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ARTICLE

Progression of posterior vitreous detachment after cataract surgery

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PURPOSE: To compare the progression of posterior vitreous detachment (PVD) between eyes that underwent cataract surgery and eyes that did not undergo surgery in non-highly myopic patients.
METHODS: One-hundred twenty-five eyes of 125 patients scheduled for phacoemulsification and 125 eyes of 125 age-matched patients who did not undergo surgery were enrolled. PVD status was evaluated using swept-source optical coherence tomography at 2 days (baseline), and 1, 3, 6, and 12 months postoperatively, and classified into five stages: 0 (no), 1 (paramacular), 2 (perifoveal), 3 (peripapillary), and 4 (complete). The PVD stage and incidence of progression to complete PVD were compared between groups.
RESULTS: The mean PVD stage significantly progressed over the 12 months in the surgery group ($P = 0.0004$), but did not change significantly in the non-surgery group. The PVD stage did not differ significantly between groups at 2 days, or 1, 3, and 6 months postoperatively, but was significantly more progressed in the surgery group than in the non-surgery group at 12 months ($P = 0.0390$). After adjusting for age, sex, axial length, and baseline PVD stage, the relative risk for progression to complete PVD was 7.1-fold higher in the surgery group than in the non-surgery group ($P < 0.0001$, 95% confidence interval 2.9–17.3).
CONCLUSION: PVD progressed significantly faster in eyes after cataract surgery compared with eyes that did not undergo surgery, and the relative risk of progression to complete PVD was approximately seven-fold higher within 1 year, indicating that the risk for PVD-related diseases is high after cataract surgery.

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INTRODUCTION

Progression of posterior vitreous detachment (PVD) causes many retinal diseases, including retinal tears, rhegmatogenous vitreous hemorrhage, retinal detachment, macular holes, and vitreomacular traction syndrome, depending on the stage of the PVD [1–8]. Of these PVD-related retinal diseases, peripheral retinal diseases develop when the stage of the PVD progresses to complete PVD [1–5], while macular diseases may occur in a stage of partial PVD around the fovea [6–8]. Evaluating the detailed progression of the PVD stage is therefore clinically relevant.

Previous studies using various methods to assess PVD revealed that PVD occurs more frequently after cataract surgery [9–14]. Mirshahi et al. [10] using B-scan ultrasonography reported that PVD occurs in 58.6% of eyes until 1 year postoperatively. Ivastinovic et al. [11] using spectral-domain optical coherence tomography (OCT) and ultrasonography found some degree of PVD in 71.4% of eyes at 3 months postoperatively. These studies, however, did not examine the progression of the PVD stage in detail.

The present study compared the stage of PVD using swept-source OCT between eyes that underwent phacoemulsification surgery and eyes that did not undergo surgery for up to 12 months postoperatively in non-highly myopic eyes. Specifically, because most serious PVD-related diseases occur in association with complete PVD [1–5], we determined the relative risk for progression to complete PVD until 1 year postoperatively.

PATIENTS AND METHODS

Study design

This study was a prospective case-control study conducted at the Hayashi Eye Hospital, Fukuoka, Japan between August 28, 2018 and September 11, 2020. The study protocol was approved by the Institutional Review Board of the Hayashi Eye Hospital on August 28, 2018. Written informed consent was obtained from each patient. The study protocol adhered to the tenets of the Declaration of Helsinki. The study is registered in the University Hospital Medical Information Network (UMIN000042994).

Sample size determination

The sample size needed for a statistical power of more than 80% to detect a clinically meaningful magnitude of difference in the progression of the PVD stage between eyes that underwent cataract surgery (surgery group) and eyes that did not undergo surgery (non-surgery control group) was determined on the basis of data from a pilot study. Assuming that a 15% difference in the progression of the PVD stage between the two groups at 12 months postoperatively was a clinically meaningful difference, we calculated that 113 eyes per group were required based on the standard deviation of the pilot study. Assuming a possible 10% loss to follow-up, we determined that 125 eyes were necessary for each group.

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Participants

All consecutive patients who were scheduled to undergo cataract surgery at the Hayashi Eye Hospital were screened beginning on August 28, 2018. The main inclusion criterion for the surgery group was eyes that were to undergo phacoemulsification and implantation of a hydrophobic acrylic intraocular lens (IOL), and only the first-operated eyes were enrolled. The preoperative exclusion criteria were (1) aphakic or pseudophakic eyes, (2) eyes with serious ocular pathologies of the cornea, vitreous, or optic nerve, (3) eyes with clinically significant cataracts, (4) eyes with retinal pathologies around the macula, including epiretinal membrane, macular hole, and vitreoretinal traction syndrome, (5) eyes with an axial length of 26.0 mm or longer, (6) eyes with a history of ocular surgery or inflammation, (7) patients with diabetes mellitus, (8) patients who refused to participate in the study, and (9) patients who had any difficulties undergoing the examinations. Eyes that underwent eventful surgery and had stage 4 complete PVD at 2 days postoperatively were excluded. Main inclusion criteria for the non-surgery control group were eyes that did not undergo surgery, and eyes that were age- (±5 years old) and sex-matched to the surgery group. The exclusion criteria for the non-surgery group were the same as for the surgery group. Patient screening was continued until 125 eyes of 125 patients in each group were enrolled, with the last eye enrolled on August 30, 2019.

Surgical procedures

Two surgeons (MY, KH) performed all of the surgeries. The surgeons created a clear corneal incision or transconjunctival corneoscleral incision according to previously described procedures [15]. First, two side ports were made with a 0.6-mm slit knife at approximately 90° to the main incision. After performing a continuous curvilinear capsulorrhexis using a bent needle or anterior capsule forceps, the main incision was made with a 2.0- or 2.4-mm steel keratome. After thorough hydrodissection, phacoemulsification of the nucleus and aspiration of the residual cortex were conducted. The lens capsule was filled with 1% sodium hyaluronate (Hyaguard®; Nitten Pharmaceutical, Tokyo, Japan), and a single-piece hydrophobic acrylic IOL (ZCB00V; Johnson and Johnson Vision, Santa Anna, California, USA) was inserted into the capsule using a Monarch II injector with a C or D cartridge (Alcon Laboratories, Fort Worth, Texas, USA). Upon completion of the surgery, the viscoelastic material was removed, and the main incision and side ports were hydrated with balanced saline solution. In this series, all surgeries were uneventful, and all IOLs were implanted completely in the lens capsule.

Outcome measures

All patients underwent examinations preoperatively, and at 2 days and 1, 3, 6, and 12 months postoperatively. The stage of the posterior vitreous was examined in all patients using a swept-source OCT (PLEX Elite 9000 version 1.7; Carl Zeiss Meditec, Jena, Germany). Because the PVD stage was difficult to classify before surgery due to a moderate degree of cataract in some eyes, the PVD stage at 2 days postoperatively was considered the baseline PVD stage. The measurement procedures for the swept-source OCT are described previously [16, 17]. In brief, we used the HD Spotlight 1 protocol covering a 16-mm wide section, which allowed us to obtain a horizontal image centered on the fovea and disc, and a vertical image centered on the fovea using this protocol. The scans were repeated 100 times in enhanced-depth imaging mode and averaged to create the OCT image. In addition, FastTrac motion correction software of the PLEX Elite 9000 was utilized during image acquisition. Three experienced ophthalmic technicians enhanced the visualization of the posterior vitreous by manually changing the contrast and brightness of the images.

In the present study, the PVD stage in 35 (28.9%) eyes of the 121 enrolled eyes in the surgery group could be classified preoperatively. In all 35 eyes, the preoperative PVD stage was the same as that at 2 days postoperatively. Furthermore, we performed an additional study to evaluate if the PVD stage change between the preoperative examination and 2 days postoperatively using 50 other eyes for which the PVD stage could be precisely determined both preoperatively and postoperatively (data not shown). The PVD stage progressed in 1 (2.0%) eye from stage 3 PVD to stage 4 PVD, but the stage was the same in the other 49 (98.0%) eyes. These results indicate that classification of the PVD stage at 2 days postoperatively is appropriate because the PVD stage barely progresses for up to 2 days postoperatively.

The PVD stage was classified according to the 5-stage classification system described by Itakura and Kishi [18]; stage 0 (no PVD), stage 1 (paramacular PVD), stage 2 (perifoveal PVD), stage 3 (vitreofoveal separation or peripapillary PVD), and stage 4 (complete PVD). Although other classification systems [19, 20] have been proposed, the system described by Itakura and Kishi is currently the only established and useful system for assessing PVD progression. One of the three experienced technicians acquired high-quality images of the posterior vitreous and retina from each patient using the swept-source OCT, and the images were stored in a computer. The two other technicians then independently determined the PVD stage. When a technician differed in the classification of the PVD stage using the horizontal and vertical scans, the more advanced stage determined was regarded as the representative stage. Furthermore, when the two technicians differed in their classification of the PVD stage, the more advanced stage was regarded as the representative PVD stage. The inter- and intra-examiner reproducibility for classifying the PVD stage was assessed previously, and the PVD stage determination was almost perfectly consistent between the two examiners and among multiple examinations by each examiner [17]. The examiners manually determined the foveal thickness of each eye using the swept-source OCT.

Refractive spherical and cylindrical powers and corneal astigmatism were measured using an autokerato/refractometer (KR-7100, Topcon, Tokyo, Japan). The manifest refractive spherical equivalent (MRSE) was determined as the spherical power plus half the cylindrical power. The axial length was measured using a swept-source OCT (IOLMaster® 700, version 1.14; Carl Zeiss Meditec). The corrected distance decimal visual acuity was evaluated, and the decimal visual acuity was converted to the logarithm of the minimum angle of resolution (logMAR) scale for statistical analysis. Ophthalmic technicians who were unaware of the purpose of the study performed all examinations.

Statistical analysis

The normality of the data distribution of continuous variables was assessed by inspection of histograms. Normally distributed data of continuous variables were compared between the surgery and non-surgery groups using the unpaired *t* test and not normally distributed data were compared using the Mann–Whitney *U* test. The homogeneity of the variance was tested using the Bartlett test. An unpaired *t* test was used when the data exhibited homoscedasticity, and a Welch *t* test was used when the data did not have homoscedasticity. Categorical variables were compared between groups using the χ^2 test or Fisher exact probability test where applicable. Because the PVD stage is a rank categorical variable, it was compared between groups using the Mann–Whitney *U* test. Longitudinal changes in the PVD stage were compared among the postoperative time-points using the Kruskal–Wallis test. The incidence of progression to complete PVD was compared between groups using the Kaplan–Meyer survival analysis, and the difference was tested using the log-rank test. The relative risk for progression to complete PVD at 12 months postoperatively was calculated using the Cox hazard model analysis with and without adjusting for possible confounding factors, including age, sex, axial length, and the PVD stage at baseline. Any difference with a *P* value less than 0.05 was considered statistically significant.

RESULTS

Of the 250 enrolled patients, 4 (1.6%) patients in the surgery group and 9 (3.6%) patients in the non-surgery group were lost to follow-up. Two patients refused to undergo examinations, 2 patients moved from the area, 4 patients were referred to other clinics, and 5 patients did not undergo the follow-up examination because of a schedule conflict. Accordingly, 121 (96.8%) patients in the surgery group and 116 (92.8%) patients in the non-surgery groups remained for the analysis.

The patient characteristics before cataract surgery and at baseline in the surgery and non-surgery groups are shown in Table 1. Before surgery, the mean age, ratio of men to women, ratio of left to right eyes, magnitude of corneal astigmatism, axial length, and central retinal thickness did not differ significantly between the two groups. The mean MRSE was significantly more myopic ($P = 0.0314$) and corrected distance visual acuity was significantly worse ($P < 0.0001$) in the surgery group than in the non-surgery groups. At baseline, the mean MRSE value, central retinal thickness, and corrected distance visual acuity did not differ significantly between the groups. The magnitude of corneal

Table 1. Comparison of patient characteristics (mean ± standard deviation) between eyes that underwent cataract surgery (surgery group) and eyes that did not undergo surgery (non-surgery group).

Characteristic	Surgery group ($n = 121$ eyes)	Non-surgery group ($n = 116$ eyes)	*P* value
Preoperatively			
Age (years)	59.9 ± 10.9	57.5 ± 9.28	0.0664
Sex (M/F)	56 M/65 F	66 M/50 F	0.1323
Left/right	55 L/65 R	45 L/71 R	0.3644
MRSE (D)	−1.91 ± 3.12	−1.17 ± 1.95	0.0314*
Corneal astigmatism (D)	0.98 ± 0.92	0.78 ± 0.58	0.1161
Corrected distance			
logMAR visual acuity	0.32 ± 0.33	−0.02 ± 0.07	<0.0001*
Central retinal thickness (μ)	218.5 ± 19.9	223.0 ± 22.5	0.1025
Axial length (mm)	23.86 ± 1.09	24.04 ± 1.01	0.1848.
Baseline			
MRSE (D)	−1.09 ± 1.28	−1.17 ± 1.95	0.6827
Corneal astigmatism (D)	1.02 ± 0.69	0.78 ± 0.58	0.0005*
Corrected distance			
logMAR visual acuity	0.00 ± 0.06	−0.02 ± 0.07	0.0970
Central retinal thickness (μ)	224.7 ± 30.0	222.9 ± 23.9	0.6857

M male, *F* female, *D* diopter, *logMAR visual acuity* logarithm of minimal angle of resolution visual acuity, *MRSE* manifest refractive spherical equivalent.
*Statistically significant difference between the two groups.

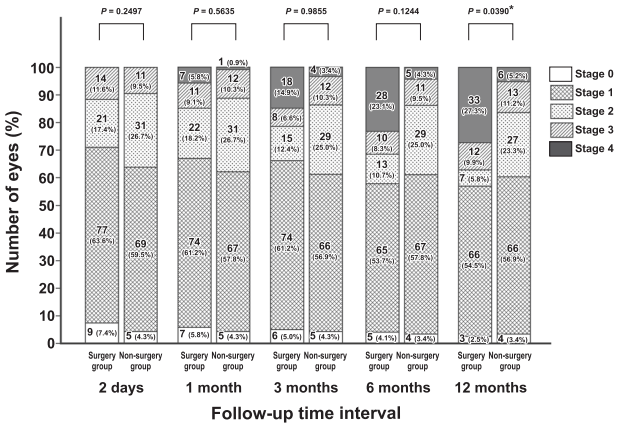

Fig. 1 Comparison of the stage of posterior vitreous detachment (PVD) between eyes that underwent cataract surgery (surgery group) and eyes that did not undergo surgery (non-surgery group). The PVD stage did not differ significantly between the surgery and non-surgery groups at 2 days, or 1, 3, and 6 months after baseline, but became significantly more progressed in the surgery group than in the non-surgery group at 12 months after baseline.

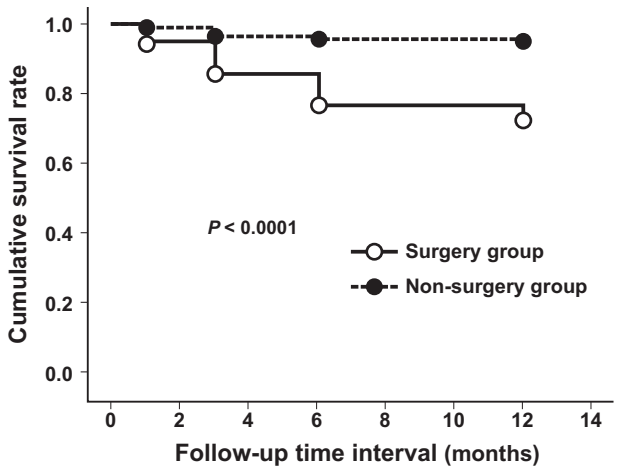

Fig. 2 Kaplan–Meyer survival analysis comparing the incidence of progression to complete posterior vitreous detachment (PVD) between eyes that underwent cataract surgery (surgery group) and eyes that did not undergo surgery (non-surgery group). The cumulative survival rate for progression to complete PVD was significantly lower in the surgery group than in the non-surgery group.

astigmatism was significantly greater in the surgery group than in the non-surgery group ($P = 0.0005$).

Comparison of the PVD stage between the surgery and non-surgery groups

All 237 eyes could be classified according to the classification system of Itakura and Kishi [18]. The mean PVD stage progressed significantly during the 12-month follow-up period in the surgery group ($P = 0.0004$), but did not change significantly in the non-surgery group ($P = 0.8773$). The PVD stage did not differ significantly between the surgery and non-surgery groups at 2 days, or 1, 3, and 6 months after baseline, but the stage became significantly more progressed at 12 months after baseline in the surgery group than in the non-surgery group ($P = 0.0390$; Fig. 1).

Comparison of the incidence of progression to complete PVD during the 12 months follow-up period between the surgery and non-surgery groups

The PVD stage progressed to stage 4 complete PVD in 33 (27.3%) eyes in the surgery group and 6 (5.2%) eyes in the non-surgery group within 12 months after baseline. Kaplan–Meyer survival analysis showed that the cumulative survival rate for progression to complete PVD was significantly lower in the surgery group than in the non-surgery group ($P < 0.0001$; Fig. 2). The hazard risk ratio for progression to complete PVD within 12 months postoperatively was 5.9-fold higher in the surgery group than in the non-surgery group ($P < 0.0001$, 95% confidence interval 2.5–14.2) without adjusting for possible confounding factors (Supplementary Table). When we adjusted for age, sex, axial length, and the PVD stage at baseline, the hazard risk ratio was 7.1-fold higher in the surgery group ($P < 0.0001$, 95% confidence interval 2.9–17.3).

Postoperative retinal complications in the surgery and non-surgery groups

In the surgery group, transient cystoid macular oedema was detected in two (1.7%) eyes with stage 0 PVD at 1 and 3 months postoperatively and with stage 1 PVD at 3 months postoperatively, and epiretinal membrane developed in two (1.7%) eyes with stage 4 PVD at 12 months postoperatively (Fig. 3). In the non-surgery group, no marked retinal disease was detected during the follow-up period. The incidence of postbaseline retinal complications did not differ significantly between the two groups ($P = 0.1222$).

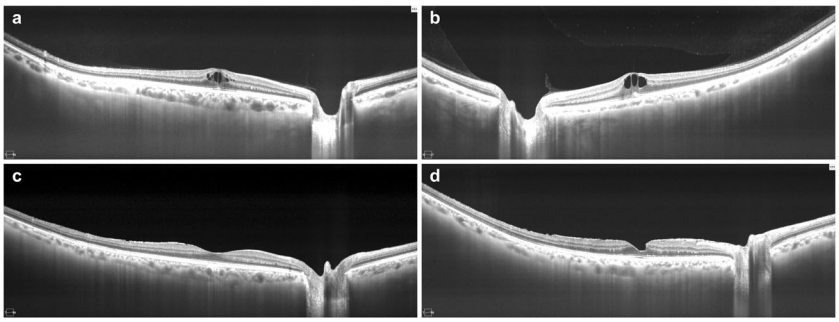

Fig. 3 Swept-source optical coherence tomography images of postoperative complications in eyes that underwent cataract surgery. Transient cystoid macular oedema was detected in one eye with no PVD at 1 and 3 months postoperatively (**a**) and in one eye with paramacular PVD at 3 months postoperatively (**b**), and epiretinal membrane developed in two eyes with complete PVD at 12 months postoperatively (**c**, **d**).

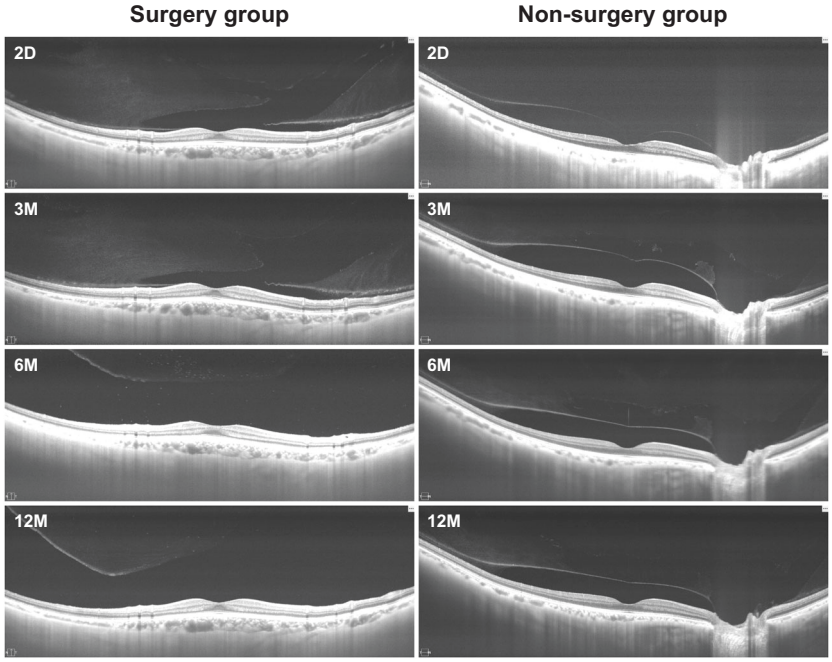

Fig. 4 Swept-source optical coherence tomography images of a representative eye among eyes that underwent cataract surgery (surgery group) and an eye that did not undergo surgery (non-surgery group). In the eye from the surgery group, the PVD stage progressed from stage 1 paramacular PVD at baseline to stage 4 complete PVD by 6 months postoperatively. In the eye from the non-surgery group, the PVD stage changed from stage 2 perifoveal PVD at baseline to stage 3 peripapillary PVD at 3 months after baseline, but remained at stage 3 PVD until 12 months after baseline.

Swept-source OCT images of a representative in the surgery and non-surgery groups

The swept-source OCT images of a representative eye in the surgery and non-surgery groups are shown in Fig. 4. At baseline, the PVD stage was stage 1 paramacular PVD in an eye in the surgery group and stage 2 perifoveal PVD in an eye in the non-surgery group. In the eye in the surgery group, the PVD stage progressed over time and became stage 4 complete PVD by 6 months after baseline. In the eye in the non-surgery group, the PVD stage changed to stage 3 peripapillary PVD at 1 month after baseline, but remained in stage 3 PVD until 12 months after baseline.

DISCUSSION

The findings of the present study revealed that the mean PVD stage progressed significantly during the 12-month follow-up period in eyes that underwent uneventful phacoemulsification surgery, whereas it did not change significantly in eyes that did not undergo surgery. From baseline to 6 months postoperatively, the mean PVD stage did not differ significantly between eyes with and without surgery. At 12 months after baseline, however, the PVD stage was significantly more progressed in eyes that underwent surgery than in eyes that did not undergo surgery. Indeed, at 12 months after baseline, complete PVD was detected in 27.9% of eyes with surgery and in 5.2% of eyes without surgery. These findings suggest that cataract surgery stimulates the progression of PVD.

PVD-related retinal diseases are considered to occur when PVD becomes complete PVD [1–8]. When we compared the incidence of progression to complete PVD, the cumulative survival rate was significantly worse in eyes that underwent surgery than in eyes that did not undergo surgery. Furthermore, the relative risk for progression to complete PVD at 12 months after baseline was approximately seven-fold higher in the surgery group compared with the non-surgery group. On the basis of these findings, the

risk for PVD-related diseases is quite high in the early period after cataract surgery.

Several studies using various methods to evaluate the states of PVD demonstrated that PVD occurs at a high incidence after cataract surgery [9–14]. Ivastinovic et al. [11] using spectral-domain OCT noted some degree of PVD in 71.4% of eyes at 3 months after surgery. Park et al. [14] reported that the status of PVD at baseline and the cup-to-disc ratio is associated with the onset and progression of PVD. In these studies, however, detailed progression of the PVD stage was not determined because a PVD classification system had not been established. The present study revealed that the PVD stage significantly progresses within 1 year after cataract surgery.

The present study has several limitations. First, the follow-up duration was only 12 months. The significance level of the difference in the PVD stage between groups at 12 months after baseline was not high. It is expected, however, that the PVD stage will progress in eyes that underwent surgery and that the difference will become greater. Second, the sample size was not large enough for subgroup analyses, such as of the incidence of PVD-related retinal complications and sex-related differences in PVD progression. A considerably larger sample size is required to examine the incidence of PVD-related complications, and therefore a multicenter study should be conducted in the future.

In conclusion, the PVD stage was significantly more progressed in eyes that underwent cataract surgery compared with eyes that did not undergo surgery at 12 months after baseline in non-highly myopic patients. Furthermore, the incidence of progression to complete PVD was approximately seven-fold higher in eyes that underwent surgery compared with eyes that did not undergo surgery. Thus, the risk for PVD-related retinal diseases is thought to be high within the first year after cataract surgery. Accordingly, surgeons should be aware of the potential occurrence of retinal diseases in the early postoperative period, including retinal tears, rhegmatogenous vitreous hemorrhage, retinal detachment, and macular holes. These retinal diseases are well known to occur especially in eyes with high myopia [21–26]. Further studies are necessary to examine the progression of PVD after cataract surgery in highly myopic patients.

Summary

What was known before

- Previous studies using various methods to assess posterior vitreous detachment (PVD) revealed that PVD occurs more frequently after cataract surgery.
- Details of the progression of the PVD stage were not examined, because a PVD classification system had not been established.

What this study adds

- The PVD stage was significantly more progressed in eyes that underwent cataract surgery compared with eyes that did not undergo surgery at 12 months after baseline in non-highly myopic patients.
- The relative risk for progression to complete PVD was approximately seven-fold higher in eyes that underwent surgery compared with eyes that did not undergo surgery.

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AUTHOR CONTRIBUTIONS

SH: study conception, study design, data analysis/interpretation of data, and writing and revising of the manuscript. MY: data acquisition and final approval. KH: study

conception, study design, data acquisition, data analysis/interpretation of data, and writing and revising of the manuscript, and final approval. KT: study conception, study design, data analysis/interpretation of data, and final approval.

COMPETING INTERESTS

The authors declare no competing interests.

ETHICS APPROVAL

The Institutional Review Board of Hayashi Eye Hospital approved the study protocol.

ADDITIONAL INFORMATION

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