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Effect of posterior chamber phakic refractive lens implantation on the ocular surface and tear film

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To evaluate changes in dry eye-related parameters after posterior chamber phakic refractive lens (PC-PRL) implantation. This prospective study included 21 highly myopic patients (39 eyes) who underwent PC-PRL implantation at Lanzhou Huaxia Eye Hospital between January 2021 and June 2022, with a 3-month postoperative follow-up. In addition to routine preoperative examinations, dry eye assessments were conducted preoperatively and at 1 week, 1 month, and 3 months postoperatively. These assessments included the Ocular Surface Disease Index (OSDI) questionnaire score, non-invasive first tear break-up time (NIF-BUT), non-invasive average tear break-up time (NIA-BUT), tear meniscus height (TMH), meibomian gland loss (MGL) rate, and Schirmer I test (SIt). Repeated measures ANOVA was used to compare the differences in parameters across different time points, with pairwise comparisons conducted using the LSD-*t* test. After grouping, the Student's t-test was applied to compare normally distributed data, while the Mann–Whitney U test was used for non-normally distributed data. Categorical data were analyzed using the chi-square test. A total of 21 patients (39 eyes) were included, comprising 10 males (19 eyes) and 11 females (20 eyes), aged 19 to 49 years (33.76 ± 7.87). All patients completed the 3-month follow-up. Significant differences in OSDI scores were observed pre- and post-surgery ($P = 0.008$), with a peak at one week post-surgery ($P < 0.001$), then stabilizing at one and three months post-surgery. Postoperative NIF-BUT and NIA-BUT significantly decreased ($P < 0.001$ for both) but returned to preoperative levels within three months. There were no significant changes in TMH, MGL, or SIt postoperatively ($P > 0.05$). Significant differences in dry eye parameters were observed between the dry eye and control groups before and after surgery ($P < 0.001$). PC-PRL implantation impacts tear film stability on the ocular surface after surgery, leading to varying degrees of dry eye symptoms in patients. After surgery, all dry eye parameters return to their preoperative levels within three months.

Keywords Dry eye, Phakic intraocular lens implantation, Tear film

Abbreviations

PC-PRL	Posterior chamber phakic refractive lens
OSDI	Ocular surface disease index
NIF-BUT	Non-invasive first tear film break-up time
NIA-BUT	Non-invasive average tear film break-up time
MGL	Meibomian gland loss
TMH	Tear meniscus height
SIt	Schirmer I test
ICL	Implantable collamer lens
UCVA	Uncorrected visual acuity
BCVA	Best corrected visual acuity
SE	Spherical equivalent
IOP	Intraocular pressure
WTW	White-to-white distance
ECD	Corneal endothelial cell density

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ACD	Anterior chamber depth
LT	Lens thickness
AL	Axial length
ACA	Anterior chamber angle
ATA	Angle-to-angle distance
hSTS	Horizontal sulcus-to-sulcus distances
vSTS	Vertical sulcus-to-sulcus distances
ACV	Anterior chamber volume
PD	Pupil diameter
CFDA	China food and drug administration
IOL	Intraocular lens
OVD	Ophthalmic viscosurgical device
BUT	Break-up time
SMILE	Small incision llenticule extraction
LASIK	Laser-assisted in situ keratomileusis

Background

Significant advancements in refractive surgery have led to a substantial reduction in severe complications. However, postoperative dry eye symptoms, such as ocular dryness, foreign body sensation, and visual fluctuation, continue to affect many patients[1]. These issues not only impact visual quality and overall satisfaction but may also cause long-term ocular discomfort and functional impairment. Refractive surgery can be categorized into corneal and intraocular procedures based on the surgical site. Studies have shown that dry eye symptoms are relatively common after corneal refractive surgery, significantly affecting patients' quality of life[2–4]. Among intraocular surgeries, the Implantable Collamer Lens (ICL) is widely used for correcting moderate to high myopia, but it cannot correct extreme myopia beyond − 18.00 diopters[5]. To address this limitation, the PC-PRL was developed.

PC-PRL is designed to correct extreme myopia in the range of − 10.00 to − 30.00 diopters, addressing the international gap in refractive correction technology for myopia greater than − 18.00 diopters[6]. This procedure preserves the patient's natural crystalline lens without involving corneal ablation and offers extensive correction, safety, and reversibility[7]. Patients with extreme myopia are particularly susceptible to dry eye symptoms due to factors such as increased axial length, abnormal corneal morphology, and compromised tear film function. Studies have shown a significant association between high myopia and dry eye, with these patients frequently experiencing symptoms like dryness, irritation, and visual fatigue[8,9]. The unique ocular conditions in these patients underscore the importance of investigating dry eye issues following PC-PRL implantation. This study aims to assess the impact of this procedure on ocular surface and tear film stability by tracking changes in dry eye parameters postoperatively. Through a comprehensive analysis, we seek to address the current research gap, provide a scientific basis for clinical practice, and offer new insights into the prevention and management of postoperative dry eye symptoms.

Subjects and methods

Subjects

A prospective analysis was performed on 21 patients (39 eyes) with high myopia who underwent PC-PRL implantation at Lanzhou Huaxia Eye Hospital between January 2021 and June 2022, with a 3-month postoperative follow-up. The study included 10 male patients (19 eyes) and 11 female patients (20 eyes), aged 19–49 years (33.76 ± 7.87). The study protocol adhered to the Declaration of Helsinki and was approved by the Ethics Committee of Lanzhou Huaxia Eye Hospital (Approval No. LXLL-20221001). All patients and their families were fully informed of the study details, and written informed consent was obtained.

Inclusion criteria

1. Age between 18 and 50 years;
2. Complete follow-up data available;
3. Discontinuation of soft contact lenses for at least 2 weeks and hard contact lenses for at least 4 weeks prior to surgery;
4. Spherical power ranging from − 10.00 to − 30.00 diopters (D).
5. No use of medications that affect tear secretion or tear film stability;
6. Patent lacrimal ducts;
7. Stable refractive status (annual increase in myopic refraction ≤ 0.5D) for over one year;
8. Anterior chamber depth (ACD) ≥ 2.5 mm;
9. Horizontal corneal diameter (white-to-white, WTW) ≥ 10.3 mm;
10. Corneal endothelial cell density (ECD) ≥ 2000 cells/mm^2;

No significant postoperative complications, such as cataracts, iris prolapse, or secondary glaucoma.

Exclusion criteria

1. History of severe dry eye, keratoconus, corneal endothelial dystrophy, corneal opacity, glaucoma, cataracts, uveitis, retinal detachment, optic neuropathy, or choroidal retinal disease significantly affecting vision;
2. Presence of systemic autoimmune diseases (e.g., Sjögren's syndrome, rheumatoid arthritis, systemic lupus erythematosus, Waldenström's macroglobulinemia, sarcoidosis), diabetes, or severe mental disorders;
3. Previous history of corneal refractive surgery or intraocular surgery;

Use of antidepressants, antihistamines, diuretics, or other relevant medications within the past year.

Methods

Preoperative routine examinations

All patients underwent comprehensive preoperative examinations, including measurements of uncorrected visual acuity (UCVA) and best-corrected visual acuity (BCVA) using an international standard visual acuity chart, both reported in LogMAR units. Spherical power, cylindrical power, and spherical equivalent (SE) were assessed under both cycloplegic and non-cycloplegic conditions using an automatic refractor (NIDEK, Japan). Intraocular pressure (IOP) was measured with a non-contact tonometer (NIDEK, Japan). Anterior segment examination was conducted with a slit-lamp microscope (ZEISS, Germany), while fundus examination was performed after mydriasis using a fundus lens and an OPTOS ultra-widefield fundus camera (NIKON, Japan). WTW was manually measured with calipers. ECD was evaluated using a corneal endothelial cell analyzer (CSO, Italy). ACD and lens thickness (LT) were measured with an ophthalmic A/B ultrasound system (AVISO, France), while axial length (AL), ACD, and WTW were assessed using an IOL Master optical biometer (ZEISS, Germany). Anterior chamber angle (ACA) and angle-to-angle distance (ATA) were measured using ultrasound biomicroscopy (UBM) (AVISO, France) to determine if the angle was open, the presence of any iris-ciliary body cysts, and to measure horizontal and vertical sulcus-to-sulcus distances (hSTS and vSTS). The SIRIUS 3D anterior segment analysis system (CSO, Italy) was employed to measure ACD, ACA, anterior chamber volume (ACV), and pupil diameter (PD) under scotopic conditions. All measurements were recorded in detail, with each parameter measured three times by the same examiner, and the average value was used. Preoperative and postoperative examinations were conducted under consistent lighting and temperature conditions, with all measurements performed by the same operator.

Selection of PC-PRL model

The PC-PRL, also known as the "floating lens," is a product with independent intellectual property rights in China and has been approved for market release by the China Food and Drug Administration (CFDA). It is manufactured by Hangzhou Aijinglun Technology Co., Ltd., Zhejiang, China. The intraocular lens (IOL) model was selected preoperatively based on the WTW corneal diameter. For patients with WTW ≤ 11.0 mm, the BK108 model (lens diameter: 10.8 mm) was chosen, while the BK113 model (lens diameter: 11.3 mm) was used for patients with WTW > 11.0 mm. The diopter calculation was performed by the manufacturer based on the preoperatively obtained SE, and the surgeon could choose whether to reserve a certain degree of undercorrection depending on the patient's specific condition.

Surgical procedures

All surgeries were performed by the corresponding author, an experienced ophthalmologist responsible for all patients' postoperative care.

Preoperative preparation

Two weeks before surgery, YAG laser peripheral iridotomy was performed at the 10:30 and 1:30 positions of the surgical eye, followed by topical anti-inflammatory medication. For three consecutive days before surgery, levofloxacin eye drops and gatifloxacin gel were applied topically three times daily. One hour before surgery, compound tropicamide eye drops were administered 3 to 4 times to achieve full mydriasis.

Surgical methods

Under topical anesthesia, a 3.0 mm main incision was made in the clear cornea at the 10:00 to 11:00 position, with an auxiliary incision at the 2:00 to 2:30 position. The PC-PRL lens was injected into the anterior chamber using an injector, ensuring that its anterior surface faced upward. After the lens unfolded, an appropriate amount of ophthalmic viscosurgical device (OVD) was injected, and the lens was maneuvered behind the iris into the correct position in the posterior chamber using a positioning hook. The OVD was then replaced with a balanced salt solution, and the corneal incisions were sealed watertight. At the conclusion of the surgery, tobramycin-dexamethasone eye ointment was applied, and the eye was patched.

Postoperative treatment

Postoperatively, the patient was prescribed preservative-free eye gel containing deproteinized calf blood extract, to be applied to the operated eye four times daily for one month or until the supply was finished. Tobramycin-dexamethasone eye drops (with preservative) were also prescribed for use four times daily, along with tobramycin-dexamethasone eye ointment, applied once nightly. After one week, the tobramycin-dexamethasone medications were discontinued and replaced with fluorometholone eye drops (with preservative), applied four times daily for an additional week, after which they were also discontinued.

Dry eye-related examinations
All patients underwent dry eye examinations before surgery. Follow-up tests were conducted and documented by the same experienced ophthalmologist at one week, one month, and three months post-surgery.

OSDI
The questionnaire consists of 12 questions, each rated on a five-point scale based on frequency: 0 for none, 1 for occasional, 2 for about half the time, 3 for most of the time, and 4 for continuous occurrence. The score is calculated by summing the scores for the 12 questions, dividing by the total number of questions answered, and then multiplying by 25. According to the Chinese Dry Eye Expert Consensus: Dry Eye Associated with Ocular Surgery (2021), an OSDI score of ≥ 13 indicates dry eye symptoms and was used for grouping in this study.

NIF-BUT and *NIA*-BUT
Tear film break-up time was assessed using a Keratograph 5 M ocular surface analyzer (OCULUS, Germany). The instrument automatically detected tear film break-up time after two normal blinks. The time from the second blink to the first tear film break-up was recorded as NIF-BUT, while the average time for all break-up sites was recorded as NIA-BUT.

TMH
TMH was measured using the Keratograph 5 M ocular surface analyzer (OCULUS, Germany). Images of the tear meniscus were captured, and the height beneath the pupil center was measured using the software's ruler function. The final measurement was the average of three consecutive readings.

MGL
The upper and lower eyelids of the patients were inverted, and the meibomian glands were imaged using a Keratograph 5 M ocular surface analyzer (OCULUS, Germany). The software analyzed the images to determine the area of gland loss relative to the total gland area, calculating the MGL rate.

SIt
A 5 mm × 35 mm filter paper strip was placed in the lower conjunctival fornix of the patient's eye, positioned in the middle and outer third. The length of wetting (0–30 mm) was measured after 5 min without topical anesthesia.

Statistical analysis
Statistical analysis was conducted using SPSS 26.0. The Kolmogorov–Smirnov test assessed the normality of all collected data. Measurement data following a normal distribution were expressed as mean ± standard deviation. Repeated measures ANOVA was used to compare parameter differences at various follow-up time points before and after surgery. The LSD-*t* test was used for pairwise comparisons. A P-value < 0.05 was considered statistically significant. For normally distributed data, the Student's t-test was applied after grouping, while the Mann–Whitney U test was used for non-normally distributed data.

Results
General conditions
A total of 21 patients (39 eyes) were included in this study, consisting of 10 males (19 eyes) and 11 females (20 eyes), with an age range of 19–49 years (33.76 ± 7.87). All surgeries were successfully completed. The UCVA (LogMAR) was 1.71 ± 0.81 preoperatively and improved to 0.01 ± 0.12, 0.01 ± 0.10, and 0.01 ± 0.08 at 1 week, 1 month, and 3 months postoperatively, respectively. The BCVA (LogMAR) improved from 0.50 ± 0.27 preoperatively to 0.01 ± 0.13, 0.01 ± 0.12, and 0.01 ± 0.11 at 1 week, 1 month, and 3 months postoperatively, respectively. IOP (mmHg) was 16.30 ± 3.80 preoperatively and measured 15.10 ± 2.70 and 15.40 ± 2.30 at 1 week and 1 month postoperatively, respectively. Other preoperative examination parameters are shown in Table 1.

Changes in dry eye-related parameters before and after surgery
OSDI scores significantly differed before and after surgery ($F = 7.13$, $P = 0.008$), with a marked increase at 1 week post-surgery compared to pre-surgery ($t = -4.03$, $P < 0.001$). However, no significant differences were observed at 1 month and 3 months post-surgery compared to pre-surgery ($t = -1.37$, $P = 0.179$; $t = -0.43$, $P = 0.671$). Both NIF-BUT and NIA-BUT showed significant changes before and after surgery ($F = 28.85$, $P < 0.001$; $F = 33.48$, $P < 0.001$). NIF-BUT significantly decreased at 1 week and 1 month post-surgery compared to pre-surgery ($t = 3.65$, $P = 0.001$; $t = 3.77$, $P = 0.001$), with no significant difference at 3 months post-surgery ($t = 0.75$, $P = 0.459$). NIA-BUT also significantly decreased at 1 week and 1 month post-surgery compared to pre-surgery ($t = 3.26$, $P = 0.002$; $t = 3.94$, $P < 0.001$), but there was no significant difference at 3 months post-surgery compared to pre-surgery ($t = 0.83$, $P = 0.372$). Additionally, there were no significant differences in TMH, MGL, and SIt at any time point after surgery compared to pre-surgery ($F = 0.71$, $P = 0.450$; $F = 3.39$, $P = 0.074$; $F = 0.74$, $P = 0.534$), as shown in Table 2.

Ocular surface characteristics of patients with severe preoperative dry eye symptoms
Comparison of preoperative dry eye-related parameters between two groups
Patients were divided into control (OSDI < 13, Group A) and dry eye (OSDI ≥ 13, Group B) groups based on their preoperative OSDI scores. Group A included 12 patients (22 eyes), with seven males and five females, and

Parameters	Cases	Eyes	Means ± standard	Range
SE, D	21	39	− 17.21 ± 6.95	10.15 ~ 24.50
WTW, mm	21	39	11.62 ± 0.87	10.49 ~ 12.38
ECD, cells/mm^2	21	39	2863.28 ± 410.72	2118 ~ 3662
ACD, mm	21	39	3.07 ± 0.58	2.72 ~ 3.64
LT, mm	21	39	3.75 ± 0.62	3.19 ~ 4.43
AL, mm	21	39	27.66 ± 4.73	24.58 ~ 33.31
ATA, mm	21	39	11.12 ± 0.63	10.34 ~ 12.60
ACA, degree	21	39	45.43 ± 6.22	33 ~ 52
hSTS, mm	21	39	11.25 ± 0.86	9.84 ~ 12.46
vSTS, mm	21	39	11.58 ± 0.74	10.37 ~ 13.10
ACV, mm^3	21	39	178.53 ± 36.80	124 ~ 235
PD, mm	21	39	6.53 ± 0.89	4.48 ~ 8.12

Table 1. Eye examination parameters before PC-PRL implantation.
Data is expressed as means ± standard deviation.

Time	OSDI scores	NIF-BUT, s	NIA-BUT, s	TMH, mm	MGL, %	S I t, mm
Pre-operative	11.91 ± 7.14	9.29 ± 2.35	9.89 ± 2.61	0.22 ± 0.05	32.83 ± 17.13	9.26 ± 3.62
1 w post-operative	18.80 ± 9.52[a]	5.22 ± 3.53[a]	5.37 ± 3.09[a]	0.22 ± 0.09	39.93 ± 15.42	7.84 ± 6.68
1 m post-operative	14.61 ± 6.32	5.86 ± 3.10[a]	6.12 ± 3.43[a]	0.20 ± 0.06	32.98 ± 19.81	8.36 ± 3.07
3 m post-operative	12.83 ± 6.48[b]	8.82 ± 3.52[b,c]	9.13 ± 3.65[b,c]	0.22 ± 0.08	32.81 ± 19.29	8.06 ± 4.30
F	7.13	28.85	33.48	0.71	3.38	0.74
P	0.008	< 0.001	< 0.001	0.450	0.074	0.534

Table 2. Comparison of dry eye-related parameters before and after PC-PRL implantation.
Data is expressed as means ± standard deviation. $n = 21$ cases (39 eyes). LSD-*t* test: [a]compared with pre-operative, $P < 0.05$; [b]compared with 1 week post-operative. $P < 0.05$; [c]compared with 1 month post-operative, $P < 0.05$. PC-PRL, posterior chamber phakic refractive lens; w, week; m, month; OSDI, ocular surface disease index; NIF-BUT, non-invasive first tear break-up time; NIA-BUT, non-invasive average break-up time; TMH, tear meniscus height; MGL, meibomian gland loss; S I t, Schirmer I test.

a mean age of 30.6 ± 6.3 years. Group B included 9 patients (17 eyes), with three males and six females, and a mean age of 39.0 ± 6.5 years. There was a significant age difference between the two groups ($t = -3.314$, $P = 0.004$). However, there was no significant difference in gender distribution between the groups ($\chi^2 = 0.245$, $P = 0.245$). Preoperative dry eye-related parameters, including OSDI scores ($F = 6.795$, $P < 0.001$), NIF-BUT ($F = 30.205$, $P < 0.001$), NIA-BUT ($F = 28.211$, $P < 0.001$), TMH ($F = 5.339$, $P < 0.001$), MGL ($F = 18.412$, $P < 0.001$), and SIt ($F = 3.476$, $P < 0.001$), showed significant differences between the two groups, as shown in Table 3.

Compare OSDI before and after surgery for two groups
Significant differences in OSDI scores were observed between the two groups at various time points before and after surgery ($F = 6.795$, $P < 0.001$; $F = 12.476$, $P < 0.001$; $F = 8.733$, $P < 0.001$; $F = 7.908$, $P < 0.001$). Differences in OSDI scores were also significant when comparing the two groups ($F_{time} = 51.485$, $P < 0.001$, $\eta^2 = 0.582$; $F_{groups} = 93.712$, $P < 0.001$, $\eta^2 = 0.712$). The interaction effect between OSDI and observation time was statistically significant ($F_{time*groups} = 6.847$, $P = 0.001$, $\eta^2 = 0.156$), as shown in Table 4.

Groups	Cases	Eyes	Age (years)	Gender (M/F)	OSDI, scores	NIF-BUT, s	NIA-BUT, s	TMH, mm	MGL,%	SIt, mm
A	12	22	30.6 ± 6.3	7/5	7.1 ± 2.4	12.3 ± 2.8	13.1 ± 3.0	0.26 ± 0.03	20.9 ± 10.1	11.7 ± 5.9
B	9	17	39.0 ± 6.5	3/6	18.7 ± 4.1	5.8 ± 2.4	5.9 ± 3.1	0.17 ± 0.03	37.2 ± 11.9	6.1 ± 4.8
***F*/*t*/χ^2**			-3.314	0.256	6.795	30.205	28.211	5.339	18.412	3.476
P			0.004	0.245	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Table 3. To compare baseline parameters for two groups. Data is expressed as means ± standard deviation.
Group A, control group (OSDI < 13); Group B, dry eye group (OSDI ≥ 13);
OSDI, ocular surface disease index; NIF-BUT, non-invasive first tear break-up time; NIA-BUT, non-invasive average break-up time; TMH, tear meniscus height; MGL, meibomian gland loss; SIt, Schirmer I test.

Groups	Eyes	Preoperative	Postoperative		
			1 week	1 month	3 months
A	22	7.1 ± 2.4	11.8 ± 5.1	9.6 ± 5.7	5.5 ± 4.7
B	17	18.7 ± 4.1	27.8 ± 9.5	25.7 ± 10.4	21.0 ± 7.4
F		6.795	12.476	8.773	7.908
P		< 0.001	< 0.001	< 0.001	< 0.001

Table 4. Compare OSDI before and after surgery for two groups. Data is expressed as means ± standard deviation. Group A, control group; Group B, dry eye group; $F_{time} = 51.485$, $P < 0.001$, $\eta^2 = 0.582$; $F_{groups} = 91.571$, $P < 0.001$, $\eta^2 = 0.712$; $F_{time*groups} = 6.847$, $P = 0.001$, $\eta^2 = 0.156$.

Groups	Eyes	Preoperative	Postoperative		
			1 week	1 month	3 months
A	22	12.3 ± 2.8	8.3 ± 2.3	8.3 ± 3.1	10.9 ± 3.1
B	17	5.8 ± 2.4	3.3 ± 1.3	2.9 ± 1.5	2.9 ± 1.8
F		30.205	58.126	38.442	46.995
P		< 0.001	< 0.001	< 0.001	< 0.001

Table 5. Compare NIF-BUT before and after surgery for two groups. Data is expressed as means ± standard deviation. Group A, control group; Group B, dry eye group; $F_{time} = 23.288$, $P < 0.001$, $\eta^2 = 0.769$; $F_{groups} = 56.493$, $P < 0.001$, $\eta^2 = 0.604$; $F_{time*groups} = 8.992$, $P < 0.001$, $\eta^2 = 0.196$.

Compare NIF-BUT before and after surgery for two groups

Significant differences in NIF-BUT were observed between the two groups at various time points before and after surgery ($F = 30.205$, $P < 0.001$; $F = 58.126$, $P < 0.001$; $F = 38.442$, $P < 0.001$; $F = 46.995$, $P < 0.001$). Significant differences were also found in NIF-BUT between the two groups over time ($F_{time} = 23.288$, $P < 0.001$, $\eta^2 = 0.769$; $F_{group} = 56.493$, $P < 0.001$, $\eta^2 = 0.604$). The interaction effect between NIF-BUT and observation time was statistically significant ($F_{time*group} = 8.992$, $P < 0.001$, $\eta^2 = 0.196$), as shown in Table 5.

Discussion

Our research systematically evaluated changes in dry eye-related parameters in patients with extremely high myopia following PC-PRL implantation. By analyzing tear film function before and after surgery, we further explored the specific effects of this procedure on postoperative dry eye symptoms. The findings provide new reference data for understanding the mechanisms by which this surgery affects tear film function and may contribute to optimizing strategies for preventing and managing postoperative dry eye, ultimately enhancing patient quality of life and satisfaction.

In this study, the OSDI questionnaire was used to assess subjective dry eye symptoms in patients after PC-PRL surgery, focusing on three aspects: ocular symptoms, visual function, and environmental triggers, demonstrating its high reliability. The results showed that OSDI scores at 1 week postoperatively were significantly higher than preoperative levels, reflecting an exacerbation of early dry eye symptoms. However, over time, OSDI scores gradually returned to preoperative levels at 1 month and 3 months postoperatively, indicating a recovery of tear film function and a reduction in subjective discomfort. This trend aligns with findings from other intraocular surgery studies, such as those by Cung et al.[10], which reported a significant increase in OSDI scores at 1 month after cataract phacoemulsification, followed by a return to preoperative levels at 3 months. ICL implantation, a common intraocular refractive surgery, has also been shown to significantly increase OSDI scores at 1 week and 1 month postoperatively, with a return to preoperative levels by 3 months[11]. However, different studies have suggested variations in the speed of postoperative recovery. For instance, Chen et al.[12] found that OSDI scores in ICL patients remained significantly higher than preoperative levels at 1 month postoperatively and had not fully recovered by 3 months. In contrast, PC-PRL surgery is often used to correct extremely high myopia, where patients have relatively poor preoperative vision. The significant postoperative visual improvement may cause patients to be less aware of minor postoperative discomfort, including dry eye symptoms. Additionally, subgroup analysis revealed that patients with preoperative dry eye symptoms (Group B) exhibited more pronounced subjective dry eye symptoms postoperatively, with OSDI scores approximately three times higher than the control group (Group A) at 1 week and 1 month postoperatively, and still significantly higher than Group A at 3 months. This suggests that patients with preoperative dry eye symptoms are more likely to experience tear film instability postoperatively and have a slower recovery rate, necessitating closer monitoring and management of dry eye prevention and treatment after surgery.

Previous studies have compared the effects of different corneal refractive surgeries on tear film break-up time (BUT), showing that both small incision lenticule extraction (SMILE) and laser-assisted in situ keratomileusis (LASIK) significantly reduce tear film BUT at 1 week postoperatively. However, tear film BUT typically recovers to preoperative levels within 1–6 months after SMILE, while LASIK recovery usually takes longer, requiring 3

to 9 months[13]. In this study, NIF-BUT and NIA-BUT in patients after PC-PRL implantation were significantly reduced at 1 week and 1 month postoperatively but generally returned to preoperative levels by 3 months. Compared to corneal refractive surgery, intraocular refractive surgery changes refractive status by implanting an intraocular lens without corneal ablation, thereby causing less damage to corneal nerves. Although the surgical incision may directly damage corneal nerves, the absence of corneal ablation means that corneal morphology remains largely unchanged, resulting in milder nerve damage and subsequently less impact on corneal sensation, neurotrophic factor release, and tear film dynamics. This also explains why the recovery of tear film BUT after PC-PRL implantation is similar to that observed in other intraocular refractive surgeries. The subgroup analysis further revealed that patients with preoperative dry eye symptoms (Group B) had poorer tear film stability. During postoperative follow-up, some patients in Group B experienced blurred vision and visual fluctuations, suggesting that their ocular surface microenvironment was already fragile before surgery and more susceptible to the impact of surgery. Additionally, unlike other intraocular refractive surgeries, YAG laser iridotomy is required before PC-PRL implantation. This invasive procedure may affect the ocular surface and tear film stability postoperatively. Future studies should explore the specific mechanisms of this effect to provide more precise guidance for postoperative management.

In ocular surgeries, meibomian gland function can be influenced by various factors, including surgery-related ocular surface inflammation, the use of eyelid retractors, postoperative medication, and perioperative dry eye development[14]. In this study, MGL rate returned to preoperative levels within one month postoperatively, suggesting that the long-term impact of surgery on meibomian gland structure may be minimal. This rapid recovery may be attributed to the good overall health of the participants, absence of comorbidities, and adherence to regular follow-up and medication postoperatively. Additionally, the surgeon's skilled and gentle technique may have minimized damage to the meibomian glands. Although the meibomian glands recovered well, changes in tear film lipid layer thickness after surgery still require further investigation. Previous studies have shown that changes in the tear film lipid layer after ocular surgery are closely related to dry eye symptoms[15]. For instance, a postoperative decrease in tear film lipid layer thickness may lead to increased tear evaporation, exacerbating dry eye symptoms. While no significant changes in tear film lipid layer thickness were observed in this study, future research should explore the dynamic changes in the tear film lipid layer after PC-PRL surgery and their long-term impact on dry eye symptoms.

In conclusion, PC-PRL implantation initially disrupts tear film stability, causing varying degrees of dry eye symptoms, but it does not significantly affect tear secretion or meibomian gland morphology. By 3 months postoperatively, both tear film stability and subjective dry eye symptoms generally returned to preoperative levels. For patients with high postoperative OSDI scores, symptomatic treatment should be promptly administered to reduce discomfort complaints and improve postoperative satisfaction. Additionally, since tear film BUT changes significantly after surgery, close monitoring of tear film stability-related parameters is essential to prevent severe dry eye symptoms.

Conclusions

PC-PRL implantation initially disrupts tear film stability, leading to temporary dry eye symptoms. However, these parameters generally return to baseline within three months post-surgery. Patients with severe preoperative dry eye symptoms experience slower postoperative recovery, indicating greater susceptibility to surgical impact.

Limitations of this study

This study has several limitations. The small sample size may limit the representativeness of the statistical analysis and the generalizability of the results. The relatively short follow-up period did not allow for comprehensive observation of long-term changes in tear film function and dry eye symptoms. The assessment methods for tear film function were limited, suggesting that future studies should incorporate more advanced evaluation techniques. Additionally, potential confounding factors, such as differences in postoperative medication regimens and environmental conditions, were not fully controlled. Future research should focus on validating and expanding the findings of this study by increasing the sample size, extending the follow-up period, incorporating more comprehensive evaluation methods, and strictly controlling potential confounders.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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Author contributions
Z.Y. designed the study. Z.Y. and Y.L. performed the study. Z.Y. and Y.L. analyzed data and drafted the manuscript. Z.Y. acquired funding. The guarantor: Z.Y. All authors read and approved the final version of the manuscript.

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Competing interests
The authors declare no competing interests.

Ethics approval
This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Lanzhou Huaxia Eye Hospital (approval ID: LXLL-20221001).

Consent to participate
Informed consent was obtained from all individual participants included in the study.

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