Comparison of the Effects of Hydrophobic and Hydrophilic Acrylic Intraocular Lenses on Lenticular Astigmatism

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ABSTRACT

Purpose: The aim of this study was to investigate the extent of lenticular astigmatism (LA) and the factors affecting LA in patients implanted with hydrophobic (HPo) and hydrophilic (HPi) acrylic IOLs.

Methods: This retrospective study included patients who underwent cataract surgery at the Çanakkale Onsekiz Mart University Ophthalmology Clinic between 2020 and 2025. Patient demographics and ophthalmologic examination findings were recorded. Autorefractometry data obtained at the first postoperative month, preoperative anterior chamber depth (ACD), axial length (AL), postoperative keratometry values, and dioptric power of the implanted IOL (IOL-D) were included in the study. Postoperative LA values were calculated using two different artificial intelligence programs using the Jaffe vector analysis method. Factors affecting LA were investigated using one-way linear regression analysis (LRA).

Results:A total of 58 patients were included in the study: 29 patients implanted with an HPo acrylic monoblock foldable IOL (Group 1) and 29 patients implanted with an HPi acrylic IOL (Group 2). No statistically significant differences were found between the groups in terms of age, gender, AL, ACD, IOL-D, keratometry, and LA ($p > 0.05$). LRA in Group 1 found that the preoperative ACD was significantly associated with the LA, and this variable explained 19.1% of the LA variance ($p = 0.02$; 95% CI: 0.051–0.683).

Conclusions: In the HPo IOL group, a significant and positive correlation was found between preoperative ACD and LA. Therefore, it is recommended that preoperative ACD be taken into account to optimize refractive outcomes in patients planned for HPo acrylic IOL implantation.

Keywords: cataract surgery, hydrophobic IOL, hydrophilic IOL, lenticular astigmatism, anterior chamber depth

INTRODUCTION

Cataract surgery is one of the most commonly performed surgical procedures worldwide, with the primary goal of restoring visual acuity and optimizing refractive outcomes.[1] While modern phacoemulsification techniques and advanced intraocular lens (IOL) designs have significantly improved postoperative visual outcomes, residual refractive errors, particularly astigmatism, remain a concern for both patients and surgeons.[2] Postoperative astigmatism can arise from multiple sources, including preoperative keratometry values, wound-induced astigmatism, and IOL positioning irregularities—the latter being attributed to IOL tilt, decentration, or capsular interactions that affect

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the effective lens position within the eye and cause lenticular astigmatism.[3–5]

The choice of IOL material, particularly between hydrophobic (HPo) and hydrophilic (HPi) acrylic lenses, has been shown to influence various postoperative outcomes, including posterior capsular opacification rates and IOL stability. HPo IOLs demonstrate stronger and more rapid capsular adhesion compared to HPi counterparts, potentially affecting IOL positioning and subsequent optical performance.[6,7] However, there is limited evidence regarding the relationship between IOL material properties and lenticular astigmatism, and further research is needed to identify factors that may predict postoperative astigmatic outcomes in different IOL materials.

This study aims to compare the magnitude of lenticular astigmatism between HPo and HPi acrylic IOLs following uncomplicated cataract surgery and to identify potential predictive factors associated with lenticular astigmatism development in each IOL group.

METHODS

Study Design and Setting

This retrospective comparative cohort study was conducted at the Department of Ophthalmology, Canakkale Onsekiz Mart University Faculty of Medicine, Canakkale, Turkey. The study population comprised patients who underwent uncomplicated phacoemulsification cataract surgery with implantation of either HPo or HPi acrylic IOLs between January 2020 and April 2025. Demographic characteristics, preoperative parameters, and 1-month postoperative data were retrospectively collected from medical records. The study protocol was approved by the Non-Interventional Clinical Research Ethics Committee of Canakkale Onsekiz Mart University and conducted in accordance with the principles of the Declaration of Helsinki. Informed consent for surgery was obtained from all participants in accordance with institutional protocols.

Study Population

A total of 58 eyes from 58 patients diagnosed with age-related cataract were included in the study following uncomplicated phacoemulsification surgery. The cohort was divided into two groups: 29 eyes received HPo IOLs (Zeiss CT Lucia 621/PY (Carl Zeiss Meditec AG, Jena, Germany)) and 29 eyes received HPi IOLs (Acriva UD 613 (VSY Biotechnology BV, Amsterdam, The Netherlands)). Exclusion criteria included history of ocular trauma, intraoperative or postoperative complications, unsuccessful continuous curvilinear capsulorhexis, poor adherence to postoperative medical therapy, prior intraocular or ocular surface surgery history, zonular instability, and postoperative capsular phimosis.

Outcome Measures and Variables

The primary outcomes were the magnitude of postoperative lenticular astigmatism at 1 month and the identification of factors associated with lenticular astigmatism in eyes implanted with either HPo or HPi IOLs. Lenticular astigmatism was calculated using vector analysis methods, as described by Alpins et al., incorporating postoperative total refractive astigmatism and corneal keratometric values to determine the vectorial difference.8 LA was derived using vector analysis based on the Jaffe/Alpins method, specifying the use of power vector components (J0 and J45), the reference meridian, and the equation used to obtain the final LA magnitude in diopters. LA was manually cross-checked by the investigators, without any reference to AI tools.

The primary exposure variable in this study was IOL material type, which was analyzed in relation to postoperative lenticular astigmatism outcomes. Predictor and confounding variables included age, sex, preoperative axial length (AL), preoperative anterior chamber depth (ACD), preoperative and postoperative keratometric values (flat and steep K values), and the dioptric power (D) of the implanted IOL, based on their established relevance in lenticular astigmatism development.

Data Collection and Measurements

All data were extracted from medical records. Preoperative biometric measurements, including AL, ACD, and keratometric values, were obtained using the Zeiss IOLMaster 500 (Carl Zeiss Meditec AG, Jena, Germany). Postoperative refractive cylinder measurements were performed using the Nidek ARK-500A Autorefractor-Keratometer (Nidek Co., Ltd., Gamagori, Aichi, Japan).

Bias Minimization Strategies

To minimize bias, only patients with complete records and standardized follow-up were included. All surgeries were performed by experienced cataract surgeons using standard stop and chop phacoemulsification technique via 2.8 mm incision. Identical equipment and protocols were used for all measurements. Lenticular astigmatism calculations were independently validated, confirming internal consistency.

Sample Size and Statistical Analysis

As a retrospective study, no formal sample size calculation was performed, and all patients meeting the inclusion and exclusion criteria were enrolled, totaling 58 eyes. Quantitative variables were analyzed as continuous data, with normality assessed using the Shapiro-Wilk test. Normally distributed variables are presented as mean ± standard deviation, while non-normally distributed variables are expressed as median (range). Independent samples t-test or Mann-Whitney U test were employed for between-group comparisons depending on data distribution, while categorical variables were compared using chi-square test. Spearman correlation analysis and univariable linear regression were used to explore relationships with lenticular astigmatism. Because our sample size (n = 58) was relatively small for a stable multivariable analysis including several correlated biometric variables, we intentionally limited our analysis to univariate regression to avoid overfitting. Statistical analyses were conducted using SPSS version 26 (IBM Corp.), and statistical significance was set at $p < 0.05$.

RESULTS

Participants and Descriptive Data

The study included 58 patients: 29 in the HPo group and 29 in the HPi group. The mean age was 70.72 ± 7.56 years (HPo) and 69.31 ± 10.96 years (HPi). The HPo group included 12 women and 17 men; the HPi group, 14 women and 15 men. The mean AL was 23.38 ± 1.05 mm (HPo) and 23.37 ± 0.91 mm (HPi). Mean ACD was 3.36 ± 0.46 mm (HPo) and 3.21 ± 0.50 mm (HPi). Mean IOL power was 22.17 ± 1.58 D (HPo) and 21.29 ± 1.57 D (HPi). Preoperative K1/K2 values were 43.02 ± 1.75 D / 44.05 ± 1.68 D (HPo) and 43.06 ± 1.31 D / 44.10 ± 1.51 D (HPi). Postoperative K1/K2 values were 43.07 ± 1.82 D / 43.93 ± 1.63 D (HPo) and 42.99 ± 1.12 D / 43.94 ± 1.16 D (HPi). Median lenticular astigmatism was 0.36 D (0.03–1.48) (HPo) and 0.40 D (0–2.46) (HPi). Median postoperative total astigmatism was 0.75 D (0.25–2.00) (HPo) and 0.75 D (0.25–2.50) (HPi). No statistically significant differences were observed between the groups across all measured parameters; the results of intergroup comparisons and corresponding p-values are presented in **Table 1**.

Table 1. *Demographic and Pre/Postoperative Ocular Characteristics of Patients in the HPo and HPi IOL Groups*

Group	HPo	HPi	p value
Age (yr) (Mean±SD)	70.72 ± 7.56	69.31 ± 10.96	0.88*
Sex (n) (Female/ Male)	12/17	14/15	0.6*
Preoperative AL (mm) (Mean±SD)	23.38 ± 1.05	23.37 ± 0.91	0.98**
Preoperative ACD (mm) (Mean±SD)	3.36 ± 0.46	3.21 ± 0.50	0.26**
Preoperative K1 (D) (Mean±SD)	43.02 ± 1.75	43.06 ± 1.31	0.92**
Preoperative K2 (D) (Mean±SD)	44.05 ± 1.68	44.10 ± 1.51	0.91**
Postoperative K1 (D) (Mean±SD)	43.07 ± 1.82	42.99 ± 1.12	0.85**
Postoperative K2 (D) (Mean±SD)	43.93 ± 1.63	43.94 ± 1.16	0.85**
Diopter of IOL (D) (Mean±SD)	22.17 ± 1.58	21.29 ± 1.57	0.094**
LA (D) (Median (Range))	0.36 D (0.03–1.48)	0.40 D (0–2.46)	0.98*
Total Astigmatism (D) (Median (Range))	0.75 D (0.25–2.00)	0.75 D (0.25–2.50)	0.78*

Hpo: Hydrophobic intraocular lens group, HPi Hydrophilic intraocular lens group, SD: Standard deviation, AL: Axial length, ACD: Anterior chamber depth, K1: Flat keratometry, K2: Steep keratometry, D: Diopter, IOL: Intraocular lens, LA: Lenticular astigmatism, * Mann-Whitney U test, ** Independent samples t test

Outcome Data and Main Results

In the HPo group, the median lenticular astigmatism at 1 month postoperatively was 0.36 D (range: 0.03–1.48), while in the HPi group, it was 0.40 D (range: 0–2.46). There was no statistically significant difference between the two groups in terms of lenticular astigmatism ($p > 0.05$).

In the Hpo group, Spearman correlation analysis revealed a statistically significant moderate positive correlation between preoperative ACD and the magnitude of lenticular astigmatism ($\rho = 0.444$, $p = 0.016$). Simple linear regression analysis confirmed this association (p=0.02), showing that ACD accounted for approximately 19.1% of the variability in lenticular astigmatism ($R^2 = 0.191$). The resulting regression equation was $y = 3.12 + 0.47x$, indicating that each 1.0 mm increase in ACD corresponded to an estimated 0.47 D increase in lenticular astigmatism. On the other hand, in the HPi, the correlation between ACD and lenticular astigmatism did not reach statistical significance ($\rho = -0.071$, $p = 0.72$), and the linear regression model demonstrated poor explanatory power ($R^2 = 0.019$) **(Table 2)**. The corresponding regression equation was $y = 3.29 - 0.09x$, suggesting a negligible and inverse relationship.

These findings were further illustrated by scatter plots depicting the relationship between lenticular astigmatism and preoperative ACD in both groups **(Figure 1 and 2)**. In the HPo group, the data points showed a clear positive linear trend, in line with the regression model ($R^2 = 0.191$), supporting a meaningful association. In contrast, the HPi group displayed a dispersed pattern with no evident linear relationship, consistent with the weak and statistically insignificant regression model ($R^2 = 0.019$).

Table 2. *Univariate Linear Regression Analysis for Lenticular Astigmatism in HPo and HPi IOL Groups*

Predictor Variable	Group	β Coefficient (Unstandardized)	95% CI for β	Standard Error	t-value	p-value	R²
Age	HPo	-0.004	(-0.026 to 0.016)	0.011	-0.409	0.67	0.006
	HPi	-0.008	(-0.030 to 0.020)	0.013	-0.561	0.57	0.012
Sex	HPo	0.199	(-0.065 to 0.501)	0.161	1.242	0.2	0.054
	HPi	0.216	(-0.363 to 0.797)	0.287	0.75	0.45	0.02
AL	HPo	0.061	(-0.119 to 0.214)	0.077	0.789	0.51	0.023
	HPi	-0.191	(-0.419 to 0.151)	0.158	-1.214	0.16	0.052
ACD	HPo	0.405	(0.051 to 0.683)	0.161	2.523	**0.02**	0.191
	HPi	-0.211	(-0.893 to 0.253)	0.292	-0.721	0.48	0.019
IOL Power (D)	HPo	-0.063	(-0.185 to 0.009)	0.051	-1.248	0.17	0.055
	HPi	-0.034	(-0.218 to 0.125)	0.094	-0.367	0.68	0.005

HPo: Hydrophobic intraocular lens group, HPi: Hydrophilic intraocular lens group, AL: Preoperative axial length, ACD: Preoperative axial length, IOL: Intraocular lens, D: Diopter

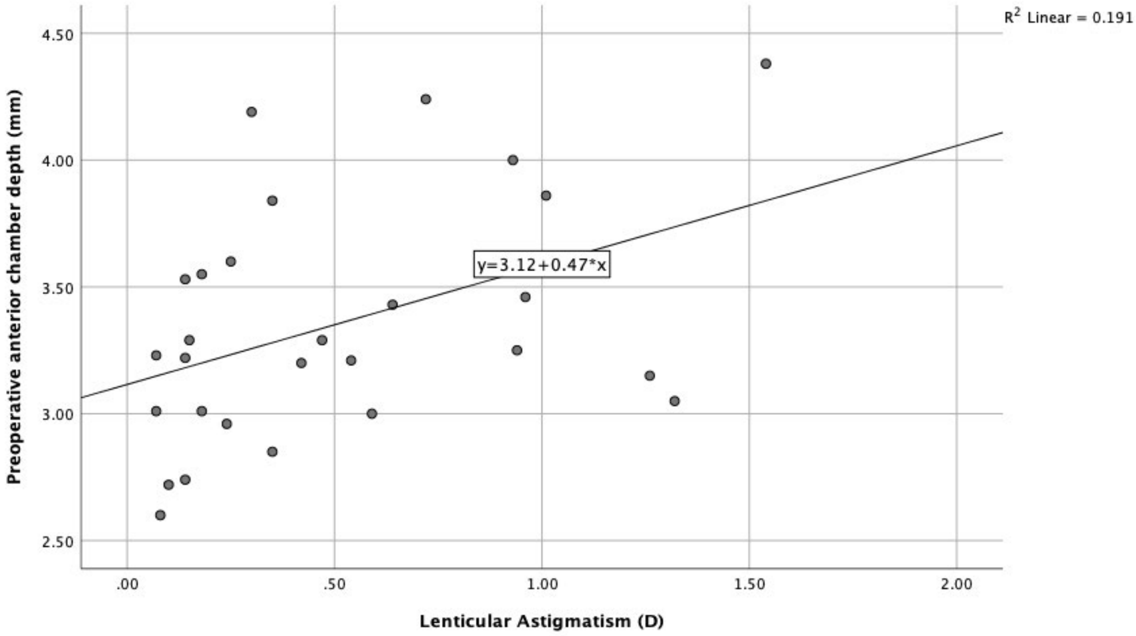

Figure 1. *Scatter Plot for Hydrophobic Intraocular Lens Group*

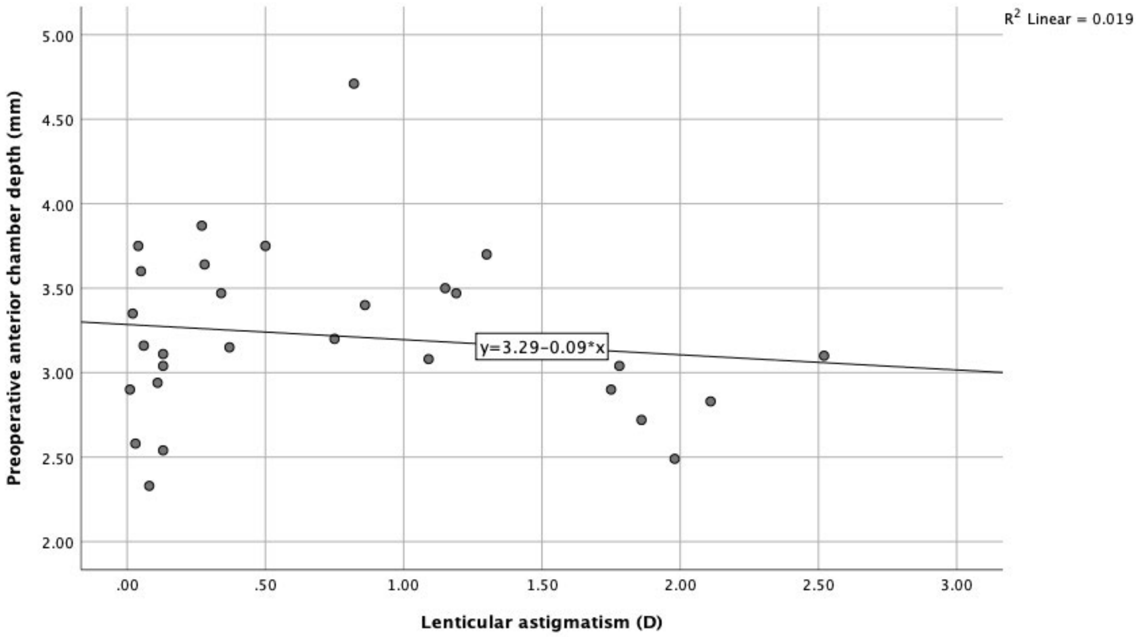

Figure 2. *Scatter Plot for Hydrophilic Intraocular Lens Group*

DISCUSSION

This study evaluated early postoperative lenticular astigmatism after uncomplicated cataract surgery and explored whether IOL material and preoperative biometric factors were associated with its magnitude. Overall, lenticular astigmatism at 1 month was low and did not differ significantly between hydrophobic (HPo) and hydrophilic (HPi) acrylic IOLs, suggesting that under routine surgical conditions both materials achieve comparable early optical alignment and refractive stability. Although the regression model showed a statistically significant association, most of the variance remained unexplained, suggesting that additional factors (e.g., capsular bag behavior, postoperative IOL tilt/decentration, and measurement variability) likely contribute to lenticular astigmatism. To contextualize the practical impact, the regression equation implies that across typical preoperative ACD values, the expected change in lenticular astigmatism is incremental rather than deterministic; therefore, ACD should be viewed as a potential contributing factor rather than a stand-alone predictor of postoperative astigmatic outcomes.

Lenticular astigmatism can be analyzed using vector mathematics by decomposing astigmatic values into vectors characterized by both magnitude and direction. Since astigmatism has a directional component, it is well-suited to vectorial representation.[8,9] In this study, total and corneal astigmatism values were decomposed into their respective vectors, and lenticular astigmatism magnitude was calculated based on the vectorial difference between them.

Both hydrophobic and hydrophilic acrylic IOLs are widely used in cataract surgery and are known to provide favorable visual and safety outcomes.[10] However, hydrophobic IOLs tend to adhere more strongly and rapidly to the posterior capsule compared to hydrophilic IOLs, leading to significantly lower rates of posterior capsular opacification (PCO) over a 1- to 3-year period. Although the precise timing of full adhesion remains unclear, the long-term advantage of hydrophobic IOLs in preventing PCO has been well documented in the literature.[6,7,11,12] The primary contributors to lenticular astigmatism following cataract surgery include IOL tilt and decentration, as well as posterior capsular fibrosis—factors that can influence lens position and thereby induce astigmatic changes.[13–15] Given the differences in posterior capsular adhesion characteristics between hydrophobic and hydrophilic IOLs, it is theoretically plausible that these materials may differentially affect IOL alignment stability. To explore this hypothesis, vector analysis was employed in the present study to compare the magnitude of lenticular astigmatism between the two groups. However, the results demonstrated no statistically significant difference in lenticular astigmatism between hydrophobic and hydrophilic IOLs at 1 month postoperatively. Previous studies have shown that, in standard cataract surgery, both hydrophilic and hydrophobic IOLs generally achieve stable postoperative positioning with low rates of tilt and decentration, with no significant difference between the two materials under routine surgical conditions.[10,16,17] However, hydrophilic IOLs have been associated with a higher risk of clinically significant tilt or decentration in more complex scenarios, such as eyes with a history of pars plana vitrectomy.[18,19]

Several studies in the literature have focused on quantifying IOL tilt and decentration, as well as identifying the anatomical and surgical factors contributing to these postoperative misalignments. However, it is noteworthy that most of these investigations do not specifically examine lenticular astigmatism as an outcome. Factors shown to influence IOL positioning include preexisting crystalline lens tilt or decentration, axial length—where shorter eyes tend to exhibit more tilt and longer eyes more decentration—and a history of pars plana vitrectomy or intraocular silicone oil tamponade, both of which have been associated with increased risks of IOL malposition.[18,20–22] These factors and IOL material may theoretically contribute to lenticular astigmatism by altering the effective lens position and optical alignment. However, in the present study, no statistically significant difference in lenticular astigmatism was observed between hydrophobic and hydrophilic IOL groups at 1 month postoperatively. This suggests that any material-related differences in IOL positioning may be either minimal or not yet clinically manifest within the early postoperative period.

When evaluating potential predictors of lenticular astigmatism, the present study found no significant associations in the hydrophilic IOL group. In contrast, in the hydrophobic IOL group, a slightly positive correlation was observed between preoperative ACD and lenticular astigmatism. We thought that ACD accounts for a limited proportion of the variance, suggesting that other unmeasured factors may likely contribute to LA. To date, no studies have directly investigated the relationship between preoperative ACD and the magnitude of lenticular astigmatism. However, a limited number of reports have examined the association between ACD and IOL positioning parameters, such as tilt and decentration—both recognized contributors to refractive error. In contrast to our findings, Wu et al. reported that a shallower ACD was associated with greater IOL tilt, whereas Fus et al. identified only a weak and statistically nonsignificant correlation between preoperative ACD and IOL decentration or tilt.[23,24] On the other hand, supporting our findings, Xu et al. reported a modest but significant relationship between deeper ACD and increased vertical IOL decentration—which can increase lenticular astigmatism—after cataract surgery, suggesting that ACD may influence IOL positioning through multiple mechanisms. The authors proposed that IOLs are more likely to shift within the more spacious intraocular environment provided by deeper anterior chambers.[25] Overall, these discrepancies may be reflecting differences in patient populations, IOL types, imaging techniques, or follow-up durations across studies.

This study has several limitations that should be acknowledged. The 1-month follow-up is a major limitation, as capsular contraction and IOL settling (including tilt and decentration) may continue beyond this early period; therefore, longer-term prospective studies with at least 6–12 months of follow-up are needed to confirm the stability of our findings and determine whether the observed ACD–lenticular astigmatism relationship persists or evolves over time. Second, the relatively small sample size (29 eyes per group) is an other major limitation that reduces statistical power and increases the risk of type II error, particularly for between-group comparisons. Third the retrospective design inherently limits causal inferences and depends on the completeness and accuracy of existing medical records. Fourth, as a single-center study, the findings may not be generalizable to broader populations or different surgical settings. Fifth, the analysis focused primarily on biometric and refractive parameters; other IOL-related factors such as haptic design, posterior surface geometry, or capsular interaction were not assessed and may also contribute to astigmatic outcomes.

In conclusion, this study demonstrated that hydrophobic and hydrophilic acrylic IOLs produce comparable levels of lenticular astigmatism at 1 month following uncomplicated cataract surgery. However, preoperative anterior chamber depth emerged as a significant predictor of lenticular astigmatism specifically in eyes implanted with hydrophobic IOLs, with deeper chambers associated with greater astigmatic outcomes. These findings suggest that IOL material properties may influence the relationship between anatomical factors and postoperative refractive outcomes. Larger, adequately powered studies with longer follow-up are needed to confirm the stability of these observations and to clarify their clinical relevance, including potential material-specific effects on IOL positioning and optical performance.

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