· Clinical Research ·

Axial length, vitreoretinal pathology, and anterior chamber depth can predict postoperative refractive outcomes in phacovitrectomy/silicone oil removal

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Abstract

● **AIM:** To evaluate the postoperative refractive prediction error (PE) and determine the factors that affect the refractive outcomes of combined pars plana vitrectomy (PPV) or silicone oil removal (SOR) with cataract surgery.

● **METHODS:** The study is a retrospective, case-series study. Totally 301 eyes of 301 patients undergoing combined PPV/SOR with cataract surgery were enrolled. Eligible individuals were separated into four groups according to their preoperative diagnoses: silicone oil-filled eyes after PPV (group 1), epiretinal membrane (group 2), macular hole (group 3), and primary retinal detachment (RD; group 4). The variables affecting postoperative refractive outcomes were analyzed, including age, gender, preoperative best-corrected visual acuity (BCVA), axial length (AL), keratometry average, anterior chamber depth (ACD), intraocular tamponade, and vitreoretinal pathology. The outcome measurements include the mean refractive PE and the proportions of eyes with a PE within ±0.50 diopter (D) and ±1.00 D.

● **RESULTS:** For all patients, the mean PE was -0.04±1.17 D, and 50.17% of patients (eyes) had a PE within ±0.50 D. There was a significant difference in refractive outcomes among the four groups (P=0.028), with RD (group 4) showing the least favorable refractive outcome. In multivariate regression analysis, only AL, vitreoretinal pathology, and ACD were strongly associated with PE (all P<0.01). Univariate analysis revealed that longer eyes (AL>26 mm) and a deeper ACD were correlated with hyperopic PE, and shorter eyes (AL<26 mm) and a shallower ACD were correlated with myopic PE.

● **CONCLUSION:** RD patients have the least favorable refractive outcome. AL, vitreoretinal pathology, and ACD are strongly associated with PE in the combined surgery. These three factors affect refractive outcomes and thus can be used to predict a better postoperative refractive outcome in clinical practice.

● **KEYWORDS:** axial length; vitreoretinal pathology; anterior chamber depth; intraocular lens; pars plana vitrectomy; silicone oil removal; cataract; combined surgery; refractive error; intraocular tamponade

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INTRODUCTION

Pars plana vitrectomy (PPV) is a common surgical procedure for various vitreoretinal diseases[1-2]. Patients with vitreoretinal pathology often have coexisting cataracts at the same time. The most common postoperative complication with PPV is cataract development or progression, especially with silicone oil tamponade[3-5]. Patients often need subsequent cataract surgery to restore vision after PPV[6]. Hence, PPV or silicone oil removal (SOR) combined with cataract surgery is now commonplace in many vitreoretinal diseases[7-9]. In addition, the safety and efficacy of the combined surgery have been greatly improved with the continual advances in instrumentation and surgical techniques[6-8]. For these reasons, the combined surgery is increasingly a preferred choice for many patients with vitreoretinal disorders.

It has been largely demonstrated that patients can achieve perfect refractive outcomes after regular cataract surgery, but not always when cataract surgery is performed in conjunction with PPV[10-11]. A few studies have reported less favorable refractive outcomes after combined surgery[6,12-13], which brings up concern over the choice of combined surgery for both the patient and surgeon. We think three primary reasons may contribute to this. First, the vitreoretinal pathology will likely make measuring preoperative ocular biometry and estimating lens position more challenging[12,14-18]. Second, the formulas for calculating intraocular lens (IOL) power are designed for regular cataract surgery rather than the combined surgery. Third, gas or sterilized air filling the vitreous cavity after removing the vitreous body will affect the position of the implanted IOL, which may change the postoperative refractive state[14,19].

Previous studies had investigated the variables determining the refractive outcomes after combined surgery, but most of them were based on relatively small samples and included only one or two types of vitreoretinal pathology[6,12,14]. It is not fully elucidated what factors contribute to the less favorable refractive outcomes after combined surgery. Therefore, we aim to evaluate the postoperative refractive outcomes and find out the factors affecting the refractive outcomes of combined surgery for vitreoretinal diseases in a larger cohort of patients. Hopefully, we can find the crucial factors that can improve refractive prediction error (PE) and guide clinical practice.

SUBJECTS AND METHODS

Ethical Approval This study is a single-center retrospective case-series study. The study adhered to the principles outlined in the Declaration of Helsinki and was approved by the First Hospital's Ethics Committee, affiliated with Army Medical University (Southwest Hospital), Chongqing, China (Batch number: [B] KY2021149). Because only medical records were involved, informed consent was waived.

Subjects Patients undergoing PPV/SOR and concomitant cataract surgery for vitreoretinal pathology at our institute were screened for eligibility between July 2015 and April 2021. Only patients who had monofocal IOLs implanted were included in this study. The following were the exclusion criteria: 1) having a second silicone oil tamponade due to recurrence of the original vitreoretinal disease; 2) lens displacement, ocular trauma, keratopathy, glaucoma, or uveitis; 3) surgical history of scleral buckling; 4) corneal refractive surgery history; 5) a significant opacification of the posterior capsule affecting refraction; 6) patients under 20 years of age; and 7) a poor medical record or a follow-up period shorter than three months. Only the right eye was included if a patient had both eyes that matched the criteria.

Depending on their preoperative diagnosis, eligible patients were separated into four groups. Group 1: patients diagnosed with silicone oil-filled eyes after PPV undergoing SOR and concomitant cataract surgery. Group 2: patients diagnosed with epiretinal membrane (ERM). Group 3: patients diagnosed with macular hole (MH). Group 4: patients diagnosed with primary retinal detachment (RD). All patients in groups 2, 3, and 4 underwent PPV and concomitant cataract surgery.

Data Collection and Outcome Measurements The preoperative ophthalmic examination results, including tomography using spectral-domain optical coherence tomography (OCT; by Cirrus HD-OCT 500, Carl Zeiss Meditec, Inc., Dublin, CA, USA) and optical biometry [axial length (AL)]; corneal power; anterior chamber depth (ACD); keratometry value; IOL power by IOLMaster 500 (Carl Zeiss, Oberkochen, Germany), were extracted from the patients' medical record. The SRK/T formula built into the IOLMaster 500 calculated the IOL power. At least three months after the combined operation, an ophthalmologist evaluated the postoperative refraction.

The primary outcome measurements were the postoperative refractive PE (*i.e.*, actual postoperative refraction minus expected preoperative refraction for the precise power of the implanted IOL, defined below in formula 1). Proportions of eyes with a PE within ±0.50 diopter (D), ±1.00 D, and over ±1.00 D were determined by formulas 2, 3, and 4.

$$\mathbf{PE} = \text{actual refraction}_{\text{postoperative}} - \text{formula predicted refraction}_{\text{preoperative}} \quad (1)$$

$$\mathbf{PE\ rate}_{\pm 0.5\ D}\ (\%) = \frac{N_{PE\ [-0.5\ D,\ +0.5D]}}{N_{PE\ [-\infty\ D,\ +\infty\ D]}} \times 100\% \quad (2)$$

$$\mathbf{PE\ rate}_{\pm 1.0\ D}\ (\%) = \frac{N_{PE\ [-1.0\ D,\ +1.0D]}}{N_{PE\ [-\infty\ D,\ +\infty\ D]}} \times 100\% \quad (3)$$

$$\mathbf{PE\ rate}_{>\pm 1.0\ D}\ (\%) = \frac{N_{PE\ [-\infty\ D,\ -1.0D]} + N_{PE\ [+1.0\ D,\ +\infty\ D]}}{N_{PE\ [-\infty\ D,\ +\infty\ D]}} \times 100\% \quad (4)$$

N=patient number

Surgical Procedure Two surgeons fully trained in vitreoretinal and cataract surgery performed all surgeries under local or general anesthesia. In all cases, the microincision phacoemulsification and IOL implantation were performed first in the same setting. In group 1, 23-gauge SOR was performed subsequently. In groups 2, 3, and 4, core vitrectomy, posterior vitrectomy, and vitreous base shaving were carried out using a 25-gauge PPV following cataract surgery. The vitreous cavity was filled with silicone oil (5000 centistokes), sterilized air, or perfluoropropane (C_3F_8) at the end of the surgery.

Statistical Analysis SPSS (version 26.0, IBM Corp.) for Windows and RStudio (version 4.1.3) were used to conduct the statistical analysis. The mean and standard deviation were used to represent the continuous numbers. For all computations and statistical analysis, the visual acuity of each patient was transformed to the logarithm of the minimum angle of resolution (logMAR) value. The normality of the data was examined using the Shapiro-Wilk test and the Kolmogorov-Smirnov test. The refractive PE was examined using the Wilcoxon signed-rank test or the paired *t*-test according to the normality of the data. The Mann-Whitney or Kruskal-Wallis test was used to compare the PE between two or more groups. The proportion of cases within ±0.50 D and ±1.00 D of PE was compared across the groups using the Chi-square test. Spearman rank correlation analysis and multivariate logistic regression analysis were performed in an enter manner to examine factors affecting postoperative refractive outcomes. The variables that were strongly correlated with refractive outcomes were subsequently selected to construct the nomogram, and calibration curves were created to assess the fit and accuracy of the model. Using Bonferroni's post-hoc adjustment for multiple comparisons, the *P* values were modified. Statistics were deemed significant at $P<0.05$.

RESULTS

Demographics Our study enrolled 301 eyes of 301 patients undergoing PPV or SOR combined with cataract surgery. Among them, 155 patients were diagnosed with silicone oil-filled eyes after PPV (group 1), 83 with ERM (group 2), 41 with MH (group 3), and 22 with RD (group 4) before the combined surgery. The patients' average age was 58.27±9.49y. One hundred and seven eyes (35.55%) had AL longer than 26 mm. The IOLs used in the cohort were as follows: the Lenstec Softec HD (*n*=133), the Lenstec Softec 1 (*n*=123), the Alcon AcrySof SN60WF (*n*=21), the Zeiss CT ASPHINA 509M (*n*=14), and the Zeiss CT ASPHINA 603P (*n*=10). During the combined surgery, 27 patients had silicone oil tamponade, 244 had sterilized air tamponade, and 30 had C_3F_8 tamponade. The demographic features of the patients are provided in Table 1.

Table 1 Demographic characteristics of the patients mean±SD

Parameters	Values
Eye, *n*	301
Female, *n* (%)	185 (61.46)
Age, y	58.27±9.49
Preop. BCVA, logMAR	0.87±0.53
AL, mm, *n* (%)	25.52±2.94
≤26	194 (64.45)
>26	107 (35.55)
K1, D	43.66±1.39
K2, D	44.71±1.51
K-average, D	44.19±1.40
ACD, mm	3.29±0.38
Preop. diagnoses, *n* (%)	
Silicone oil-filled eyes (group 1)	155 (51.50)
Epiretinal membrane (group 2)	83 (27.57)
Macular hole (group 3)	41 (13.62)
Primary retinal detachment (group 4)	22 (7.31)
Tamponade, *n* (%)	
Silicone oil	27 (8.97)
Sterilized air	244 (81.06)
Perfluoropropane (C_3F_8)	30 (9.97)
IOL implanted, *n* (%)	
Lenstec Softec HD	133 (44.19)
Lenstec Softec 1	123 (40.86)
Alcon AcrySof SN60WF	21 (6.98)
Zeiss CT ASPHINA 509M	14 (4.65)
Zeiss CT ASPHINA 603P	10 (3.32)
IOL power, D	14.98±7.35

SD: Standard deviation; BCVA: Best-corrected visual acuity; logMAR: Logarithm of the minimum angle resolution; AL: Axial length; K1: Keratometry 1; K2: Keratometry 2; K-average: Keratometry average; ACD: Anterior chamber depth; D: Diopter; IOL: Intraocular lens.

Total Refractive Outcomes The mean PE was -0.04 D (P=0.118) in all patients, indicating neither a myopic nor a hyperopic shift caused by the combined surgery. However, only 152 (50.17%) and 230 (76.41%) eyes achieved a PE within ±0.50 D and ±1.00 D, respectively. In comparison, more than 96 percent of patients are now within ±1.00 D of PE for regular cataract surgery (96.2% for Hoffer Q, 96.5% for SRK/T, and 97.3% for Haigis)[10]. These results suggest that there is still much room to improve refractive outcomes after the combined surgery, despite using the newly developed optical biometry.

Variables Associated with Refractive Outcomes First, we performed univariate correlation and multivariate regression analyses to find critical factors that were correlated with postoperative refractive error. The variables were gender, age, preoperative best-corrected visual acuity (BCVA), keratometry average, AL, ACD, vitreoretinal pathology, and intraocular tamponade during the combined surgery. In univariate correlation analysis, we found that gender, age, AL, ACD, and vitreoretinal pathology were correlated with postoperative refractive error (all $P<0.05$). However, in multivariate regression analysis, only AL, ACD, and vitreoretinal pathology were substantially correlated with postoperative refractive error (all $P<0.01$; Table 2). Then, these independently associated factors were included in the nomogram (Figure 1A), and the calibration curves revealed perfect model fit consistency (Figure 1B).

Effect of Vitreoretinal Pathology on Refractive Outcomes We further conducted a subgroup analysis to find out how vitreoretinal pathology affected the refractive outcomes. Comparing refractive outcomes between different vitreoretinal pathologies, the RD group (group 4) showed the highest PE (-0.40 D, P=0.028; Table 3, Figure 2A). In addition, the RD group displayed the fewest eyes that were within ±0.50 D (22.73%) and ±1.00 D (45.45%) of PE (all $P<0.01$; Table 4). Meanwhile, the ERM group (group 2) had the greatest proportion of PE within ±0.50 D (67.47%) and ±1.00 D (84.34%; Figure 3). There was no significant difference in PE among groups 1, 2, and 3. These results

Table 2 The multivariate regression analysis between postoperative refractive error and selected variables

Variables	*β*	SE	*Wald*	*P*	OR	95%CI	
						Lower	Upper
Age	-0.005	0.016	0.08	0.777	0.995	0.965	1.027
Patient sex	0.119	0.274	0.19	0.663	1.127	0.659	1.926
Preop. BCVA (logMAR)	-0.13	0.258	0.253	0.615	0.878	0.530	1.456
Axial length	-0.159	0.053	9.103	0.003	0.853	0.769	0.946
Anterior chamber depth	1.483	0.419	12.541	<0.001	4.408	1.939	10.018
K average	-0.133	0.098	1.836	0.175	0.876	0.723	1.061
Tamponade			2.021	0.364			
C_3F_8	0.247	0.428	0.333	0.564	1.280	0.553	2.962
Silicone oil	0.675	0.576	1.374	0.241	0.509	0.165	1.574
Vitreoretinal pathology			13.217	0.004			
Epiretinal membrane	1.031	0.354	8.457	0.004	2.803	1.399	5.615
Macular hole	0.61	0.399	8.457	0.126	1.841	0.843	4.021
Primary retinal detachment	-0.968	0.685	1.999	0.157	0.380	0.099	1.453

logMAR: Logarithm of the minimum angle resolution; BCVA: Best-corrected visual acuity; K average: Keratometry average; C_3F_8: Perfluoropropane; OR: Odds ratio; CI: Confidence interval.

Table 3 The postoperative refractive outcomes in different groups mean±SD

Parameters	Predicted (D)	Achieved (D)	Prediction error (D)	*P*[a]
Diagnose				0.028[b,d]
Silicone oil-filled eyes	-0.53±0.61	-0.44±1.11	0.09±1.12	
Epiretinal membrane	-0.51±0.68	-0.59±0.93	-0.08±0.87	
Macular hole	-0.62±0.68	-0.83±1.14	-0.21±0.97	
Primary Retinal detachment	-0.36±0.38	-0.76±2.28	-0.40±2.32	
AL, mm				0.000[c,d]
≤26	-0.19±0.30	-0.44±1.26	-0.25±1.22	
>26	-1.13±0.61	-0.78±1.04	0.35±0.98	
Tamponade				0.642[b]
Silicone oil	-0.52±0.53	-0.37±2.62	0.16±2.57	
Sterilized air	-0.54±0.64	-0.59±0.93	-0.05±0.91	
Perfluoropropane (C_3F_8)	-0.42±0.62	-0.48±1.13	-0.06±1.17	
IOL type				0.136[b]
Lenstec Softec HD	-0.37±0.49	-0.54±0.89	-0.17±0.82	
Lenstec Softec 1	-0.69±0.72	-0.55±1.47	0.14±1.48	
Alcon AcrySof SN60WF	-0.38±0.40	-0.36±0.58	0.02±0.37	
ZEISS CT ASPHINA 509M	-0.89±0.69	-1.00±1.87	-0.11±1.89	
ZEISS CT ASPHINA 603P	-0.37±0.67	-0.75±0.67	-0.38±0.28	

AL: Axial length; SD: Standard deviation; D: Diopter; IOL: Intraocular lens. [a]Comparison of prediction error between different groups; [b]Mann-Whitney test; [c]Kruskal-Wallis test; [d]Statistically significant (*P*<0.05).

Table 4 The association between postoperative refractive outcomes and AL in different groups

Parameters	Group 1	Group 2	Group 3	Group 4	*P*
All					
Prediction error (D)	0.09±1.12	-0.08±0.87	-0.21±0.97	-0.40±2.32	0.028[a,c]
±0.50 D (%)	46.45	67.47	56.10	22.73	0.001[b,c]
±1.00 D (%)	76.13	84.34	82.93	45.45	0.001[b,c]
Over ±1.00 D (%)	23.87	15.66	17.07	54.55	0.001[b,c]
AL≤26 mm					
Prediction error (D)	-0.13±1.24	-0.24±0.89	-0.36±0.60	-0.69±2.23	0.031[a,c]
AL>26 mm					
Prediction error (D)	0.39±0.87	0.40±0.55	-0.03±1.31	1.42±2.47	0.680[a]

AL: Axial length; D: Diopter. [a]Comparison of postoperative prediction error between different groups (Kruskal-Wallis test); [b]Comparison of percentage of cases within ±0.50, ±1.00 D or over ±1.00 D between different groups (Chi-square test); [c]Statistically significant (*P*<0.05).

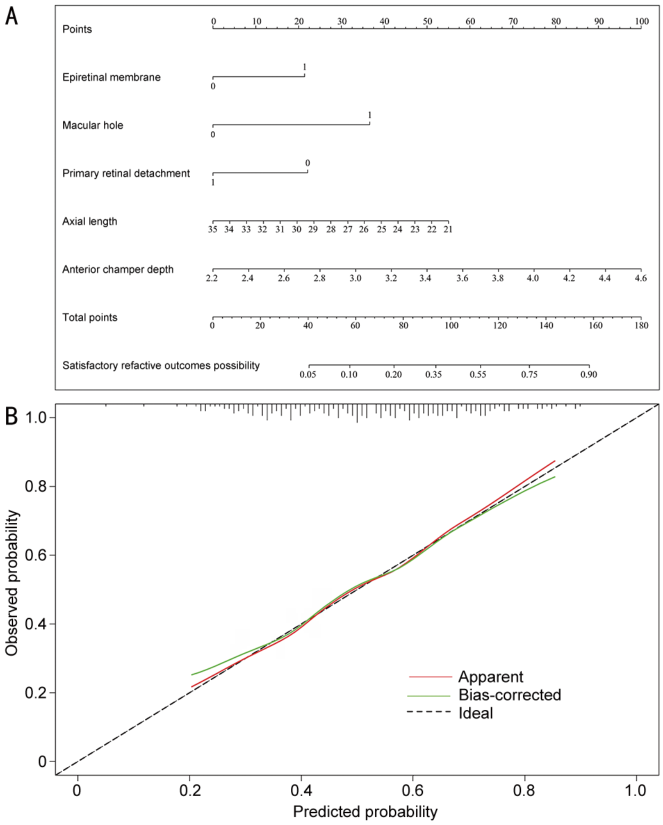

Figure 1 Nomogram model (A) and calibration curves (B) A: The satisfactory refractive outcomes possibility nomogram was developed with the predictors: axial length, vitreoretinal pathology, and anterior chamber depth. B: The Y-axis indicates the actual refractive outcomes, and the X-axis indicates the predicted possibility of satisfactory refractive outcomes. The diagonal dashed line indicates a perfect prediction by an ideal model. The solid line shows the performance of the model, indicating that a better prediction is shown by a tighter match to the diagonal dashed line.

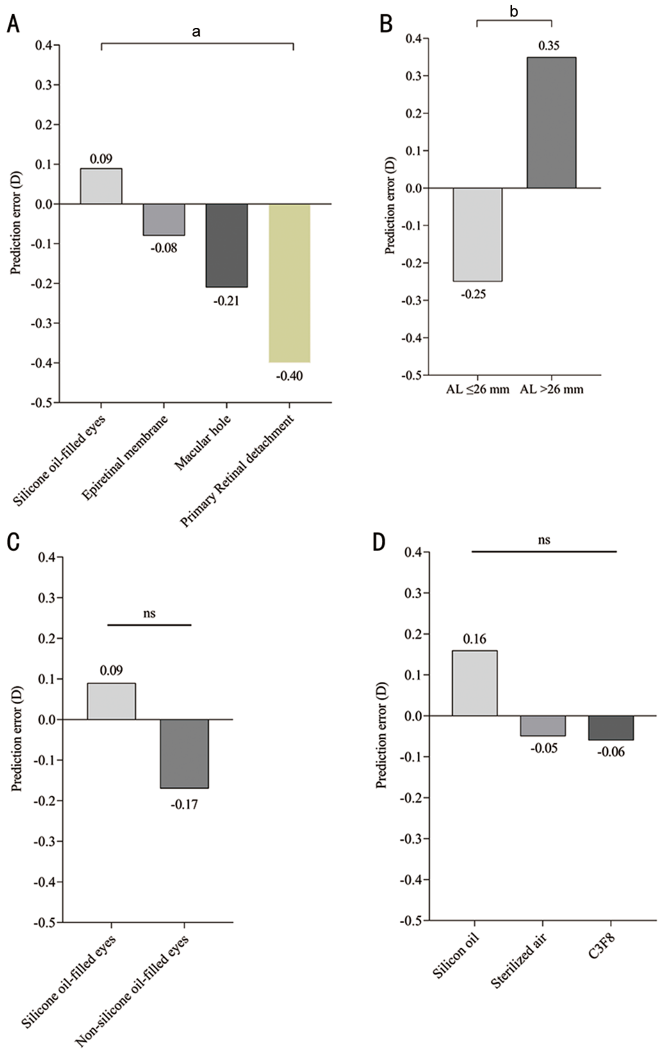

Figure 2 Comparison of postoperative refractive PE within vitreoretinal pathology (A), AL (B), intraocular tamponade filled before the combined surgery (C), and intraocular tamponade filled during the surgery (D) PE was significantly correlated with vitreoretinal pathology and AL (P=0.0028, Kruskal-Wallis test, A; P<0.01, Mann-Whitney test, B). While PE was not significantly correlated with the type of intraocular tamponade filled before or during the combined surgery (P=0.07, Mann-Whitney test, C; P=0.64, Kruskal-Wallis test, D). $^{a}P<0.05$, $^{b}P<0.01$. D: Diopter; ns: No significance; AL: Axial length; PE: Prediction error.

indicate that vitreoretinal diseases correlate with refractive outcomes, and the RD group had the worst refractive outcome in our cohort.

Effect of AL on Refractive Outcomes When comparing refractive outcomes between longer eyes (AL>26 mm) and shorter eyes (AL≤26 mm), we found the longer eyes tend to have a more profound hyperopic PE (0.35 *vs* -0.25 D, P<0.001; Table 3, Figure 2B). A significant hyperopic shift in patients with longer eyes was observed in groups 1, 2, and 4 (Table 4, Figure 4). A more significant hyperopic shift with no statistical difference was found in group 4 (1.42 D, P=0.680). In shorter eyes patients, a significant myopic shift was observed in all groups, with the RD group showing the highest myopic shift (-0.69 D, P=0.031). These results indicate that AL correlates with refractive outcomes, with longer eyes prone to hyperopic shift and shorter eyes prone to myopic shift after the combined surgery.

Effect of Intraocular Tamponade on Refractive Outcomes We next examined if the different intraocular tamponades filled before and during the combined surgery affected the refractive outcomes. First, we subdivided all patients into two groups based on whether the eye was filled with silicone oil before the combined operation. The first subgroup was patients from group 1, whose eyes were filled with silicone oil before the combined operation. The second subgroup was all patients combined from groups 2, 3, and 4, who had no intraocular tamponade before the combined surgery. We found no significant difference in PE between the two groups (0.09 *vs* -0.17 D, P=0.07; Figure 2C). Our patients had tamponades of silicone oil, sterilized air, or C_3F_8 during the combined surgery. Likewise, no significant difference was observed regarding

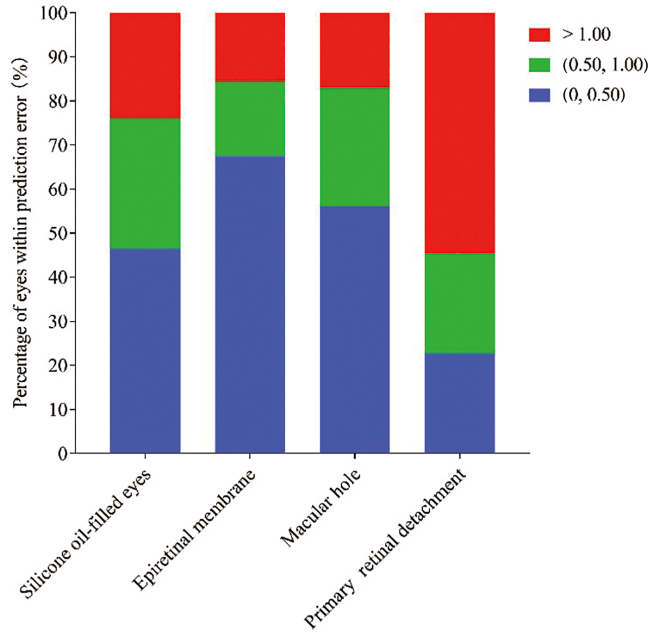

Figure 3 Stacked histogram showing percentage of eyes within ±0.50 diopters (D), ±1.00 D, and >1.00 D of prediction error in different groups.

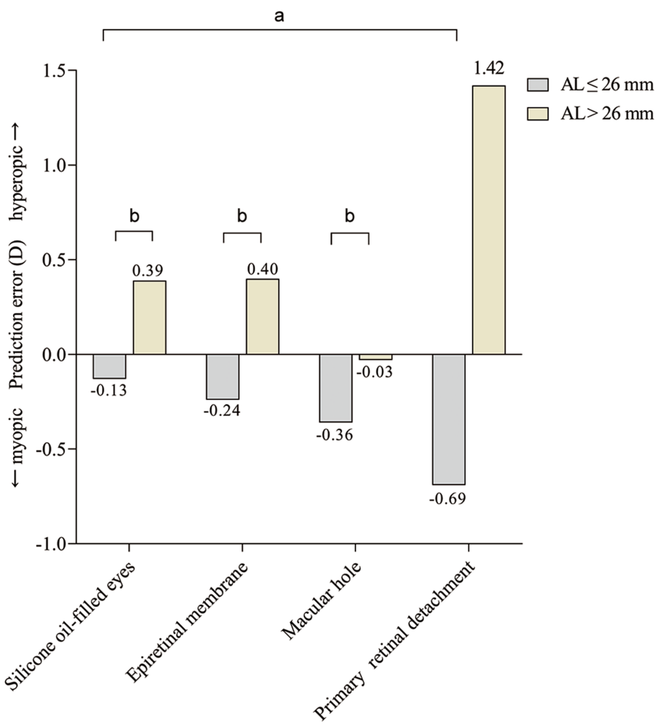

Figure 4 Comparison of postoperative refractive PE within axial length or vitreoretinal pathology The PE of longer eyes (AL>26 mm) was significantly different from the shorter eyes (AL≤26 mm) in silicone oil-filled eyes after pars plana vitrectomy (group 1), epiretinal membrane (group 2), and macular hole (group 3), but not in primary retinal detachment (group 4). In addition, the longer eyes showed a hyperopic shift in groups 1, 2, and 4 but not in group 3. [a]*P*<0.05, [b]*P*<0.01. D: Diopter; AL: Axial length; PE: Prediction error.

refractive outcomes among these three types of intraocular tamponade (*P*=0.64; Table 3, Figure 2D). These results indicate that different intraocular tamponades filled before or during the combined surgery do not affect the refractive outcomes after surgery.

DISCUSSION

Combining PPV or SOR with cataract surgery is a safe and promising procedure to treat vitreoretinal diseases and cataract[7]. Although continuous advances in biometric instruments and surgical techniques have significantly improved the safety of the combined surgery, the challenge remains. It has a highly variable and unsatisfactory refractive outcome after the surgery compared with regular cataract surgery[6,12,16-17,20]. To achieve better visual function after the combined surgery, investigators are working hard to find the factors that can reduce refractive PE and improve patients' visual quality. To this end, our study aims to evaluate the refractive outcomes and find out the factors that affect the refractive outcomes of the combined surgery.

We found that the RD patients had a significant myopic shift and the least favorable refractive outcome. Vitreoretinal pathology was one of the critical factors associated with postoperative refractive PE in multivariate regression analysis (*P*<0.01). Similar results were reported by Shiraki *et al*[12], who investigated patients undergoing phacovitrectomy for RD and ERM. They found that the RD group displayed a higher myopic shift than the ERM group (-0.63 *vs* -0.16 D, *P*<0.001), and RD was the only factor that was substantially linked with the postoperative refractive error. Tan *et al*[6] also found that patients with RD had less favorable refractive outcomes after phacovitrectomy than those who underwent PPV and delayed cataract surgery, particularly in patients with macula-off. These studies concluded the refractive outcomes were notably not satisfied because of AL underestimation, and the reasons for AL underestimation were multifactorial, including weak fixation with deflection of the visual axis, reduced reflectivity of the retinal pigment epithelium due to subretinal fluid, and interference from the detached retina. All these factors or errors will result in a shorter AL measurement[6,12,14,21]. To improve the accuracy of the AL measurement in patients with RD, both optical and A-scan ultrasound biometry were used for bilateral AL measurement, and the longer AL measurement value was selected for IOL power calculation[21-22]. Despite this, postoperative refractive PE was not significantly improved, and only 75.8% of patients were within ±1.00 D of PE[23], which is comparable to the refractive outcome of the RD group in our study. These results indicate other critical factors other than AL played roles in the unsatisfactory refractive outcomes after the combined surgery in RD patients. Therefore, in clinical practice, for RD patients with macula-off, we recommend a two-step strategy for PPV and cataract surgery, and we believe that adding +0.50 D to the preoperative predicted refractive power is acceptable to minimize the refractive error if the IOL is selected in patients with RD.

Many studies have shown that AL is closely related to the refractive outcomes after the combined surgery[14,19]. Our study found that patients with longer eyes (AL>26 mm) tended to have a hyperopic PE, and those with shorter eyes (AL<26 mm) tended to have a myopic PE, as confirmed by Pearson correlation analysis. However, Tranos *et al*[24] discovered that the refractive shift was towards myopia in patients who had phacovitrectomy for MH and ERM, which differs slightly from our results. The possible explanation is that the mean AL in their study was 23.3±0.86 mm compared with 25.52±2.94 mm in our study, which means the proportion of patients whose AL was greater than 26 mm was much higher. Furthermore, in our study, the mean PE was -0.04 D (P=0.118) in total, indicating neither a myopic nor a hyperopic refractive error shift in total, and the hyperopic overcorrection is most frequently seen in patients with longer eyes (AL>26 mm), which shows that our results are comparable to the above study. Tan *et al*[25] who evaluated refractive outcomes after cataract surgery in vitrectomized eyes, found that traditional formulas showed a significant hyperopic shift in long eyes (Haigis: 0.25 D, STK/T: 0.29 D, Holladay 1: 0.51 D, Hoffer Q: 0.39 D), which is consistent with the results in our study. Liu *et al*[26] also found that patients with longer eyes (AL>26 mm) had a hyperopia PE when using SRK/T for IOL power calculation after regular cataract surgery. One possible reason is that posterior staphyloma tends to result in a falsely longer AL measurement in patients with longer eyes. Another reason is the IOL calculation formula used in this study. This formula works well if AL is within the normal range, but it is inaccurate if the AL value is beyond the normal range. In order to increase the accuracy of the calculations used for IOL power in long eyes, Wang and Koch[27] proposed a method to optimize AL, which could significantly reduce the percentage of hyperopic outcomes in longer eyes undergoing regular cataract surgery. Nevertheless, we did not utilize this modified formula in our study because there is no adequate evidence of its accuracy in combined surgery.

In recent years, new formulas have emerged that employ new methodologies and additional preoperative eye parameters to calculate IOL power, such as Barrett Universal II, Kane, and Emmetropia Verifying Optical[28-29]. There is already sufficient evidence that the new formula performs well in cataract surgery for both normal and long eyes[10-11]. In addition, Hipólito-Fernandes *et al*[30] revealed that new formulas performed better than conventional formulas in patients who underwent phacovitrectomy, with BUII exhibiting the best overall performance. Similar results were reported by Sato *et al*[31]. Thus, it is advisable to apply new formulas to patients who plan to undergo phacovitrectomy. At present, the performance of Wang and Koch[27] AL adjustment in combined surgery is still elusive. The performance of new-generation formulas and Wang and Koch[27] AL adjustment in combined surgery will be further investigated in our future research. Back to the clinical practice, since hyperopic overcorrection is most frequently seen in patients with longer eyes (AL>26 mm), this could be counteracted by aiming for residual myopia preoperatively.

In addition, the multiple regression analysis revealed that ACD was another significant factor associated with postoperative PE. Similarly, ACD was related to the degree of refractive error in a study by Katz *et al*[18]. They thought ACD influenced the IOL position. So far, it is still controversial whether intraocular tamponade, ACD, and the IOL position correlate with the postoperative refractive outcomes after the combined surgery. There is no concrete proof that the combined surgery's postoperative myopic shift and the amount of forwarding IOL displacement are related. Therefore, further research is required to determine if the IOL location influences the results of combined surgery for refractive errors.

The combined surgery differs from single cataract surgery in the absence of the vitreous and the effect of filling agents on the IOL position. We compared the refractive outcomes of different intraocular tamponades used during the combined surgery. No significant difference in PE was found between different intraocular tamponades, as confirmed by our multivariate analysis. A similar result was reported by Hötte *et al*[14]. Likewise, there was no significant difference in PE regarding whether the eye was filled with silicone oil before the surgery. These findings suggest that if adequate optical biometry is used during the procedure, a satisfactory refractive outcome can be obtained regardless of what intraocular tamponade is filled before or during the surgery.

Our research has certain drawbacks. First, the number of RD patients in the sample was rather modest, which limited the sub-analysis of this group of patients. Second, the next-generation IOL power calculation formulae, such as Kane, Barrett Universal II, and Emmetropia Verifying Optical, were not evaluated in our research. Third, the surgeries were conducted by two different surgeons, which may be a confounding factor impacting the results. Fourth, our study is a retrospective case-series study, which reports clinical characteristics and outcomes from some groups of patients without a control group. Further prospective comparative studies based on large samples are required to confirm the conclusion of our study. Despite these limitations, our study represents a real-world scenario and is more applicable than a single-surgeon study.

In summary, our study showed RD patients have the least favorable refractive outcome after combined PPV or SOR with cataract surgery. Age, gender, preoperative BCVA, keratometry, and different intraocular tamponades filled during the combined surgery are not significantly correlated with PE. However, AL, vitreoretinal pathology, and ACD are strongly associated with PE in the combined surgery. These three factors affect refractive outcomes and thus can be used to predict a better postoperative refractive error in clinical practice.

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