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Characteristics and Risk Factors of Intraocular Lens Tilt and Decentration of Phacoemulsification After Pars Plana Vitrectomy

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Purpose: The purpose of this study was to investigate the characteristics and risk factors of intraocular lens (IOL) tilt and decentration of phacoemulsification after pars plana vitrectomy (PPV) using swept-source optical coherence tomography (SS-OCT).

Methods: One hundred four eyes with prior PPV and 104 eyes without PPV undergoing uneventful cataract surgery were enrolled in this study. IOL tilt and decentration were measured by SS-OCT (CASIA2) 3 months postoperatively.

Results: The mean IOL tilt and decentration were greater in the PPV group (5.36 ± 2.50 degrees and 0.27 ± 0.17 mm, respectively) than in the non-PPV group (4.54 ± 1.46 degrees, $P = 0.005$; 0.19 ± 0.12 mm, $P < 0.001$, respectively). Multiple logistic regression showed that silicone oil (SO) tamponade (odds ratio [OR] = 5.659, $P = 0.021$) and hydrophilic IOL (OR = 5.309, $P = 0.022$) were associated with IOL tilt over 7 degrees, and diabetes mellitus (DM; OR = 5.544, $P = 0.033$) was associated with IOL decentration over 0.4 mm. Duration of SO tamponade was positively correlated with IOL tilt ($P = 0.014$) and decentration ($P < 0.001$). The internal total higher-order aberration, coma, trefoil, and secondary astigmatism in the PPV group were higher than in the non-PPV group, and positively correlated with IOL tilt ($P < 0.05$).

Conclusions: Patients with prior vitrectomy had greater IOL tilt and decentration than the non-PPV group. Longer duration of SO tamponade, hydrophilic IOL, as well as DM were the risk factors of greater IOL tilt and decentration in patients with prior PPV.

Translational Relevance: Optically sophisticated designed IOLs should be used cautiously in vitrectomized eyes.

Introduction

Cataract formation is the most common postoperative complication of pars plana vitrectomy (PPV).[1,2] As PPVs have achieved high anatomic success rates and satisfactory functional outcomes due to the improved vitreoretinal surgical techniques, more and more surgeons attempt to use the sophisticated designed intraocular lens (IOL), such as aspheric, multifocal, and astigmatism correcting IOLs in vitrectomized eyes.[3,4] However, optically sophisticated designed IOLs are more sensitive to tilt and decentration compared with conventional IOLs.[5,6] It has been reported that visual performance of multifocal and toric IOLs was profoundly affected by decentration and tilt.[7–11] Furthermore, optical quality of aspheric IOL even decreased below that of conventional spherical IOL when decentration was greater than 0.4 mm and tilt was more than 7 degrees.[12] Therefore, it is imperative to investigate the characteristics and the risk factors of IOL tilt and decentration in patients with prior PPV.

Exact positioning and alignment of the IOL with the visual axis are the prerequisites of high-quality visual performance after cataract surgery. A certain degree of IOL tilt and decentration occur after

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cataract surgery, most of which are clinically tolerant.[13] However, greater IOL tilt and decentration could cause defocus, astigmatism, and coma-like aberration, leading to the deterioration of visual function.[5] Previous studies have reported the increased IOL tilt and decentration in special populations, such as patients with pseudoexfoliation syndrome or undergoing IOL scleral-suturing.[14,15] Few studies have assessed the impact of intravitreal tamponades (IVTs) on IOL tilt and decentration of combined phacoemulsification-vitrectomy, but the conclusions were inconsistent.[16–18] The possible explanation for the variable results is that the air tamponade may induce greater IOL position abnormality in cases with large continuous curvilinear capsulorhexis (CCC) than those with small CCC.[16] As far as we known, there are no published reports regarding IOL tilt and decentration of phacoemulsification in patients with prior PPV.

Several methods have been used to measure IOL tilt and decentration, such as the Scheimpflug method,[5,14,19] the Purkinje method,[20,21] or anterior segment optical coherence tomography (OCT).[15] These methods utilize different reference axes, the pupillary or visual axis, to assess the IOL position. However, the method using pupillary axis can be affected by the shape of the pupil.[22] Currently, the newly developed swept-source OCT (SS-OCT; CASIA2; Tomey Corp., Nagoya, Japan) can automatically measure IOL tilt and decentration relative to the corneal topographic axis and showed good accuracy and repeatability.[23,24] In this study, we measured IOL tilt and decentration in vitrectomized eyes using SS-OCT (CASIA2) and aimed to investigate whether prior PPV could increase the IOL tilt and decentration and identify the risk factors.

Materials and Methods

This study was approved by the Institutional Review Board/Ethics Committee of Zhongshan Ophthalmic Center, Sun Yat-sen University (2019KYPJ033), and the tenets of the Declaration of Helsinki were followed throughout this study. All enrolled patients were willing and able to participate in the current study, and written informed consent was obtained from each participant.

Participants

We retrospectively reviewed the medical charts of patients who had phacoemulsification and IOL implantation from December 2018 to August 2019 at the Cataract Department of Zhongshan Ophthalmic Center, Sun Yat-sen University, China. Patients with prior PPV were selected as the PPV group. The inclusion criteria were as follows: (1) patients who underwent uneventful phacoemulsification after PPV, (2) in-the-bag IOL implantation, and (3) willingness to participate in the study. The exclusion criteria were as follows: (1) multiple PPVs; (2) crystalline lens injury caused by cutter during PPV; (3) silicone oil (SO) tamponade has not been removed before cataract surgery or obvious SO remnants observed during cataract surgery or subsequent follow-up; (4) Toric or multifocal IOL implantation; (5) severe posterior capsular opacification affecting manifest refraction or requiring YAG laser capsulotomy; (6) keratopathy, glaucoma, uveitis, ocular trauma, pseudoexfoliation syndrome or lens dislocation; and (7) a history of intraocular surgery other than PPV. Axial length (AL) matched patients with cataract who underwent uneventful phacoemulsification and IOL implantation without prior PPV were selected as the non-PPV group. The right eye was selected if patients had bilateral cataract surgery.

Swept-Source OCT Imaging

All enrolled participants were measured by SS-OCT (CASIA2) 3 months after cataract surgery. CASIA2 uses a swept-source laser with a 1310-nm wavelength at a velocity of 30,000 A-scan/second and provides higher resolution images of IOLs. In IOL scan mode, it produces 8 SS-OCT images from 8 different scanning axes (0–180, 90–270, 23–203, 113–293, 45–225, 135–315, 68–248, and 158–338) and eventually generates a 3D image. IOL tilt and decentration results were automatically generated by built-in software (version SS2000) relative to the corneal topographic axis. All patients were measured three times under mydriatic conditions, and the best scan was selected for the final analysis. An example image in the PPV group is shown in Figure 1.

Outcome Measures

The main outcome measures were IOL tilt and decentration measured by CASIA2. The demographic information, previous systemic disease, indications for PPV, use of SO tamponade or scleral buckle at the time of vitrectomy, duration of SO tamponade, preoperative ocular biometric parameters (AL, lens thickness [LT], anterior chamber depth [ACD, measured from epithelium to lens]) measured by IOLMaster 700 (1.80; Carl Zeiss, Oberkochen, Germany), preoperative and postoperative best-corrected visual acuity (BCVA), IOL material (hydrophobic or

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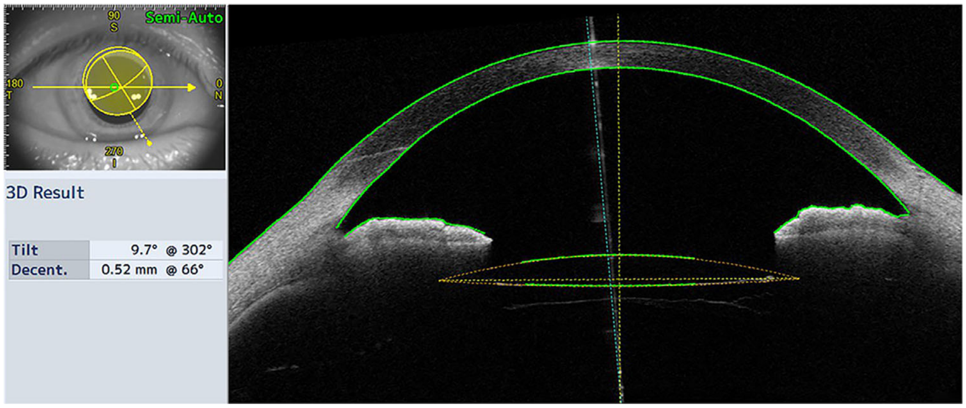

Figure 1. Measurement of IOL tilt and decentration using swept-source optical coherence tomography (CASIA2). The optic axis of IOL (*yellow dotted line*) and the corneal topographic axis (*blue dotted line*) are automatically drawn by the built-in software. IOL, intraocular lens.

hydrophilic), IOL haptics (single-piece or 3-piece), power of IOL implanted, wavefront aberration, and manifest refraction results 3 months after surgery were also collected. In addition, the capsulorhexis-IOL overlap was recorded as complete (360 degrees continuous) or incomplete overlap according to the retroillumination slit-lamp image under mydriatic conditions 3 months after cataract surgery. The image of each patient was evaluated by two ophthalmologists independently (authors J.Q.Z. and G.Y.Y.). When the classification results were controversial, the images were re-assessed by a senior ophthalmologist (author X.H.T.). The associations between clinical factors and IOL tilt or decentration were assessed.

Wavefront aberrations were measured by the iTrace aberrometer (Tracey Technologies, Houston, TX) with a fixed entrance pupil scan size of 5.0 mm under mydriatic conditions. Measurements were repeated at least three times and the best scan was chosen for the final analysis. Root mean square (RMS) values of internal higher-order aberrations (HOAs), including total HOA (THOA), coma, spherical aberration (SA), trefoil, and secondary astigmatism were collected.

The refractive prediction error (PE) was calculated as the difference between the postoperative and formula-predicted spherical equivalent using the IOL power implanted.[25] We calculated the PE using the Barrett Universal II formula[26] and the User Group for Laser Interference Biometry (ULIB) constants. The mean error (ME) was the mean of all the PEs and the absolute PE was the absolute value of each PE.

Statistical Analysis

The quantitative data were represented by mean ± standard deviation and the qualitative data were represented by frequency percentage. The differences of participant characteristics, IOL tilt and decentration, internal HOAs, and refractive error between the PPV and the non-PPV groups were compared using an independent *t*-test or Mann-Whitney *U* tests for continuous variables, χ^2 test for categorical variables, and ordinal logistic regression for ordinal variables. The BCVA was recorded in decimal units and converted to the logarithm of the minimum angle resolution (logMAR) units. The internal HOAs were converted to the natural logarithm (base e) of the RMS values for statistical analyses. Multiple logistic regression was used to investigate the risk factors of IOL tilt over 7 degrees and decentration over 0.4 mm in the PPV group. The collinearity among the potential risk factors was checked by calculating Spearman correlation, and factors with collinearity were excluded from the multiple logistic regression model. Pearson correlation analysis was used to assess the correlations among the duration of SO tamponade, internal HOAs or refractive error, and IOL tilt or decentration. Chi-squared test was used to assess the associations between SO emulsion and IOL tilt or decentration. The one-sample *t*-test was used to test whether the ME was significantly different from zero. A P value of < 0.05 was considered to be significant. The data analysis was performed using SPSS version 20.0 (SPSS, Inc., Chicago, IL).

Results

In total, 122 patients with cataract (122 eyes) with prior PPV who underwent uneventful phacoemulsification and IOL implantation from December 2018 to August 2019 were identified from the medical charts of the Cataract Department in Zhongshan Ophthalmic

Table 1. Demographic and Clinical Characteristics of Participants

Characteristic	Non-PPV	PPV	*P* Value
Eye, *n*	104	104	
Age, y	65.54 ± 11.08	57.59 ± 10.70	<0.001*
Male, *n* (%)	46 (44.23)	57 (54.81)	0.127
DM, *n* (%)	12 (11.54)	9 (8.65)	0.490
Preoperative BCVA (log MAR)	0.79 ± 0.52	1.16 ± 0.58	<0.001*
Postoperative BCVA (log MAR)	0.06 ± 0.10	0.50 ± 0.61	<0.001*
AL, mm	24.39 ± 2.09	24.88 ± 2.02	0.089
LT, mm	4.50 ± 0.51	4.61 ± 0.46	0.098
Preoperative ACD, mm	3.17 ± 0.45	3.09 ± 0.41	0.145
AL > 26 mm, *n* (%)	16 (15.38)	21 (20.19)	0.365
IOL material			0.714
Hydrophilic, *n* (%)	19 (18.27)	17 (16.35)	
Hydrophobic, *n* (%)	85 (81.73)	87 (83.65)	
Capsulorhexis-IOL overlap			0.375
Complete, *n* (%)	37 (35.58)	31 (29.81)	
Incomplete, *n* (%)	67 (64.42)	73 (70.19)	

PPV, pars plana vitrectomy; mm, millimeter; DM, diabetes mellitus; BCVA, best-corrected visual acuity; log MAR, logarithm of the minimum angle resolution; AL, axial length; LT, lens thickness; ACD, anterior chamber depth; IOL, intraocular lens.

*Statistically significant ($P < 0.05$).

Center. After exclusion of 18 patients (18 eyes, including 2 eyes with multiple PPVs, 7 eyes without SO removal, 1 eye with Toric IOL implantation, 2 eyes with posterior capsular opacification affecting manifest refraction or requiring YAG laser capsulotomy, 1 eye with ocular trauma, 2 eyes with uveitis, and 3 eyes lost to follow-up), 104 patients (104 eyes, 57 men) were enrolled. Meanwhile, 104 patients with cataract (104 eyes, 46 men) without prior PPV were selected as the non-PPV group. Of the PPV group, indications for PPV (Supplementary Table S1) included retinal detachment in 53 eyes (50.96%), macular pucker in 21 eyes (20.19%), macular hole in 12 eyes (11.54%), vitreous hemorrhage in 10 eyes (9.62%), and proliferative diabetic retinopathy (PDR) in 8 eyes (7.69%). Twenty-two eyes received balanced salt solution and 27 eyes received air tamponade at the end of surgery. Another 55 eyes received intravitreal SO tamponade and underwent SO removal before cataract surgery. The silicone oil used in our study was 5000 centistokes. In addition, scleral buckling was performed on nine eyes. The time between PPV and cataract surgery was 19.04 ± 19.05 months (range = 3–108 months).

The mean age of the PPV group (57.59 ± 10.70 years, range = 21–78 years) was younger than that of the non-PPV group (65.54 ± 11.08 years, range = 25–90 years, $P < 0.001$) due to the earlier onset of cataract in vitrectomized eyes. The preoperative ocular biometric parameters (AL, LT, and ACD) were comparable between the two groups ($P > 0.05$). All cataract surgeries were performed by experienced cataract surgeons using the Centurion Vision System (Alcon Laboratories, Fort Worth, TX). The CCC with the diameter in 5.0 to 5.5 mm was made during surgery. There were no intra-operative and postoperative complications in all enrolled patients. The BCVA in both the PPV group and the non-PPV group were significantly improved after cataract surgery. The optical diameter of all IOLs implanted in our study was 6.0 mm. More than 80% of the patients were implanted with hydrophobic IOL. There were only five patients in the non-PPV group and four patients in the PPV group implanted with three-piece hydrophobic acrylic IOLs. Due to the small number of three-piece hydrophobic acrylic IOLs, this model was combined with single-piece hydrophobic IOL for analysis. The IOL material and the classification of capsulorhexis-IOL overlap were comparable between the two groups ($P = 0.714$ and $P = 0.375$). The demographic and clinical characteristics of participants are listed in Table 1.

All patients underwent SS-OCT examination 3 months after cataract surgery. The mean IOL tilt and decentration were higher in the PPV group (5.36 ± 2.50 degrees, 0.27 ± 0.17 mm) than in the non-PPV group (4.54 ± 1.46 degrees, $P = 0.005$ and 0.19 ± 0.12 mm, $P < 0.001$, respectively). Furthermore, age-adjusted IOL tilt and decentration were also greater

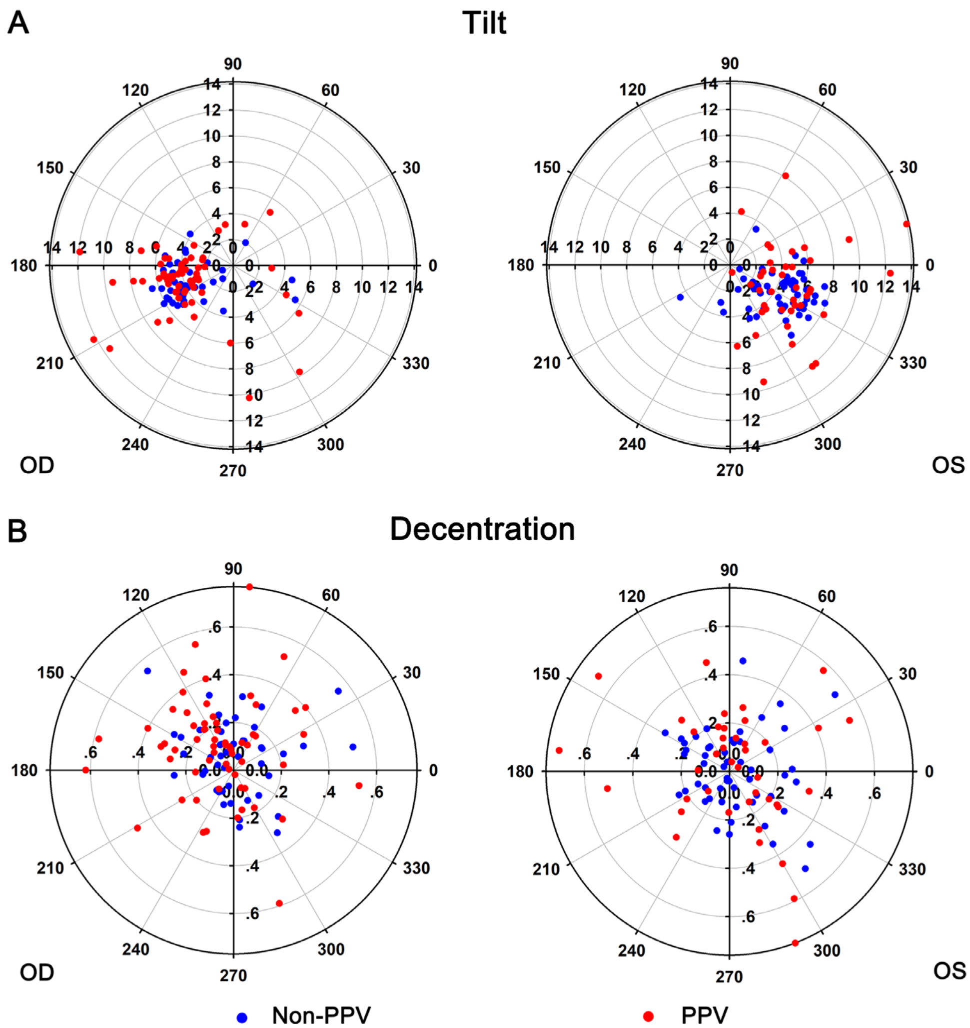

Figure 2. (**A**) Coordinate graphics show the orientations and the values of the IOL tilt of the PPV group and the non-PPV group. The IOLs tend to tilt toward the inferotemporal direction in both groups. (**B**) Coordinate graphics show the orientations and the values of the IOL decentration of the PPV group and the non-PPV group. The IOLs decenter toward any directions without obvious tendency in both groups. Notes: *blue circle*: non-PPV group; *red circle*: PPV group. PPV, pars plana vitrectomy; IOL, intraocular lens.

in the PPV group than in the non-PPV group (P = 0.020 and P = 0.003, respectively). Nineteen eyes (18.27%) in the PPV group and 6 eyes (5.77%) in the non-PPV group had IOL tilt greater than 7 degrees. Meanwhile, 22 eyes (21.25%) in the PPV group and 7 eyes (6.73%) in the non-PPV group had a decentration more than 0.4 mm. For both the PPV and the non-PPV groups, IOLs tilted mainly toward the inferotemporal direction relative to the corneal topographic axis, while they decentered toward any directions without obvious tendency. The distribution of IOL tilt and decentration are shown in Figure 2. The postoperative ACD were comparable between the two groups (P = 0.087). A hyperopic refractive error was found in the PPV group (0.22 ± 0.84 D, P = 0.015) but not in the non-PPV group (-0.02 ± 0.47, P = 0.658). There was a significant difference in ME between the PPV and the non-PPV groups (P = 0.019). However, no significant difference was found in MAE between the two groups (P = 0.715). The IOL position and refractive error of the subgroups are listed in Table 2. No correlations were found between PE and IOL tilt (R = 0.135, P = 0.202) or decentration (R = 0.019, P = 0.859) in the PPV group.

As IOL tilt greater than 7 degrees and decentration great than 0.4 mm could cause obvious wavefront aberrations that impair the optical performance of IOL,[5,12] we investigated the risk factors of IOL tilt ≥ 7 degrees and decentration ≥ 0.4 mm in the PPV group. The distribution of potential factors associated with great IOL tilt and decentration in the PPV group are shown inTable 3. Multiple logistic regression analyses demonstrated that SO tamponade (odds ratio [OR] = 5.659, 95% confidence interval

Table 2. IOL Position and Refractive Error of Subgroups

Parameter	Non-PPV	PPV	*P* Value
Tilt, degree	4.54 ± 1.46	5.36 ± 2.50	0.005[*,a]
<7 degrees, n (%)	98 (94.23)	85 (81.73)	0.006[*,b]
≥7 degrees, n (%)	6 (5.77)	19 (18.27)	
Decentration, mm	0.19 ± 0.12	0.27 ± 0.17	<0.001[*,a]
<0.4 mm, n (%)	97 (93.27)	82 (78.85)	0.003[*,b]
≥0.4 mm, n (%)	7 (6.73)	22 (21.25)	
Postoperative ACD, mm	4.62 ± 0.34	4.53 ± 0.41	0.087[a]
ME, D	-0.02 ± 0.47	0.22 ± 0.84	0.019[*,a]
MAE, D	0.39 ± 0.26	0.52 ± 0.69	0.715[c]
MedAE, D	0.38	0.31	–

IOL, intraocular lens; PPV, pars plana vitrectomy; mm, millimeter; ACD, anterior chamber depth; ME, mean refractive prediction error; MAE, mean absolute refractive prediction error; MedAE, median absolute error; D, diopter.

[*]Statistically significant ($P < 0.05$).

[a]Independent *t* test.

[b]Chi-square test.

[c]Mann-Whitney *U* test.

[CI] = 1.492–25.059, $P = 0.021$) and hydrophilic IOL (OR = 5.309, 95% CI = 1.276–22.090, $P = 0.022$) were associated with IOL tilt over 7 degrees, whereas diabetes mellitus (DM; OR = 5.544, 95% CI = 1.153–26.666, $P = 0.033$) was associated with IOL decentration over 0.4 mm (Table 4). There was no collinearity among the risk factors included in multiple logistic regression model. The mean duration of

Table 3. Potential Factors Associated With Great IOL Tilt and Decentration in the PPV Group

	Tilt, *n* (%)		Decentration, *n* (%)	
Parameter	<7 Degrees	≥7 Degrees	<0.4 mm	≥0.4 mm
AL > 26 mm				
Yes	16 (76.19)	5 (23.81)	19 (90.48)	2 (9.52)
No	69 (83.13)	14 (16.87)	63 (75.90)	20 (24.10)
SO tamponades				
Yes	40 (72.73)	15 (27.27)	42 (76.36)	13 (23.64)
No	45 (91.84)	4 (8.16)	40 (81.63)	9 (18.37)
Scleral buckling				
Yes	5 (55.56)	4 (44.44)	7 (77.78)	2 (22.22)
No	80 (84.21)	15 (15.79)	75 (78.95)	20 (21.05)
Peripheral vitreous shaving				
Yes	52 (77.61)	15 (22.39)	52 (77.61)	15 (22.39)
No	33 (89.19)	4 (10.81)	30 (81.08)	7 (18.92)
Hydrophilic IOL				
Yes	11 (64.71)	6 (35.29)	12 (70.59)	5 (29.41)
No	74 (85.06)	13 (14.94)	70 (80.46)	17 (19.54)
DM				
Yes	8 (88.89)	1 (11.11)	4 (44.44)	5 (55.56)
No	77 (81.05)	18 (18.95)	78 (82.11)	17 (17.89)
Capsulorhexis-IOL overlap				
Complete	27 (87.10)	4 (12.90)	26 (83.87)	5 (16.13)
Incomplete	58 (79.45)	15 (20.54)	56 (76.71)	17 (23.29)

IOL, intraocular lens; PPV, pars plana vitrectomy; mm, millimeter; AL, axial length; SO, silicone oil; DM, diabetes mellitus.

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Table 4. Multiple Logistic Regression of the Risk Factors of Greater IOL Tilt and Decentration in the PPV Group

	Tilt ≥ 7 Degrees		Decentration ≥ 0.4 mm	
Clinical Characteristic	Odds Ratio (95% CI)	*P* Value	Odds Ratio (95% CI)	*P* Value
AL > 26 mm	0.756 (0.182 to 3.134)	0.699	0.326 (0.058 to 1.826)	0.202
SO tamponades	5.659 (1.492 to 25.059)	0.021*	1.993 (0.439 to 9.042)	0.371
Scleral buckling	3.506 (0.638 to 19.277)	0.149	1.945 (0.297 to 12.745)	0.488
Peripheral vitreous shaving	0.285 (0.032 to 2.563)	0.263	0.662 (0.132 to 3.319)	0.616
DM	0.444 (0.045 to 4.387)	0.488	5.544 (1.153 to 26.666)	0.033*
Hydrophilic IOL	5.309 (1.276 to 22.090)	0.022*	1.720 (0.469 to 6.304)	0.413
Incomplete capsulorhexis-IOL overlap	3.928 (0.900 to 17.155)	0.069	2.243 (0.638 to 7.885)	0.208

IOL, intraocular lens; PPV, pars plana vitrectomy; mm, millimeter; AL, axial length; SO, silicone oil; CI, confidence interval; DM, diabetes mellitus.

*Statistically significant ($P < 0.05$).

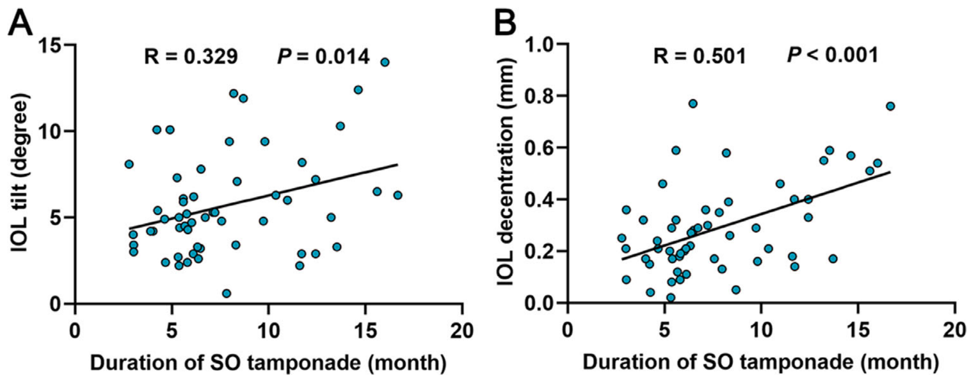

Figure 3. Scatter plots indicating the correlation of duration of SO tamponade with IOL tilt (**A**) and decentration (**B**) in the PPV group. SO, silicone oil; IOL, intraocular lens; PPV, pars plana vitrectomy.

SO tamponade was 7.81 ± 3.64 months (range = 2.80–16.67 months) in 55 eyes with previous intravitreal SO tamponade. Duration of SO tamponade was positively correlated with IOL tilt (R = 0.329, $P = 0.014$) and decentration (R = 0.501, $P < 0.001$; Fig. 3). Although SO emulsion had no associations with greater IOL tilt ($P = 0.739$) and decentration ($P = 0.284$; Supplementary Table S2).

In total, 82 eyes in the control group and 85 eyes in the PPV group were measured by iTrace aberrometer 3 months after cataract surgery. The internal THOA, coma, trefoil, and secondary astigmatism of the PPV group were significantly higher than those of the non-PPV group (0.64 ± 0.51 vs. 0.31 ± 0.17, $P < 0.001$; 0.29 ± 0.21 vs. 0.14 ± 0.06, $P < 0.001$; 0.28 ± 0.26 vs. 0.13 ± 0.12, $P < 0.001$; and 0.11 ± 0.15 vs. 0.06 ± 0.03, $P = 0.024$, respectively). However, no significant difference was found in internal SA between the two groups (0.14 ± 0.08 vs. 0.12 ± 0.03, $P = 0.142$; Fig. 4). In the PPV group, the natural logarithm (ln) of the internal THOA, coma, trefoil, and secondary astigmatism positively correlated with IOL tilt (R = 0.280,

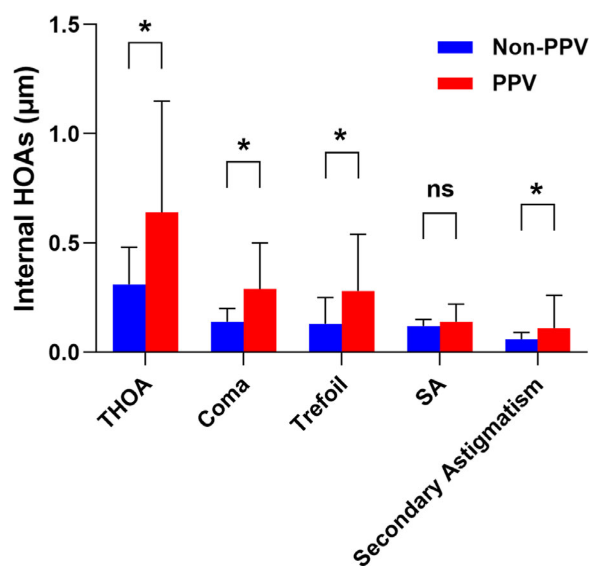

Figure 4. Comparison of internal higher-order aberrations between the PPV group and the non-PPV group. PPV, pars plana vitrectomy; HOA, higher-order aberration; THOA, total higher-order aberration; SA, spherical aberration; ns, not significant. * Statistically significant ($P < 0.05$).

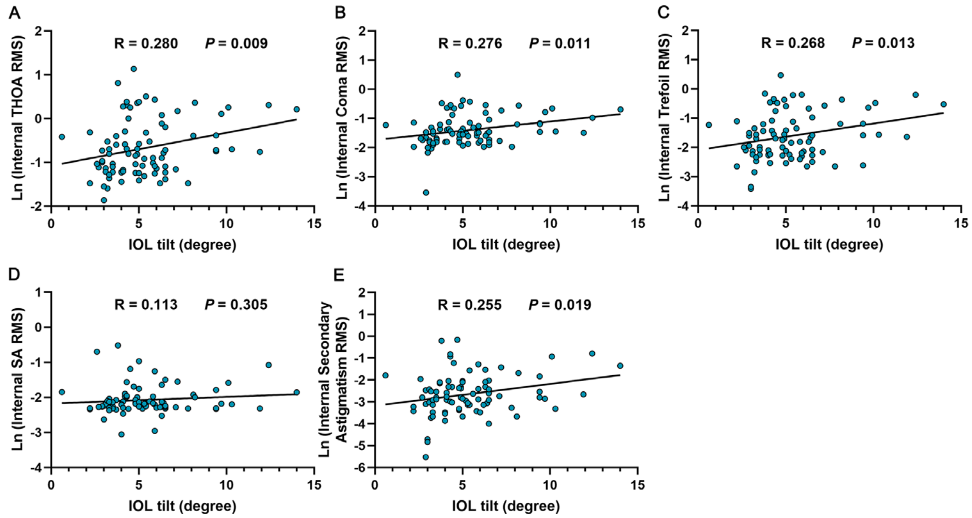

Figure 5. Scatter plots indicating the correlation of the RMS values of internal THOA (**A**), coma (**B**), trefoil (**C**), SA (**D**), and secondary astigmatism (**E**) with IOL tilt in the PPV group. IOL, intraocular lens; RMS, root mean square; Ln, natural logarithm; THOA, total higher-order aberration; SA, spherical aberration.

$P = 0.009$; $R = 0.276$, $P = 0.011$; $R = 0.268$, $P = 0.013$; and $R = 0.255$, $P = 0.019$, respectively), whereas there was no correlation between the ln of internal SA and IOL tilt ($R = 0.113$, $P = 0.305$; Fig. 5). No correlations were found between the ln of internal HOAs and IOL decentration ($P > 0.05$).

Discussion

In this study, we first demonstrated that IOL tilt and decentration were greater in the PPV group than in the non-PPV group. In the PPV group, approximately 20% eyes had IOL tilt greater than 7 degrees and decentration more than 0.4 mm. SO tamponade and hydrophilic IOL were associated with IOL tilt over 7 degrees, and DM was associated with IOL decentration over 0.4 mm. Furthermore, duration of SO tamponade was positively correlated with IOL tilt and decentration.

Phacoemulsification after PPV is challenging with a higher rate of complications. The absence of vitreous support in the posterior segment results in an unusually deep and fluctuating anterior chamber during phacoemulsification, increasing the posterior capsule mobility and zonular instability.[27] In addition, the use of IVT, such as silicone oil or expansile gas, may push the superior parts of the lens more forward than the inferior parts and lead to the stretching of the zonules.[1] All factors mentioned above may contribute to the increased IOL tilt and decentration in vitrectomized eyes, as we found in this study. In both the non-PPV and PPV groups, IOLs tilted mostly toward the inferotemporal direction relative to the corneal topographic axis, which was consistent with the findings of Kimura et al.[23] and Chen et al.[28] However, the IOL decentration had no obvious tendency toward any directions, which was same as Chen et al.'s results.[28]

Ozates et al.[17] and Shiraki et al[29] have reported that SO and long acting gas tamponade increased IOL tilt and decentration in combined phacoemulsification and vitreoretinal surgery. On the other hand, the conclusions on the impact of air tamponade on IOL position were variable.[16,18] Iwama et al. speculated that air tamponade may induce greater IOL position abnormality in cases with relatively large CCC (5.5–5.8 mm) than those with small CCC size (4.5–5.0 mm).[16,18] However, the influence of potential risk factors, such as IVTs, scleral buckling, IOL material, DM, SO emulsion, and duration of SO tamponade on the IOL position after phacoemulsification with prior vitrectomy are unknown. Our study first demonstrated that SO tamponade was the risk factor of IOL tilt over 7 degrees after phacoemulsification in vitrectomized eyes. In addition, we found duration of SO tamponade was positively correlated with IOL tilt and decentration. Therefore, SO is recommended to be removed once the vitreoretinal disorders are stationary.

Our study demonstrated that hydrophilic IOL was one risk factor of larger IOL tilt in patients with prior PPV, whereas Chen et al.[28] found there was no association between IOL material and IOL tilt in nonvitrectomized eyes. The possible explanation for the above-mentioned difference is that hydrophilic material exacerbates capsular bag contraction[30–32] in vitrectomized eyes and subsequently leads to larger IOL tilt. In addition, our study showed that DM was the risk factor of IOL decentration over 0.4 mm. High risk of capsular contraction and shrinkage in patients with DM could increase the IOL shift and decentration,[33] especially in those with diabetic retinopathy. The scleral buckling procedure was reported to increase the AL and steepen the buckle area, leading to the myopia and high astigmatism.[34,35] However, there are no studies about the influence of scleral buckling on the IOL position. In this study, we did not find the significant correlations between scleral buckling and great IOL tilt and decentration. In addition, prior peripheral vitreous shaving with scleral depression did not induce greater IOL tilt and decentration, probably attributed to the standardized and prudential surgical manipulation during PPV.

It is well known that postoperative ACD or effective lens position (ELP) significantly affects refractive outcomes.[36] Shiraki et al.[29] has reported that patients underwent phacovitrectomy with gas tamponade displayed a greater myopic refractive error than those without gas tamponade due to the forward movement of the IOL. In our study, more hyperopic and variable refractive errors were found in the PPV group, which were consistent with previous studies.[37,38] The possible explanation is the refractive index change in the posterior segment due to the replacement of the vitreous with aqueous humor, and the inaccurate preoperative biometry due to retinal pathology. There were limited studies regarding the influence of IOL tilt and decentration on refractive error. Korynta et al.[39] reported that severe IOL decentration and tilt increased myopia and astigmatism, whereas mild IOL position abnormality would not. In our study, there was no significant correlation between PE and IOL tilt or decentration in the PPV group.

Higher-order aberrations caused by IOL tilt and decentration can impair visual quality after cataract surgery. Holladay et al.[12] demonstrated that the modulation transfer function (MTF) of aspheric IOLs with decentrations over 0.4 mm and tilts over 7 degrees decreased below that of conventional spherical IOLs. Zhu et al.[10] reported the decreased visual quality and higher frequencies of subjective symptoms in patients with myopia implanted with multifocal IOL, which showed decentration of 0.4 mm. In addition, misalignment of the Toric IOLs can cause axis shift and reduce the astigmatic correction and visual quality.[40] In our study, internal THOAs, coma, trefoil, and secondary astigmatism were higher in the PPV group than in the non-PPV group and positively correlated with IOL tilt. Therefore, optically sophisticated IOLs, such as aspheric, multifocal, and astigmatism correcting IOLs, should be used cautiously in vitrectomized eyes, especially those with risk factors of greater IOL tilt and decentration.

Some limitations of this study should be addressed. First, as there has no commercial perfluoropropane (C3F8) in China mainland since 2016, we did not evaluate the effect of gas tamponades on IOL tilt and decentration. Second, as it was a cross-sectional study, the pre-operative data of crystalline lens tilt and decentration, as well as the progressive changes of IOL position after surgery were not available. Third, the sample size was relatively small, which may limit the ability to detect statistically significant differences between subgroups. Fourth, as the follow-up time was only 3 months, the impact of capsular contraction and progressive zonule weakness on IOL misalignment has not been observed. Future prospective studies with pre-operative and postoperative long-term dynamically changing data are needed. Last, the percentage of complete capsulorhexis-IOL overlap was relatively low in our study, which may overestimate the influence of SO tamponade on the IOL tilt and decentration.

In summary, patients who underwent phacoemulsification after PPV have greater IOL tilt and decentration than those without prior PPV. In the PPV group, approximately 20% eyes had IOL tilt greater than 7 degrees and decentration more than 0.4 mm. Longer duration of SO tamponade, hydrophilic IOL, as well as DM were the risk factors of greater IOL tilt and decentration. Therefore, cataract surgeons should be aware of the risk factors of IOL tilt and decentration in vitrectomized eyes, and be cautious when using optically sophisticated IOLs in this special population.

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