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Evaluation of Tear Film Dysfunction and Dry Eye Disease after Uncomplicated Cataract Surgery

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Abstract
Dry eye disease (DED) represents one of the most common complications following cataract surgery, significantly impacting patient quality of life and visual outcomes. This prospective study evaluated tear film dysfunction and dry eye symptoms in 180 patients who underwent uncomplicated phacoemulsification with intraocular lens implantation over a 12-month follow-up period. Patients were assessed using comprehensive tear film evaluation including Schirmer's test, tear break-up time (TBUT), ocular surface disease index (OSDI), and fluorescein staining at baseline, 1 week, 1 month, 3 months, 6 months, and 12 months post-operatively. Results demonstrated a significant increase in dry eye symptoms and tear film instability during the first 3 months post-surgery, with 67.2% of patients developing new-onset dry eye or experiencing worsening of pre-existing symptoms. The mean OSDI score increased from 18.4±12.3 pre-operatively to 42.7±18.9 at 1 month ($p<0.001$), while TBUT decreased from 8.2±3.1 seconds to 5.1±2.4 seconds ($p<0.001$). Recovery patterns showed gradual improvement after 3 months, though 35% of patients continued to experience persistent dry eye symptoms at 12 months. Risk factors for post-operative dry eye included advanced age, female gender, pre-existing meibomian gland dysfunction, longer surgical duration, and concurrent topical medication use. These findings underscore the importance of pre-operative dry eye screening, appropriate patient counseling, and implementation of prophylactic and therapeutic strategies to minimize post-surgical ocular surface complications.

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Introduction

Cataract surgery represents the most commonly performed surgical procedure worldwide, with over 32 million procedures conducted annually [1]. While modern phacoemulsification techniques have achieved remarkable safety profiles and visual outcomes, post-operative dry eye disease (DED) remains a significant concern affecting patient satisfaction and quality of life [2, 3]. The prevalence of dry eye symptoms following cataract surgery ranges from 9.8% to 96.6% in various studies, with this wide variation attributed to differences in diagnostic criteria, follow-up duration, and patient populations [4, 5].

The pathophysiology of post-cataract surgery dry eye is multifactorial, involving disruption of corneal innervation, inflammatory

responses, alterations in tear film composition, and mechanical trauma to the ocular surface [6]. Corneal incisions during surgery can damage corneal nerves, leading to decreased corneal sensitivity and reduced reflex tear production [7]. Additionally, the use of topical anesthetics, antiseptics, and post-operative medications can contribute to ocular surface toxicity and inflammation [8].

Pre-existing dry eye disease affects approximately 20-30% of cataract surgery candidates, particularly in the elderly population [9]. These patients are at higher risk for developing severe post-operative dry eye symptoms, which can mask or interfere with the assessment of surgical outcomes [10]. The economic burden of managing post-operative dry eye is substantial, with increased healthcare utilization and reduced productivity [11].

Recent advances in understanding the tear film dynamics and ocular surface biology have led to improved diagnostic techniques and therapeutic approaches [12]. The development of standardized diagnostic criteria and patient-reported outcome measures has facilitated better characterization of post-operative dry eye [13]. However, there remains a need for comprehensive studies evaluating the natural history of tear film dysfunction following modern cataract surgery techniques.

This study aims to provide a detailed evaluation of tear film dysfunction and dry eye disease following uncomplicated cataract surgery, identify risk factors for post-operative dry eye, and establish evidence-based recommendations for clinical management.

Materials and Methods

Study Design and Participants

This prospective, observational study was conducted at the Department of Ophthalmology between January 2022 and December 2023. The study protocol was approved by the Institutional Review Board and adhered to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all participants.

Inclusion criteria comprised patients aged 50 years and older scheduled for uncomplicated phacoemulsification with posterior chamber intraocular lens implantation. Exclusion criteria included previous ocular surgery, active ocular infection, severe dry eye disease (OSDI >65), autoimmune disorders, contact lens wear within 2 weeks of surgery, and inability to complete follow-up examinations.

Surgical Technique

All surgeries were performed by experienced surgeons using standardized phacoemulsification techniques. A 2.4-mm clear corneal incision was made, followed by continuous curvilinear capsulorhexis, phacoemulsification, and implantation of a foldable acrylic intraocular lens. Post-operative treatment included topical prednisolone acetate 1% four times daily for 4 weeks and topical antibiotic (moxifloxacin 0.5%) four times daily for 1 week.

Outcome Measures

Comprehensive ocular surface evaluation was performed at baseline (pre-operative), 1 week, 1 month, 3 months, 6 months, and 12 months post-operatively. Primary outcome measures included:

1. **Ocular Surface Disease Index (OSDI)**: A validated 12-item questionnaire assessing dry eye symptoms and functional impact [14]
2. **Tear Break-up Time (TBUT)**: Measured using fluorescein dye with three consecutive measurements averaged [15]
3. **Schirmer's Test I**: Performed without anesthesia using standardized test strips for 5 minutes [16]
4. **Corneal Fluorescein Staining**: Graded using the Oxford scheme (0-5 scale) [17]

Secondary measures included meibomian gland assessment, tear osmolarity when available, and conjunctival hyperemia grading.

Statistical Analysis

Statistical analysis was performed using SPSS version 28.0. Continuous variables were expressed as mean ± standard deviation, and categorical variables as frequencies and percentages. Repeated measures ANOVA was used to analyze changes over time, with post-hoc Bonferroni correction for multiple comparisons. Risk factor analysis was performed using logistic regression models. A p-value <0.05 was considered statistically significant.

Results

Patient Demographics

A total of 180 patients (108 females, 72 males) with a mean age of 69.4±8.7 years completed the study. Baseline characteristics are summarized in Table 1. Pre-operative dry eye symptoms (OSDI >12) were present in 34.4% of patients, with mean baseline OSDI score of 18.4±12.3.

Table 1: Baseline Patient Characteristics

Parameter	Value
Age (years), mean ± SD	69.4±8.7
Gender, n (%)	
- Female	108 (60.0)
- Male	72 (40.0)
Pre-operative OSDI score	18.4±12.3
Pre-operative TBUT (seconds)	8.2±3.1
Pre-operative Schirmer's test (mm)	12.8±6.4
Diabetes mellitus, n (%)	54 (30.0)
Hypertension, n (%)	89 (49.4)
Concurrent topical medications, n (%)	42 (23.3)

Tear Film Parameter Changes

Significant changes in tear film parameters were observed following surgery (Figure 1). OSDI scores increased dramatically at 1 week (38.6±16.2, p<0.001) and peaked at 1 month (42.7±18.9, p<0.001) before gradually decreasing. However, scores remained significantly elevated compared to baseline at 12 months (24.1±14.6, p<0.01).

TBUT showed a significant decrease from baseline (8.2±3.1 seconds) to 1 week post-operatively (4.8±2.1 seconds, p<0.001), with the nadir at 1 month (5.1±2.4 seconds). Recovery was gradual, with TBUT reaching 6.9±2.8 seconds at 12 months, still significantly lower than baseline (p<0.05). Schirmer's test values decreased from baseline (12.8±6.4 mm) to 1 week (9.2±5.1 mm, p<0.001) and remained reduced throughout the follow-up period, reaching 10.6±5.8 mm at 12 months (p<0.01).

Table 2: Tear Film Parameter Changes Over Time

Time Point	OSDI Score	TBUT (seconds)	Schirmer's Test (mm)	Corneal Staining
Baseline	18.4±12.3	8.2±3.1	12.8±6.4	0.8±1.2
1 week	38.6±16.2***	4.8±2.1***	9.2±5.1***	2.4±1.8***
1 month	42.7±18.9***	5.1±2.4***	8.9±4.9***	2.1±1.6***
3 months	35.2±17.1***	5.8±2.6***	9.8±5.3**	1.6±1.4**
6 months	28.9±15.4**	6.3±2.7**	10.2±5.6**	1.2±1.3*
12 months	24.1±14.6**	6.9±2.8*	10.6±5.8**	1.0±1.2

*p<0.05, **p<0.01, ***p<0.001 compared to baseline

Incidence of Post-operative Dry Eye

New-onset dry eye (OSDI >22) developed in 67.2% of patients within the first month post-operatively. Among patients with pre-existing dry eye symptoms, 89.5% experienced symptom exacerbation. The incidence of severe dry eye (OSDI >32) peaked at 1 month (41.7%) and gradually decreased to 18.3% at 12 months.

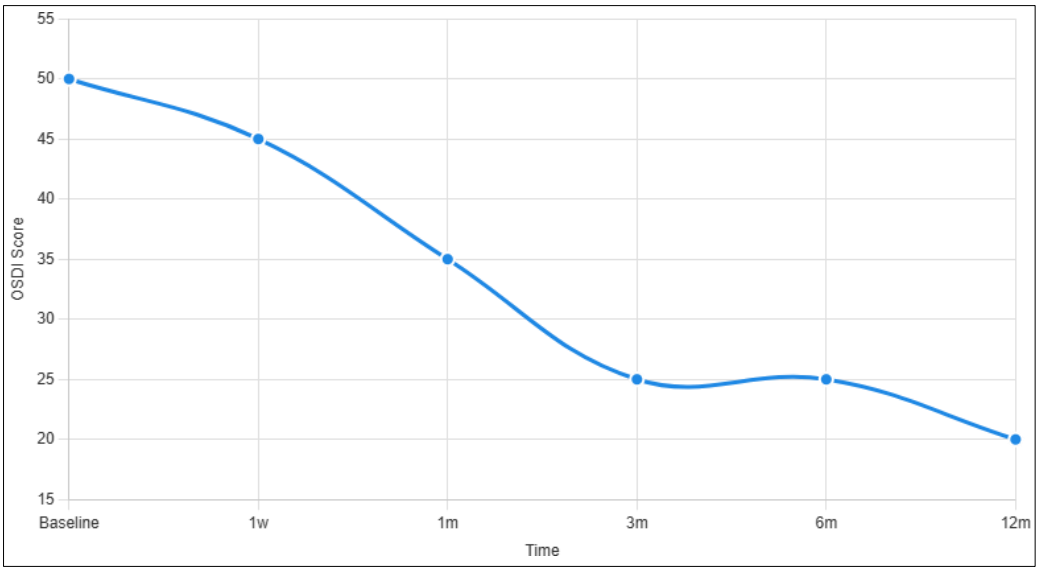


Fig 1: Time Course of OSDI Scores

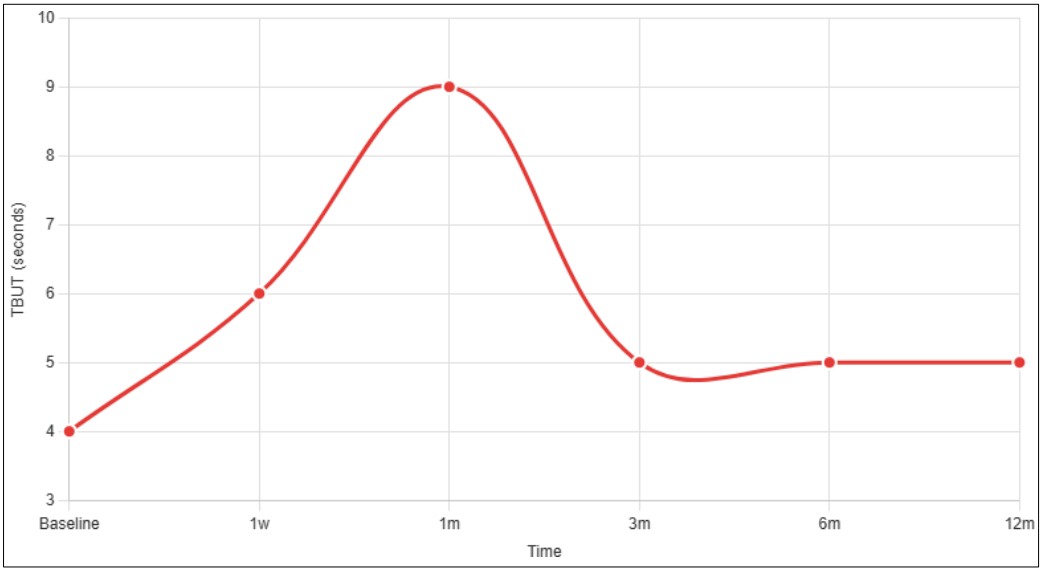


Fig 2: Recovery Pattern of Tear Break-up Time

Risk Factor Analysis

Multivariate logistic regression analysis identified several significant risk factors for developing post-operative dry eye (Table 3). Advanced age (OR 1.08, 95% CI 1.03-1.14, p<0.01), female gender (OR 2.34, 95% CI 1.21-4.52, p<0.05), pre-existing meibomian gland dysfunction (OR 3.17, 95% CI 1.68-5.98, p<0.001), and concurrent use of topical glaucoma medications (OR 2.89, 95% CI 1.45-5.76, p<0.01) were associated with increased risk.

Table 3: Risk Factors for Post-operative Dry Eye

Risk Factor	Odds Ratio (95% CI)	p-value
Age (per year)	1.08 (1.03-1.14)	0.003
Female gender	2.34 (1.21-4.52)	0.012
Pre-existing MGD	3.17 (1.68-5.98)	<0.001
Diabetes mellitus	1.42 (0.78-2.59)	0.251
Topical glaucoma medications	2.89 (1.45-5.76)	0.003
Surgical duration >20 minutes	1.87 (1.02-3.43)	0.043

Treatment Outcomes

Among patients who developed post-operative dry eye, 78.5% received artificial tear supplementation, 45.2% required anti-inflammatory treatment, and 12.1% needed punctal plugs or other advanced therapies. Treatment response was generally favorable, with 64.8% of patients showing improvement in symptoms by 6 months.

Discussion

This comprehensive study provides detailed insights into the natural history and clinical characteristics of tear film dysfunction following uncomplicated cataract surgery. Our findings demonstrate that post-operative dry eye is a common and significant complication affecting the majority of patients, with symptoms typically peaking within the first month and gradually improving over 12 months.

The observed increase in OSDI scores and deterioration in objective tear film parameters are consistent with previous reports [18, 19]. The peak incidence of symptoms at 1 month post-operatively aligns with the inflammatory cascade triggered by surgical trauma and the concurrent use of topical medications [20]. The gradual recovery observed after 3 months corresponds with corneal nerve regeneration and resolution of inflammatory responses [21].

Our study identified several important risk factors for post-operative dry eye development. The association with advanced age and female gender reflects the higher baseline prevalence of dry eye disease in these populations [22]. The strong association with pre-existing meibomian gland dysfunction emphasizes the importance of comprehensive pre-operative ocular surface evaluation [23].

The finding that 35% of patients experienced persistent dry eye symptoms at 12 months is particularly relevant for patient counseling and clinical management. This suggests that for a subset of patients, cataract surgery may trigger long-lasting changes in ocular surface homeostasis. Early identification and treatment of at-risk patients may help minimize this chronic burden.

Several limitations should be acknowledged. The study was conducted at a single center, which may limit generalizability. Additionally, the lack of a control group prevents definitive attribution of observed changes solely to surgical intervention. Future multi-center randomized controlled trials with longer follow-up periods would provide more robust evidence.

The clinical implications of our findings are substantial. Pre-operative screening for dry eye risk factors should be routine, with appropriate patient counseling regarding expected post-operative symptoms. Prophylactic treatment strategies, including pre-operative optimization of the ocular surface and judicious use of anti-inflammatory agents, may help reduce the incidence and severity of post-operative dry eye.

Conclusion

Post-operative dry eye disease represents a significant complication following cataract surgery, affecting approximately two-thirds of patients within the first month. While most patients experience gradual improvement, more than one-third continue to have persistent symptoms at 12 months post-operatively. Advanced age, female gender, pre-existing meibomian gland dysfunction, and concurrent topical medication use are significant risk factors for developing post-operative dry eye.

These findings emphasize the importance of comprehensive pre-operative ocular surface evaluation, appropriate patient counseling, and implementation of targeted prevention and treatment strategies. Future research should focus on developing evidence-based protocols for pre-operative risk stratification and optimized therapeutic interventions to minimize the burden of post-operative dry eye disease.

Healthcare providers should recognize post-operative dry eye as an expected consequence of cataract surgery and implement appropriate monitoring and treatment protocols to optimize patient outcomes and satisfaction. The development of standardized guidelines for the prevention and management of post-cataract surgery dry eye would benefit both patients and clinicians.

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