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Long-Term Results of Pseudophakic Dysphotopsia with Two Different Intraocular Lenses

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Abstract

Background and Objectives: Pseudophakic dysphotopsia is a common cause of dissatisfaction after uncomplicated cataract surgery. We compared its course with two intraocular lenses (IOLs). *Materials and Methods:* In this prospective, non-randomized study, 348 of 488 enrolled patients completed two years of follow-up after implantation of the Akreos Adapt AO (n = 176) or AcrySof IQ (n = 172) IOL through a superior or temporal corneal incision. Positive and negative dysphotopsia were assessed with a modified Radford questionnaire at one wweek, eight weeks, one year, and two years. Repeated measurements were analyzed with exact McNemar tests and generalized estimating equations adjusted for incision site, age, and sex. *Results:* At one week, dysphotopsia was reported by 45.9% of patients with the AcrySof IQ and 21.0% with the Akreos Adapt AO (adjusted odds ratio 3.27, 95% CI 2.02–5.29); negative dysphotopsia occurred only with the AcrySof IQ (8.7%). Later differences in any dysphotopsia were small and non-significant (0.9–2.2 percentage points). Dysphotopsia decreased significantly in both groups from 33.3% to 14.7% overall. Incision site was not associated with dysphotopsia. *Conclusions:* Early dysphotopsia was more frequent with the AcrySof IQ, although this represents an association rather than proof of causality; with both IOLs, symptoms became less frequent over time, and annoying symptoms became rare.

Keywords: cataract; dysphotopsia; intraocular lens; phacoemulsification; quality of life

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1. Introduction

Pseudophakic dysphotopsia is a frequent postoperative complaint and an important reason for dissatisfaction in patients after otherwise uncomplicated cataract surgery [1–4]. It includes a range of subjective visual phenomena that may occur after intraocular lens (IOL) implantation and is generally classified into positive and negative dysphotopsia.

Positive dysphotopsia is characterized by unwanted bright visual phenomena, such as halos, arcs, rings of light, flashes, or streaks. In contrast, negative dysphotopsia is typically perceived as a dark temporal crescent or shadow in the peripheral visual field, resembling a scotoma, and is thought to result from reduced illumination of a specific retinal area after in-the-bag posterior chamber IOL implantation [5]. Since its original description by

Davison more than twenty years ago, this condition has attracted considerable attention in the ophthalmic literature [6]. Its etiology remains uncertain, and several optical, anatomical, surgical, and neuroadaptation-related factors have been suggested. These include sharp or truncated optic edges, higher refractive index of the IOL material, surface reflectivity, optic configuration, the relationship between the IOL optic and the anterior capsule, the position of the optic–haptic junction, ocular anatomy such as a prominent globe or shallow orbit, an anterior IOL surface positioned more than 0.45 mm from the posterior iris plane, brown iris color, temporal clear corneal incisions, negative afterimages, neuroadaptation, angle kappa, and projection of the anterior capsulotomy edge onto the nasal peripheral retina [2–4,6–14]. More recent explanations have shifted the concept of negative dysphotopsia from a simple shadow phenomenon toward an imaging-related phenomenon, in which the smaller size of the IOL compared with the natural crystalline lens limits the extent of the focused peripheral image [15,16].

Patients generally tolerate negative dysphotopsia less well than positive dysphotopsia, resulting in poor overall visual outcomes even when final visual acuity is 20/20. Both positive and negative dysphotopsia worsen visual quality; affect daily activities such as driving (especially night driving), reading, writing, watching television, and working on a computer; and consequently impair quality of life (QoL) and working ability. Patients sometimes describe these symptoms as debilitating and frustrating, and in some cases, IOL explantation may be required [11,17]. Therefore, understanding dysphotopsia is essential for achieving a high QoL in patients following IOL implantation. Masket and Fram described the clinical features and surgical management of negative dysphotopsia [12]. Recent reviews continue to emphasize that positive dysphotopsia is most consistently related to IOL edge design and internal reflections, whereas negative dysphotopsia remains less clearly explained and is probably multifactorial [18].

Although several hypotheses have been proposed, the underlying mechanisms of negative dysphotopsia have not yet been fully clarified or validated. Holladay et al. investigated negative dysphotopsia using ray-tracing simulations performed with the Zemax optical design program and identified the “type 3 shadow-penumbra” as the optical model corresponding to this phenomenon. They suggested that this model could account for the clinical manifestations previously described by Masket and Fram [5,12]. According to their analysis, the main optical contributors to negative dysphotopsia include a small pupil, an IOL position behind the pupil within the range of $\geq$0.06 mm and $\leq$1.23 mm for acrylic IOLs and $\geq$0.06 mm and $\leq$0.62 mm for silicone IOLs, a sharp optic edge with corner edge radii $\leq$0.05 mm, and anterior extension of the functional nasal retina to the region where the shadow is perceived. The visibility of the shadow is ultimately determined by the anterior boundary of the functional nasal retina. Additional contributing factors include the refractive index of the optic material, the patient’s angle α, nasal displacement of the pupil relative to the optical axis, and whether the peripheral nasal capsule is transparent or translucent [5]. Subsequent theoretical calculations introduced the concept of “vignetting”, suggesting that the smaller size of the IOL compared with the natural crystalline lens may generate shadow-like peripheral areas resembling the clinical symptoms of negative dysphotopsia [15,16]. Accordingly, the primary etiology of negative dysphotopsia remains controversial, and there is still no consensus in the literature regarding the exact cause of this condition. Most likely, it is multifactorial.

The purpose of our study was to provide long-term clinical data on the frequency of dysphotopsia and to examine whether IOL type and corneal incision site were associated with the occurrence of dysphotopsia.

2. Materials and Methods

This was a prospective, single-center comparative study conducted at the Department of Ophthalmology, University Hospital Centre Zagreb. A total of 488 patients were enrolled over a 10-month recruitment period. Only patients who underwent uneventful cataract surgery and had a well-centered IOL with good capsulorrhexis overlap on the IOL edge, visual acuity better than 0.5, and no evidence of ocular pathology were included in the study. Preoperative data obtained for each patient included sex, age, slit-lamp examination findings, and ocular history. Ethical approval for the study was obtained from the Institutional Ethics Committee, and all study procedures followed the principles of the Declaration of Helsinki. Before inclusion, all patients were informed about the study both orally and in writing and gave written informed consent. The two study groups were defined according to the implanted IOL type: Akreos Adapt AO IOL (Bausch & Lomb, Rochester, NY, USA) or AcrySof IQ IOL (Alcon Laboratories, Inc., Fort Worth, TX, USA). The characteristics of the two IOLs are presented in Table 1.

Table 1. Characteristics of the two study intraocular lenses.

Characteristics	Akreos Adapt AO (21.0 D)	AcrySof IQ (21.0 D)
Overall length (mm)	11.0	13.0
Optic diameter (mm)	6.0	6.0
Optic design	Biconvex, aspheric anterior & posterior surface	Biconvex, posterior aspheric surface
Haptics	Single piece, four, 0°angulation	Single piece, two
Thickness (mm) central/edge	0.87/0.31	0.61/0.21
Edge design	Double square, 360° anti-PCO	Double square
Material	Hydrophilic acrylic	Hydrophobic acrylic
Refractive index	1.46	1.55
Lens spherical aberration (μm)	0.00 (aberration-free)	−0.20
A-constant (us biometry)	118.0	118.7

In all patients, phacoemulsification was carried out under topical eye-drop anesthesia by a single surgeon (S.M.) through either a superior or temporal clear corneal incision. The choice of IOL type was not randomized and was based on the surgeon's decision and the availability of the appropriate IOL power required for implantation. The incision site was selected according to preoperative keratometry. A superior clear corneal incision was performed in eyes with with-the-rule astigmatism greater than 1.0 diopter, whereas a temporal clear corneal incision was performed in all other eyes. For both IOL types, a 3.0-mm incision was used for lens insertion. An anterior continuous curvilinear capsulorrhexis measuring 5.0 to 5.5 mm was performed. Each IOL was inserted into the capsular bag using an injector system. All patients received the same standard postoperative topical treatment. Only one eye per patient was included in the analysis. If both eyes satisfied the inclusion criteria, the first operated eye was selected in order to avoid inter-eye correlation.

All patients completed a modified Radford questionnaire at each scheduled postoperative follow-up visit: 1 week, 8 weeks, 1 year, and 2 years after surgery. The six dysphotopsia-related questions were translated into Croatian from the original questionnaire described

by Radford et al. The original five-point response scale was simplified to four categories: 1 = not noticed, 2 = minimal, 3 = annoying, and 4 = debilitating (Table 2) [2]. The original separate category for mildly annoying symptoms was not retained. The Croatian adaptation was not formally validated.

Table 2. Modified Radford questionnaire to determine the severity of photic symptoms.

Study Questionnaire
(1) Since your operation, have you noticed any shadows/graininess/dark crescent on the outside of your vision?
(2) Driving at night, do you notice halos/circles around lights?
(3) Driving at night, do you notice streaks of light or starbursts when looking at the headlights of oncoming traffic?
(4) Have you noticed that your reading is affected by bright lights, for example, in the supermarket or at midday?
(5) Have you noticed increased difficulty with reading in dim lights, such as at dawn or dusk?
(6) Have you noticed any unwanted images?
1. Have not noticed.
2. Have noticed but minimal.
3. Have noticed and is annoying.
4. Have noticed and is debilitating.

Negative dysphotopsia was assessed using question 1 of the modified questionnaire, which asked patients whether they had noticed shadows, graininess, or a dark crescent in the temporal or peripheral visual field after surgery. Positive dysphotopsia symptoms were assessed using questions 2–6, which addressed halos, streaks or starbursts, light-related reading difficulties, difficulty reading in dim light, and unwanted images. In the questionnaire, patients also rated their general satisfaction with their current vision and answered additional questions regarding the possible influence of present photic phenomena on visual satisfaction. These items were not included in the dysphotopsia outcomes and are not analyzed in this report. After completing the questionnaire, patients underwent a clinical examination. Patients who met any exclusion criterion during follow-up were excluded from the final analysis.

The primary outcome was the proportion of patients reporting any dysphotopsia (positive or negative) at each postoperative follow-up visit. Secondary outcomes included the proportions of patients reporting positive and negative dysphotopsia, symptom severity, and responses to individual questionnaire items. We also assessed changes in dysphotopsia over time and its association with IOL type and corneal incision site.

Statistical Analysis

Data were summarized using absolute and relative frequencies. Dysphotopsia was considered present when a patient answered ≥2 ("noticed but minimal" or worse) to at least one question; negative dysphotopsia was defined by question 1 and positive dysphotopsia by questions 2–6. Proportions at each visit are reported with Wilson 95% confidence intervals (CIs), and between-group differences as absolute risk differences in percentage points with Newcombe 95% CIs. Between-group comparisons at individual visits used Fisher's exact test; for negative dysphotopsia, which could not be modeled because no events occurred in one group, the *p*-values of the four visits were additionally adjusted with the Holm method.

Associations between incision site and dysphotopsia were assessed with the Pearson χ^2 test without continuity correction, and questionnaire item scores were compared between the groups with the Mann–Whitney U test (asymptotic two-sided *p*-values with correction for ties). Baseline characteristics were compared with Welch's *t*-test or Fisher's exact test and with standardized mean differences (SMD). Because the same patients were assessed at every visit, changes between the first week and each later visit were assessed within patients with the exact McNemar test (Holm-adjusted across the three comparisons). To account for the correlation of repeated observations, the occurrence of any dysphotopsia at all four visits was additionally analyzed with a generalized estimating equations (GEE) model (binomial distribution, logit link, exchangeable working correlation, robust standard errors) that included IOL type, visit (categorical), the IOL type × visit interaction, incision site, age (per 10 years), and sex; the effect of IOL type at each visit and the change from one week to each later visit within each IOL group are presented as adjusted odds ratios (ORs) with 95% CIs. A model with an independent working correlation and an unadjusted model were fitted as sensitivity analyses. Negative dysphotopsia could not be analyzed with this model because no events occurred in the Akreos Adapt AO group. Instead of a post hoc power analysis, the detection capability of the study was characterized by the minimum detectable absolute difference between the groups at a two-sided α of 0.05 and 80% power. All tests were two-sided. Missing follow-up data were not imputed, and only patients who completed all scheduled follow-up visits were included in the final analysis. Statistical significance was defined as $p < 0.05$. All analyses were performed using Python 3.12 (statsmodels 0.15.0, SciPy 1.18.1). No formal a priori sample size calculation was performed. The study sample was determined pragmatically and included consecutive eligible patients who underwent uneventful cataract surgery during the predefined 10-month recruitment period and completed all scheduled follow-up visits.

3. Results

Of the 488 patients initially enrolled in this prospective study, 348 patients (187 right eyes and 161 left eyes) were retained for the final analysis and completed all follow-up visits. There were 183 women and 165 men. Fifty-eight patients did not meet the inclusion criteria, 13 died, 18 were unable to attend follow-up visits due to chronic illness, 18 did not attend scheduled follow-up visits, and 33 were unavailable by telephone. The mean patient age was 70.4 ± 7.3 years. All included patients completed the questionnaire at all follow-up visits. The flow of patients through the study is shown in Figure 1.

Among the final study cohort, 176 patients received the Akreos Adapt AO IOL and 172 patients received the AcrySof IQ IOL. A temporal clear corneal incision was used in 201 patients: 114 patients with Akreos Adapt AO and 87 patients with AcrySof IQ. A superior clear corneal incision was performed in 147 patients: 62 patients with Akreos Adapt AO and 85 patients with AcrySof IQ. Baseline characteristics of the two groups are presented in Table 3. The groups were comparable in age, operated eye, and IOL power, with a small imbalance in sex (SMD 0.13), but a temporal incision was used more often in the Akreos Adapt AO group (64.8% vs. 50.6%; $p = 0.009$).

Table 3. Baseline characteristics of the patients according to the implanted IOL.

Characteristic	Akreos Adapt AO ($n = 176$)	AcrySof IQ ($n = 172$)	SMD	*p*
Age, years, mean ± SD	70.2 ± 7.6	70.7 ± 7.0	0.06	0.580 □
Female sex, n (%)	87 (49.4)	96 (55.8)	0.13	0.240 □
Right eye, n (%)	92 (52.3)	95 (55.2)	0.06	0.592 □

Table 3. *Cont.*

Characteristic	Akreos Adapt AO ($n = 176$)	AcrySof IQ ($n = 172$)	SMD	p
Temporal incision, n (%)	114 (64.8)	87 (50.6)	0.29	0.009 □
IOL power, D, mean ± SD	22.1 ± 2.2	22.0 ± 2.2	0.02	0.887 □

Data from the medical records. SMD, standardized mean difference (>0.10 indicates imbalance); □ Welch's *t*-test; □ Fisher's exact test. Ocular biometric data (axial length, anterior chamber depth, pupil size) were not available.

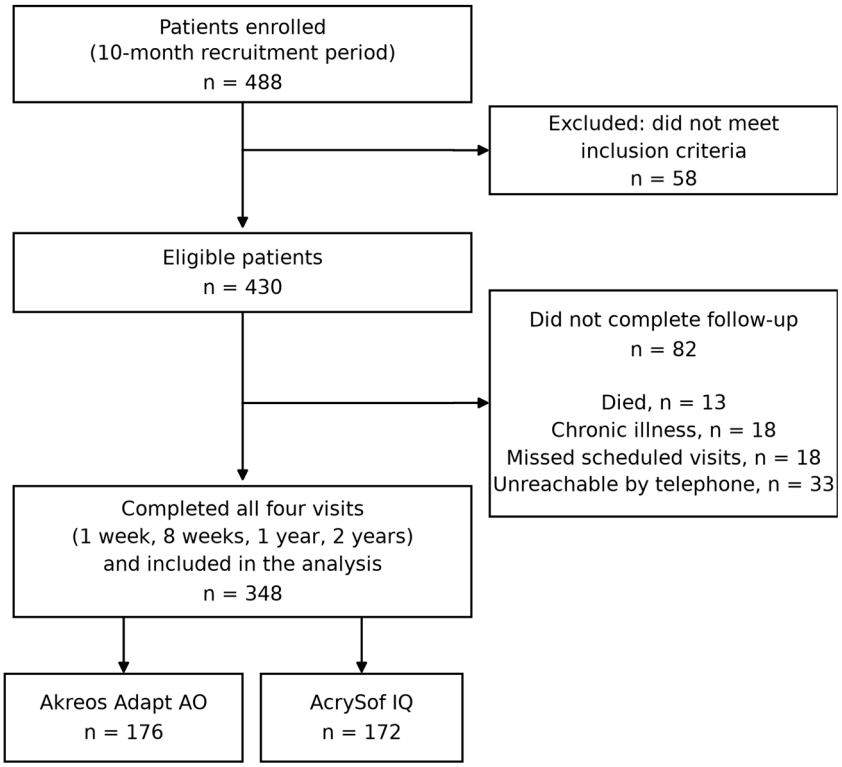


Figure 1. Flow of patients through the study.

3.1. Postoperative Week 1

At one week postoperatively, the overall incidence of dysphotopsia was 33.3%. Symptoms of dysphotopsia, either positive or negative, were reported by 45.9% ($n = 79$) of patients in the AcrySof IQ group and by 21.0% ($n = 37$) of patients in the Akreos Adapt AO group, corresponding to an absolute between-group difference of 24.9 percentage points (95% CI 15.1–34.1); this difference was statistically significant ($p < 0.001$). Negative dysphotopsia was reported by 15 patients (8.7%; 95% CI 5.4–13.9) in the AcrySof IQ group and by none of the patients in the Akreos Adapt AO group (0%; 95% CI 0–2.1; Fisher's exact test $p < 0.001$; Figure 2). None of the patients reported the symptoms as debilitating. Among all patients with dysphotopsia, 11% described the symptoms as annoying, whereas the remaining patients noticed them only minimally. When dysphotopsia symptoms at one week were analyzed according to the type of clear corneal incision, no statistically significant association was found between incision site and dysphotopsia occurrence (superior 51/147 (34.7%) vs. temporal 65/201 (32.3%); $\chi^2 = 0.21$; $p = 0.645$).

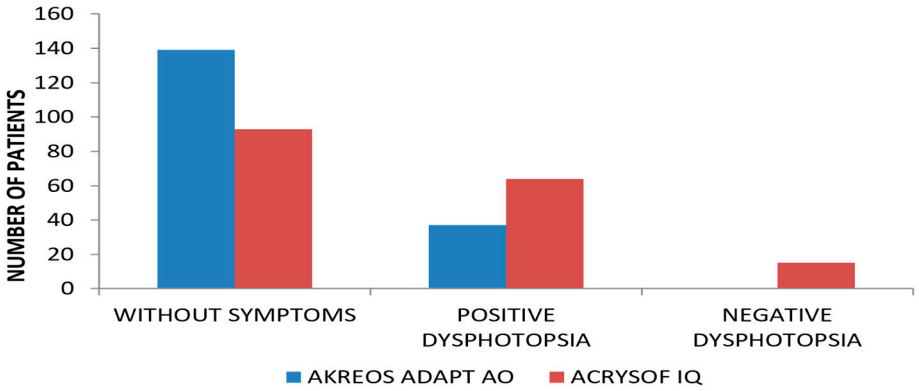


Figure 2. Distribution of dysphotopsia symptoms one week postoperatively according to intraocular lens type.

3.2. Postoperative Week 8

At eight weeks postoperatively, the overall incidence of dysphotopsia was 21.0%. Symptoms of dysphotopsia, either positive or negative, were reported by 22.1% ($n = 38$) of patients in the AcrySof IQ group and by 19.9% ($n = 35$) of patients in the Akreos Adapt AO group, corresponding to an absolute between-group difference of 2.2 percentage points (95% CI–6.4 to 10.8); this difference was not statistically significant ($p = 0.693$). Negative dysphotopsia was reported by five patients in the AcrySof IQ group and by none of the patients in the Akreos Adapt AO group (Fisher's exact test $p = 0.029$; $p = 0.086$ after Holm correction for the four visits; Figure 3). None of the patients reported the symptoms as debilitating. Among all patients with dysphotopsia, 10% described the symptoms as annoying, whereas the remaining patients noticed them only minimally. When dysphotopsia symptoms at eight weeks were analyzed according to the type of clear corneal incision, no statistically significant association was found between incision site and dysphotopsia occurrence (superior 33/147 (22.4%) vs. temporal 40/201 (19.9%); $\chi^2 = 0.33$; $p = 0.564$).

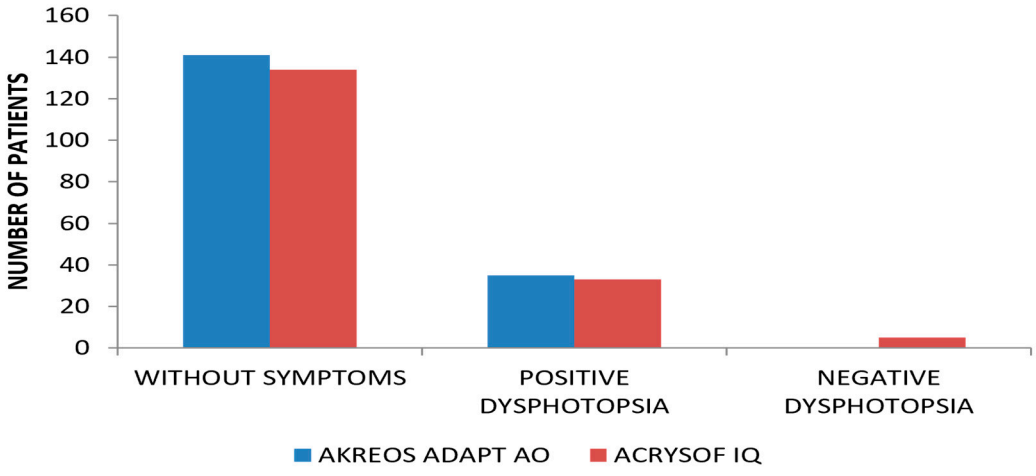


Figure 3. Distribution of dysphotopsia symptoms eight weeks postoperatively according to intraocular lens type.

3.3. Postoperative Year 1

One year after surgery, 16.4% of study patients reported dysphotopsia symptoms. Symptoms of dysphotopsia, either positive or negative, were reported by 17.4% ($n = 30$) of patients in the AcrySof IQ group and by 15.3% ($n = 27$) of those in the Akreos Adapt AO group, corresponding to an absolute between-group difference of 2.1 percentage points (95% CI–5.7 to 9.9); this difference was not statistically significant ($p = 0.665$).

Negative dysphotopsia was reported by four patients in the AcrySof IQ group and by none of the patients in the Akreos Adapt AO group (Fisher's exact test $p = 0.059$; Figure 4). None of the patients reported the symptoms as debilitating. Among all patients with dysphotopsia, 4% described the symptoms as annoying, whereas the remaining patients noticed them only minimally. When dysphotopsia symptoms at one year were analyzed according to the type of clear corneal incision, no statistically significant association was found between incision site and dysphotopsia occurrence (superior 24/147 (16.3%) vs. temporal 33/201 (16.4%); $\chi^2 < 0.01$; $p = 0.982$).

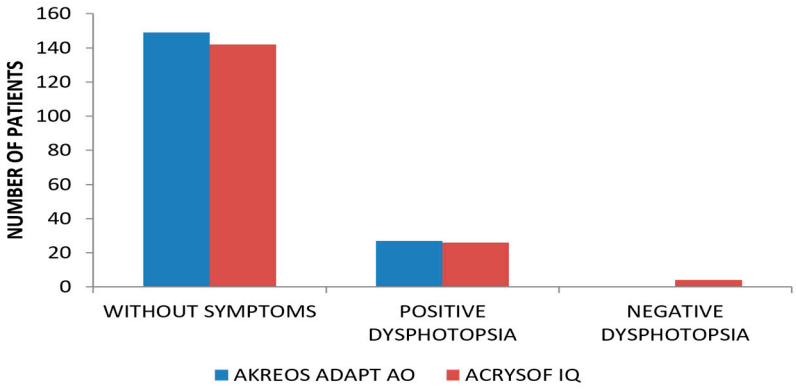


Figure 4. Distribution of dysphotopsia symptoms one year postoperatively according to intraocular lens type.

3.4. Postoperative Year 2

Two years postoperatively, dysphotopsia was reported by 14.7% of study patients. Symptoms of dysphotopsia, either positive or negative, were reported by 15.1% ($n = 26$) of patients in the AcrySof IQ group and by 14.2% ($n = 25$) of those in the Akreos Adapt AO group, corresponding to an absolute between-group difference of 0.9 percentage points (95% CI–6.6 to 8.4); this difference was not statistically significant ($p = 0.880$). Negative dysphotopsia was reported by four patients in the AcrySof IQ group and by none of the patients in the Akreos Adapt AO group (Fisher's exact test $p = 0.059$; Figure 5). None of the patients reported the symptoms as debilitating. Among all patients with dysphotopsia, 2% described the symptoms as annoying, whereas the remaining patients noticed them only minimally. When dysphotopsia symptoms at two years were analyzed according to the type of clear corneal incision, no statistically significant association was found between incision site and dysphotopsia occurrence (superior 24/147 (16.3%) vs. temporal 27/201 (13.4%); $\chi^2 = 0.57$; $p = 0.451$).

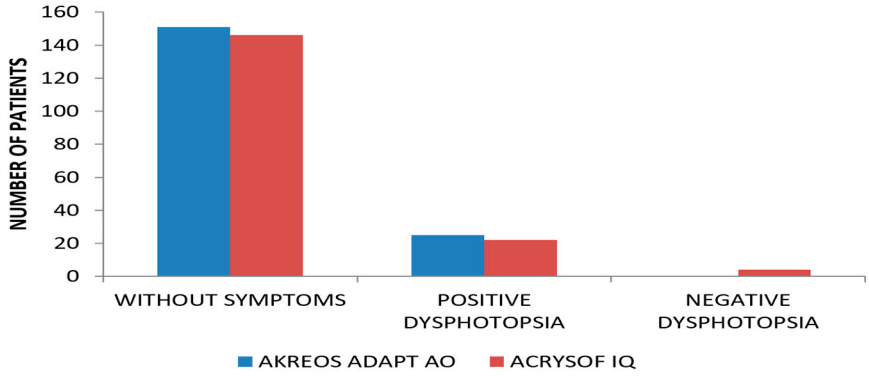


Figure 5. Distribution of dysphotopsia symptoms two years postoperatively according to intraocular lens type.

3.5. Change over Time

The proportion of patients with dysphotopsia at each visit is summarized in Table 4 and Figure 6. In paired within-patient comparisons, dysphotopsia decreased in the whole cohort from one week (116/348, 33.3%) to eight weeks (73/348, 21.0%), one year (57/348, 16.4%), and two years (51/348, 14.7%) (exact McNemar test, Holm-adjusted $p < 0.001$ for each comparison). Between one week and two years, symptoms resolved in 66 patients and newly appeared in one. The decrease was statistically significant at every later visit in the AcrySof IQ group (from 79/172 to 38/172, 30/172, and 26/172; $p < 0.001$ for each comparison). In the Akreos Adapt AO group, the proportion changed little between one week and eight weeks (37/176 vs. 35/176; Holm-adjusted $p = 0.625$) but decreased significantly by one year (27/176; $p = 0.004$) and two years (25/176; $p = 0.001$). Negative dysphotopsia in the AcrySof IQ group decreased from 15 patients at one week to five at eight weeks and four at one year and two years (Holm-adjusted $p = 0.006$, 0.007, and 0.007). In the GEE model adjusted for incision site, age, and sex, the association between IOL type and dysphotopsia differed between visits (IOL type × visit interaction, Wald $\chi^2 = 36.1$, df = 3, $p < 0.001$). Dysphotopsia was more likely in the AcrySof IQ group at one week (adjusted OR 3.27, 95% CI 2.02–5.29; $p < 0.001$), but not at eight weeks (OR 1.17, 95% CI 0.69–1.98; $p = 0.561$), one year (OR 1.19, 95% CI 0.68–2.10; $p = 0.541$), or two years (OR 1.10, 95% CI 0.61–1.99; $p = 0.751$). Incision site (temporal vs. superior, OR 1.07, 95% CI 0.67–1.72; $p = 0.768$), age (OR per 10 years 0.98, 95% CI 0.71–1.34; $p = 0.896$), and sex (female vs. male, OR 0.81, 95% CI 0.51–1.28; $p = 0.360$) were not associated with dysphotopsia. Compared with one week, the odds of dysphotopsia at two years were lower in both groups (AcrySof IQ: OR 0.21, 95% CI 0.14–0.31; Akreos Adapt AO: OR 0.62, 95% CI 0.48–0.81). The results were virtually identical with an independence working correlation (OR at one week 3.27) and without adjustment (OR 3.19).

Table 4. Proportion of patients with dysphotopsia at each visit according to IOL type and absolute between-group differences.

Outcome/Visit	Akreos Adapt AO, n/N (%; 95% CI)	AcrySof IQ, n/N (%; 95% CI)	Difference, pp (95% CI)	*p* □
Any dysphotopsia				
1 week	37/176 (21.0; 15.7–27.6)	79/172 (45.9; 38.7–53.4)	24.9 (15.1–34.1)	<0.001
8 weeks	35/176 (19.9; 14.7–26.4)	38/172 (22.1; 16.5–28.9)	2.2 (−6.4 to 10.8)	0.693
1 year	27/176 (15.3; 10.8–21.4)	30/172 (17.4; 12.5–23.8)	2.1 (−5.7 to 9.9)	0.665
2 years	25/176 (14.2; 9.8–20.1)	26/172 (15.1; 10.5–21.2)	0.9 (−6.6 to 8.4)	0.880
Negative dysphotopsia				
1 week	0/176 (0.0; 0.0–2.1)	15/172 (8.7; 5.4–13.9)	8.7 (4.7–13.9)	<0.001
8 weeks	0/176 (0.0; 0.0–2.1)	5/172 (2.9; 1.2–6.6)	2.9 (0.2–6.6)	0.029
1 year	0/176 (0.0; 0.0–2.1)	4/172 (2.3; 0.9–5.8)	2.3 (−0.2 to 5.8)	0.059
2 years	0/176 (0.0; 0.0–2.1)	4/172 (2.3; 0.9–5.8)	2.3 (−0.2 to 5.8)	0.059

pp, percentage points (AcrySof IQ minus Akreos Adapt AO; Newcombe 95% CI). □ Fisher's exact test; for negative dysphotopsia, Holm-adjusted *p*-values across the four visits are <0.001, 0.086, 0.117 and 0.117.

3.6. Questionnaire Items

Table 5 shows the differences between the two IOL groups based on the questionnaire responses; the distribution of answers to each question is given in Supplementary Table S1. At one week, scores for all six questions were higher, indicating more frequent or more severe symptoms, in the AcrySof IQ group than in the Akreos Adapt AO group (question 1: $Z = -4.00$, $p < 0.001$; questions 2–6: $p \leq 0.010$). At eight weeks, one year, and two

years, a statistically significant between-group difference remained only for question 1, which assessed negative dysphotopsia ($p = 0.023$, 0.042, and 0.042), whereas questions 2–6 did not differ significantly ($p \geq 0.079$). This reflects the small number of patients with persistent negative dysphotopsia, all of whom were in the AcrySof IQ group; when the number of affected patients was compared with Fisher's exact test (Table 4), the difference was nominally significant at eight weeks ($p = 0.029$; $p = 0.086$ after Holm correction) but not at one year and two years ($p = 0.059$).

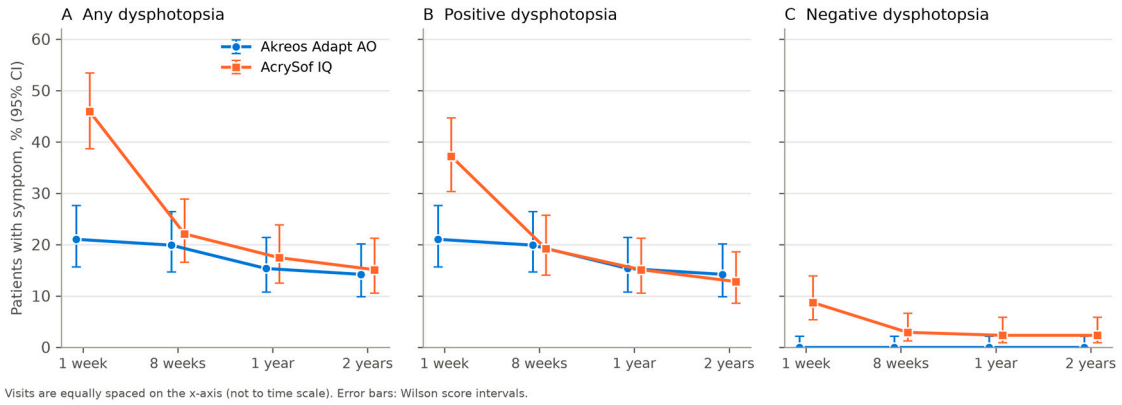


Figure 6. Proportion of patients reporting (**A**) any, (**B**) positive, and (**C**) negative dysphotopsia at each visit according to IOL type. Error bars show Wilson 95% confidence intervals; visits are equally spaced on the *x*-axis.

Table 5. Mann–Whitney test results at one week, eight weeks, one year, and two years postoperatively: differences between the Akreos Adapt AO and AcrySof IQ groups.

	Q1	Q2	Q3	Q4	Q5	Q6
One week						
Mann–Whitney U	13,816.0	12,727.5	13,076.0	13,972.0	14,160.0	14,256.0
Wilcoxon W	29,392.0	28,303.5	28,652.0	29,548.0	29,736.0	29,832.0
Z	−4.00	3.33	3.71	2.59	2.64	3.24
Asymp. Sig. (2-tailed)	<0.001	<0.001	<0.001	0.010	0.008	0.001
Eight weeks						
Mann–Whitney U	14,696.0	15,115.0	14,314.0	14,860.0	14,954.0	14,872.0
Wilcoxon W	30,272.0	30,691.0	29,890.0	30,436.0	30,530.0	30,448.0
Z	2.28	0.03	1.73	0.84	0.75	1.76
Asymp. Sig. (2-tailed)	0.023	0.973	0.084	0.403	0.455	0.079
One year						
Mann–Whitney U	14,784.0	15,073.5	14,592.0	14,688.0	15,130.0	14,958.0
Wilcoxon W	30,360.0	30,649.5	30,168.0	30,264.0	30,706.0	30,534.0
Z	2.03	0.11	1.38	1.45	0.03	1.03
Asymp. Sig. (2-tailed)	0.042	0.913	0.169	0.146	0.977	0.304
Two years						
Mann–Whitney U	14,784.0	14,828.0	14,596.0	15,040.0	15,044.0	15,046.0
Wilcoxon W	30,360.0	29,706.0	30,172.0	30,616.0	30,620.0	30,622.0
Z	2.03	0.59	1.50	0.37	0.48	0.60
Asymp. Sig. (2-tailed)	0.042	0.552	0.134	0.710	0.634	0.549

Asymp. Sig. (2-tailed) = asymptotic significance, two-tailed test, Q = question number. Values recalculated from the patient-level data of the final cohort (Akreos Adapt AO, $n = 176$; AcrySof IQ, $n = 172$). U and W refer to the group with the lower mean rank; higher scores indicate more frequent or more severe symptoms; *p*-values are not adjusted for multiple comparisons.

4. Discussion

The main finding of this study was that dysphotopsia was more frequently reported in the AcrySof IQ group than in the Akreos Adapt AO group during the early postoperative period. At one week after surgery, the overall incidence of dysphotopsia was 33.3%, with symptoms reported by 45.9% of patients in the AcrySof IQ group and by 21.0% of patients in the Akreos Adapt AO group, corresponding to an absolute between-group difference of 24.9 percentage points. This difference persisted after adjustment for incision site, age, and sex (adjusted OR 3.27, 95% CI 2.02–5.29), so the unequal distribution of incision sites between the groups is unlikely to explain it. Negative dysphotopsia was reported by 8.7% of patients in the AcrySof IQ group and by none of the patients in the Akreos Adapt AO group. However, the early difference in any dysphotopsia was not observed at later follow-up visits. At eight weeks, one year, and two years, no statistically significant between-group differences in any dysphotopsia were found, and the absolute differences between the two IOL groups were small (0.9–2.2 percentage points), although the confidence intervals do not exclude differences of up to approximately 11 percentage points. Therefore, the early difference should be interpreted as an association observed during the first postoperative week rather than evidence of overall superiority of one IOL.

During follow-up, the overall incidence of dysphotopsia decreased from 33.3% at one week to 14.7% at two years. In addition, the proportion of patients who described their symptoms as annoying decreased from 11% at one week to 2% at two years, and none of the patients reported debilitating symptoms at any follow-up visit. These findings suggest that, in many patients, dysphotopsia symptoms become less frequent and less bothersome over time after uneventful cataract surgery. Paired within-patient analysis and the GEE model confirmed that this decrease was statistically significant in both IOL groups; in the Akreos Adapt AO group, in which fewer patients were symptomatic early after surgery, the decrease became significant from one year onward. At the two-year visit, only one patient reporting dysphotopsia had been asymptomatic at the first postoperative week.

Our findings are broadly consistent with previous studies showing that dysphotopsia is relatively common in the early postoperative period but often becomes less frequently reported during follow-up. Radford et al., comparing the Akreos Adapt and AcrySof SN60-AT IOLs, found significantly more dysphotopsia with the SN60-AT at one week (37.5% vs. 24.1%; $p = 0.042$), mainly due to negative dysphotopsia, but no significant difference at approximately eight weeks (31.3% vs. 20.7%) [2], a pattern similar to that observed in our study. Osher described negative dysphotopsia in 15.2% of patients on the first postoperative day, with a decline to 3.2% after one year and 2.4% after two and three years [3]. In the present study, the long-term incidence of negative dysphotopsia was similar, with symptoms reported at both one year and two years after surgery by 2.3% (4/172) of patients in the AcrySof IQ group and 1.1% (4/348) of the whole cohort. At the level of individual questionnaire items, a between-group difference persisted only for question 1, consistent with these few persistent cases of negative dysphotopsia occurring exclusively in the AcrySof IQ group.

Several optical and anatomical mechanisms may contribute to pseudophakic dysphotopsia. Holladay et al. identified the sharp or truncated optic edge as an important factor in the development of positive dysphotopsia [7]. This has been supported by a recent comprehensive review, which identified internal reflection from the square IOL edge as a major mechanism of positive dysphotopsia, while emphasizing the multifactorial nature of negative dysphotopsia [4]. Both IOLs used in our study have truncated optic edges and may therefore be associated with edge-related photic phenomena [1,2,7,19].

Regarding IOL characteristics, AcrySof IQ is a hydrophobic acrylic lens with a higher refractive index, whereas Akreos Adapt AO is a hydrophilic acrylic lens with a lower refrac-

tive index [2,9,18]. These differences may have contributed to the higher early incidence of dysphotopsia observed in the AcrySof IQ group. In contrast, a small prospective study (n = 32) comparing hydrophilic and hydrophobic acrylic IOLs found no statistically significant differences in overall halo size or subjective dysphotopsia between the two IOL materials during the first postoperative month [20]. In addition, the two IOLs differ not only in material and refractive index, but also in other design characteristics, including optic and haptic design. Therefore, the observed early between-group difference cannot be attributed solely to hydrophilic or hydrophobic material or to refractive index.

Neuroadaptation may also play an important role in the postoperative course of dysphotopsia. The severity of dysphotopsia does not always correspond to the apparent success of IOL implantation, and persistent symptoms may occur despite otherwise uncomplicated surgery [19]. Holladay has also expressed the view that neural adaptation may reduce dysphotopsia symptoms over time, although it may not eliminate them completely [21]. This mechanism may partly explain why symptoms in our cohort were less frequently reported and less often described as annoying during later follow-up.

Other IOL-related characteristics may also influence dysphotopsia symptoms. Bournas et al. reported an inverse relationship between IOL optic diameter and the likelihood of dysphotopsia [22]; a possible explanation is that the edge of a larger optic is less likely to lie within the patient's field of view. Conversely, Arnold, who compared in-the-bag poly(methyl methacrylate) IOLs with 5.0 × 6.0-mm oval, 5.5-mm and 7.0-mm round optics, found that about 20% of patients in each group reported photic phenomena, with similar symptoms and rates of persistent phenomena between the groups [23]. Since both IOLs used in our study had the same optic diameter of 6.0 mm, differences in optic diameter are unlikely to explain the early between-group difference observed in our cohort.

Several surgical options have been described for persistent negative dysphotopsia: secondary piggyback IOL implantation and reverse optic capture resolved or reduced symptoms, whereas in-the-bag IOL exchange and iris suture fixation did not [12]; bag-to-sulcus IOL exchange was effective in a small series [11], and additional surgical experiences have been reported in smaller clinical publications and correspondence [17,24]. To reduce the likelihood of pseudophakic negative dysphotopsia in the early postoperative period, Manasseh et al. described horizontal positioning of the optic–haptic junction as a simple intraoperative maneuver that was associated with a lower observed incidence of negative dysphotopsia, although the reported difference did not reach conventional statistical significance (9/110 vs. 18/110 eyes; $p = 0.072$) [25]. In a subsequent randomized controlled trial, Pamulapati et al. found that horizontal positioning of the optic–haptic junction was associated with the lowest rate of negative dysphotopsia 4–6 weeks after surgery [26]. However, other studies have not consistently confirmed a strong effect of haptic orientation, supporting the view that negative dysphotopsia is multifactorial and may not be preventable by a single intraoperative maneuver [27]. In our study, no patient required surgical intervention for persistent dysphotopsia, and no IOL exchange was performed.

The role of incision location remains uncertain. Osher suggested that early transient negative dysphotopsia may be related to the surgical incision, particularly temporal clear corneal incisions, possibly because incision-related corneal edema may contribute to transient symptoms [3]. However, previous findings have been inconsistent. For example, Cooke described a patient in whom negative dysphotopsia developed after surgery through superior scleral tunnel incisions and resolved immediately after IOL exchange performed through temporal corneal incisions [28]. Radford et al. observed numerically higher rates of dysphotopsia after superior scleral tunnel incisions than after temporal clear corneal incisions, although the differences were not statistically significant in their small sample [2]. In the present study, when dysphotopsia symptoms were analyzed according to the type of

clear corneal incision, no statistically significant association was found between incision site and dysphotopsia occurrence at one week, eight weeks, one year, or two years, and incision site was not associated with dysphotopsia in the multivariable GEE model either (OR 1.07, 95% CI 0.67–1.72).

The postoperative decrease in dysphotopsia symptoms may be influenced by several factors, including neuroadaptation and changes in the capsular bag. Ray-tracing modeling by Hong et al. showed that the optical phenomena underlying negative dysphotopsia are mainly influenced by capsulorrhexis size and the optical diffusiveness of the capsular bag [29], and opacification of the peripheral nasal capsule has been proposed as an explanation for its spontaneous improvement [5]. In the present study, negative dysphotopsia was reported only in the AcrySof IQ group (8.7% of these patients at one week, 2.9% at eight weeks, and 2.3% at one year and two years postoperatively). This decrease was statistically significant in paired analysis (exact McNemar test, Holm-adjusted $p \leq 0.007$), although the mechanism cannot be determined from our data. No patient in the Akreos Adapt AO group reported negative dysphotopsia at any visit. Negative dysphotopsia is not limited to hydrophobic IOLs: in a randomized trial it occurred, mostly transiently, in 7% of eyes with a hydrophilic acrylic IOL, compared with 11% with a hydrophobic IOL ($p = 0.17$) [30], and negative dysphotopsia severe enough to be treated with Nd:YAG anterior capsulectomy has been reported in five eyes with the Akreos AO MI60L, another hydrophilic acrylic IOL of the same family [31]. The absence of cases in our Akreos Adapt AO group is therefore compatible with a low incidence (upper limit of the 95% CI, 2.1%) and should not be interpreted as immunity to negative dysphotopsia. It may reflect the lower refractive index and the different optic and haptic design of this IOL. In addition, the first assessment at one week, after the first postoperative days in which transient negative dysphotopsia is most often reported [3,30], probably lowered the observed incidence in both groups.

This study has several limitations that should be considered. First, this was a non-randomized prospective observational study, and allocation to IOL type and incision site was not randomized. Therefore, potential selection bias and baseline differences between groups cannot be fully excluded. In particular, the groups differed in the distribution of incision sites. Although the GEE analysis was adjusted for incision site, age, and sex, residual confounding by ocular factors that were not recorded and may influence dysphotopsia, such as pupil size, axial length, anterior chamber depth, and angle kappa, cannot be excluded. Future studies using randomized designs and recording ocular biometric parameters may help clarify independent predictors of dysphotopsia. Second, the assessment of dysphotopsia was based on patient-reported symptoms using a modified questionnaire rather than objective measurements or a fully validated standardized instrument. Although the questionnaire was based on previously published dysphotopsia questionnaires and addressed clinically relevant symptoms, the lack of formal validation may limit the reproducibility of the findings and comparability with studies using validated patient-reported outcome measures. Third, no formal a priori sample size calculation was performed, and the sample size was determined pragmatically by the number of eligible consecutive patients enrolled during the predefined recruitment period. Therefore, the study should be interpreted as a prospective observational study with a pragmatic sample size. With 176 and 172 patients, the study had 80% power to detect only absolute between-group differences of approximately 12–14 percentage points in any dysphotopsia (two-sided $\alpha = 0.05$), so smaller differences cannot be excluded. Fourth, there was substantial loss to follow-up between initial enrollment and the final analysis cohort. Although 488 patients were initially enrolled, the final analysis included 348 patients who completed all scheduled follow-up visits; therefore, the long-term results are based on a complete-case analysis. This may have introduced attrition bias, as patients who did not complete follow-up may have differed from those included in the

final analysis in terms of baseline characteristics, postoperative symptoms, satisfaction, or general health status. Consequently, the reported long-term incidence of dysphotopsia may either underestimate or overestimate the true frequency of persistent symptoms in the initially enrolled population. Although the reasons for exclusion and loss to follow-up were recorded and are presented in the patient flow diagram (Figure 1), detailed baseline data were not available for all patients who did not complete follow-up, so a formal comparison between included patients and those lost to follow-up could not be performed. Finally, although only one eye per patient was included in the analysis to avoid inter-eye correlation, the status of the fellow eye may have influenced subjective visual perception, symptom reporting, and overall satisfaction. Therefore, the possible effect of the fellow eye cannot be fully excluded.

5. Conclusions

A considerable proportion of pseudophakic patients reported positive or negative dysphotopsia after uneventful cataract surgery, particularly during the early postoperative period. During the two-year follow-up, dysphotopsia symptoms became less frequent and less bothersome, and none of the patients reported debilitating symptoms or required surgical treatment. These findings may be useful for postoperative counseling, as patients who experience photic symptoms after cataract surgery can be reassured that such symptoms often become less pronounced over time.

No statistically significant association was observed between clear corneal incision site and dysphotopsia occurrence. Early postoperative dysphotopsia was more frequently reported in the AcrySof IQ group than in the Akreos Adapt AO group; however, this finding should be interpreted as an association rather than evidence of a direct causal effect of IOL type. No statistically significant between-group differences in the overall frequency of dysphotopsia were observed at eight weeks, one year, or two years after surgery, and the incidence of dysphotopsia became similar between the two IOL groups during follow-up; the few persistent cases of negative dysphotopsia all occurred in the AcrySof IQ group.

Although IOL material and refractive index may contribute to dysphotopsia symptoms, the two IOLs evaluated in this study differ in several characteristics, including material, refractive index, and design features. Therefore, the observed early between-group difference cannot be attributed solely to hydrophilic or hydrophobic material or refractive index. Further studies are needed to clarify the relative contribution of IOL-related, anatomical, and patient-specific factors, particularly in relation to negative dysphotopsia.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/medicina62112139/s1, Table S1: Distribution of answers to the six questionnaire items at each visit according to the implanted IOL, *n* (%). 1 = not noticed; 2 = noticed but minimal; 3 = noticed and annoying; 4 = noticed and debilitating.

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Abbreviations

The following abbreviations are used in this manuscript:

AO	Advanced Optics
CI	Confidence Interval
GEE	Generalized Estimating Equations
IOL	Intraocular Lens
OR	Odds Ratio
PCO	Posterior Capsule Opacification
QoL	Quality of Life
SD	Standard Deviation
SMD	Standardized Mean Difference
US	Ultrasound

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