spectacle independence and the low incidence of disabling photic phenomena lead to somewhat higher levels of patient satisfaction compared to the trifocal IOLs.

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