Effect of Gender and Procedure on Patient-Reported Dry Eye Symptoms After Laser Vision Correction

Julie M. Schallhorn, MD, MS; Martina Pelouskova, MSc; Catherine Oldenburg, PhD; David Teenan, MD; Stephen J. Hannan, OD; Steven C. Schallhorn, MD

ABSTRACT

PURPOSE: To evaluate factors associated with the change in dry eye symptoms following laser vision correction.

METHODS: This was a retrospective case series of 13,319 patients who underwent laser in situ keratomileusis (LASIK) or photorefractive keratectomy (PRK) between January 2013 and February 2016 and completed a preoperative and 3-month postoperative patient-reported outcome questionnaire.

RESULTS: In a multivariate linear regression model, women and contact lens wearers were associated with worse preoperative dry eye symptoms. Age was not significantly associated with preoperative dry eye symptoms. The change in dry eye symptoms preoperatively to postoperatively was affected by gender, procedure type, and preoperative dry eye symptoms. Patients who underwent PRK were more likely to report an increase in dry eye after 3 months (coefficient: 3.99, 95% confidence interval (CI): 1.64 to 4.82, $P < .001$) and patients with worse preoperative dry eye were more likely to have improvement in symptoms after surgery (coefficient: -0.93, 95% CI: -0.97 to -0.90, $P < .001$). More women reported an increased level of symptoms 3 months after surgery than men (coefficient: 1.76, 95% CI: 0.68 to 2.84, $P = .001$).

CONCLUSIONS: Preoperative dry eye symptoms, female gender, and procedure type had a significant effect on preoperative to postoperative change in dry eye symptoms after laser vision correction. Age was not associated with dry eye symptoms in this population.

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Dry eye is the most commonly reported side effect of laser in situ keratomileusis (LASIK) and photorefractive keratectomy (PRK), occurring transiently in up to 50% of patients.[1,2] Ocular surface discomfort has been associated with a decline in patient satisfaction[3,4] and quality of vision,[5,6] and the development of depressive symptoms in cases of severe chronic dry eye disorder.[7,8] Because of the potential impact of significant ocular surface discomfort, it is important to understand the risk factors associated with the development of this condition to improve patient counseling and selection in refractive surgery. There has been a recent and necessary emphasis on the patient experience and patient-reported outcome measures as important considerations in the evaluation of the safety and efficacy of laser vision correction.[6]

The objective of this study was to examine the effect of age, gender, and procedure type on patient-reported dry eye symptoms following laser vision correction.

PATIENTS AND METHODS

This study was deemed exempt from review by the Committee on Human Research at the University of California in San Francisco because it used retrospective, de-identified patient data and therefore it is not considered human research. All patients provided informed consent to undergo LASIK or PRK and agreed to have their de-identified data collected for statistical analysis.

All records without patient identifiers were extracted from the Optical Express (Glasgow, United Kingdom) electronic database using the following criteria:

From the Department of Ophthalmology (JMS, SCS) and the Francis I. Proctor Foundation (JMS, CO), University of California, San Francisco, California; Optical Express, Glasgow, United Kingdom (MP, SJH); and Carl Zeis Meditec, Dublin, California (SCS).

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Correspondence: Julie M. Schallhorn, MD, MS, 10 Koret Way K323, San Francisco, CA 94143. E-mail: Julie.schallhorn@ucsf.edu

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primary LASIK or PRK performed between January 2013 and February 2016, attended the 3-month postoperative examination, and completed the preoperative and 3-month postoperative patient-reported outcome questionnaires.

All patients desired improved vision without optical aids and met the indications for laser vision correction specified by the excimer laser user manual (VISX Star S4; Johnson & Johnson Vision Care, Inc., Santa Ana, CA), with the exception that patients with an autoimmune disease could undergo surgery if their condition was stable and well controlled. Patients with significant clinical signs of dry eye or frequent users of artificial tears were not considered for laser refractive surgery based on the clinician's judgment at the time of the evaluation.

The Intralase iFS laser (Johnson & Johnson Vision Care, Inc.) was used to create all LASIK flaps with a programmed flap thickness of 100 to 120 µm and a superior hinge. For PRK procedures, the epithelium was removed using an alcohol solution, with some surgeons discarding the epithelium and some repositioning it after ablation. A bandage contact lens was placed for all patients who underwent PRK. The Visx Star S4 excimer laser (Johnson & Johnson Vision Care, Inc.) was used for all ablations.

Postoperatively, patients who underwent LASIK were prescribed a third-generation fluoroquinolone and 1% prednisolone acetate, and were instructed to instill the eye drops four times a day for 1 week and to use an artificial tear solution four times a day for 1 month. Postoperatively, patients who underwent PRK were prescribed a third-generation fluoroquinolone and fluorometholone 0.1% and instructed to instill the eye drops four times a day for 1 week (or until the epithelial defect was healed) and four times a day for the first week followed by a weekly taper off over the course of the next 3 weeks, respectively. Patients who underwent PRK were also prescribed tetracaine 1% eye drops and artificial tears and were instructed to use them as needed for pain during the first 3 postoperative days and four times a day for 1 month, respectively.

Patient and surgeon preference was the primary driver for the procedure choice. However, the following groups of patients were selected for PRK: patients with a central corneal thickness (CCT) of less than 480 µm, patients who would have a residual stromal bed of less than 250 µm with LASIK, patients who had an epithelial basement membrane disease, and patients with subtle corneal shape anomalies assessed by Scheimpflug-based topography. Surgeries were performed by 21 surgeons in 25 surgical centers throughout the United Kingdom.

Patients were asked to complete a patient-reported outcomes questionnaire preoperatively and at all postoperative examinations. It was self-administered and used a password-protected and secure computer terminal in an isolated area of the clinic. Patients were instructed that their responses would be anonymous and would not be shared with their treating physicians. There were two main questions related to dry eye symptoms regarding the severity and frequency of dry eye. For the dry eye severity question "Think about your vision during the last week. Please rate the degree of difficulty you experienced with dry eyes," patients reported the difficulty on a scale from 0 (no difficulty) to 6 (severe difficulty). The dry eye frequency question "During the last week, how often have you experienced discomfort due to dry eyes?" was reported on a scale from 0 to 4 (0 = none of the time, 1 = some of the time, 2 = half of the time, 3 = most of the time, and 4 = all of the time).

Statistical Analysis

Descriptive statistics were performed to characterize the data. For non-parametric data, the median and interquartile range (IQR) (25th to 75th percentiles) were calculated. Visual outcome data were analyzed on a per-eye basis. Patient-reported outcome data were analyzed on a per-patient basis. The Wilcoxon Mann–Whitney *U* test was used to compare means between non-parametric populations.

To analyze variables that had unique values for each eye in relation to patient-reported outcomes data, the value from the eye with the worse preoperative refractive error was used. For example, in analysis of the manifest spherical equivalent in relation to patient-reported outcomes, the eye requiring the greater amount of correction was used.

An exploratory univariate linear regression was performed to analyze factors that might influence preoperative dry eye symptoms and the preoperative to postoperative change in dry eye symptoms. This analysis was conducted on a per-patient basis. Factors that had a P value of .10 or less in the univariate model were used to construct a multivariate model. Variables that were not statistically significant in a univariate model but were potential confounders were also included in the multivariate analysis.

Because a separate analysis of dry eye frequency and severity responses indicated the same significant contributing factors, a combined dry eye score was constructed and gave equal weight to both questions. The two questions were strongly correlated both preoperatively ($r = 0.76$, $P < .001$) and postoperatively ($r = 0.80$, $P < .001$). To aid interpretation of the regression models, the scale was normalized to 0 to 100 for preoperative dry eye, with 0 being no dry eye symptoms and 100 be-

TABLE 1

Preoperative and 3-Month Postoperative Clinical Data

Parameter	Male	Female	*P*
No. of patients (eyes)	6,152 (11,902), 46.4%	7,147 (13,932), 53.6%	< .001
Preoperative age, median (IQR) (years)	34 (26 to 45)	33 (26 to 43)	< .001
LASIK	5,179 (84.2%)	6,274 (87.9%)	< .001
PRK	973 (15.8%)	867 (12.1%)	
Habitual correction			
Spectacles	1,689 (27.5%)	1,660 (23.2%)	< .001
Contact lenses	998 (16.2%)	1,515 (21.2%)	
No data provided	3,465 (56.3%)	3,972 (55.6%)	
Preoperative dry eye score			< .001
Mean ± standard deviation	8.8 ± 14.1	11.8 ± 16.7	
No symptoms	3,840 (62.4%)	3,937 (55.1%)	
>0 to 33 (mild)	1,914 (31.1%)	2,503 (35.0%)	
>33 to 6 (moderate)	357 (5.8%)	588 (8.2%)	
>66 to 100 (severe)	41 (0.7%)	113 (1.6%)	
Month 3 dry eye score			
Mean ± standard deviation	18.44 ± 20.0	20.9 ± 21.6	< .001
No symptoms [n(%)]	2,305 (37.5%)	2,419 (33.8%)	
>0 to 33 (mild)	2,753 (44.7%)	3,175 (44.4%)	
>33 to 66 (moderate)	870 (14.1%)	1,177 (16.5%)	
>66 to 100 (severe)	224 (3.6%)	370 (5.2%)	
Development of new dry eye symptoms[a]			
Total	1,361 (20.5%)	1,008 (17.5%)	< .001
>33 to 66 (moderate)	1,048 (15.8%)	800 (13.9%)	
>66 to 100 (severe)	313 (4.7%)	208 (3.6%)	
Resolution of dry eye symptoms[b]	515 (73.5%)	312 (78.9%)	.041
Myopic/hyperopic	5,289 (86.0%)/853 (14.0%)	6,371 (89.2%)/770 (10.8%)	< .001
Preoperative MSE, median (IQR) (D)			
Myopic	-2.75 (-1.25 to -4.60)	-3.25 (-2.00 to -5.00)	< .001
Hyperopic	1.625 (+1.125 to +2.375)	+1.75 (+1.25 to +2.25)	
Range	[-11.625 to +4.25]	[-11.875 to +4.375]	
Preoperative cylinder			
Median (IQR) (D)	-0.75 (-0.25 to -1.25)	-0.50 (-0.25 to -1.00)	< .001
Range	[0.00 to -6.00]	[0.00 to -6.00]	

IQR = interquartile range; LASIK = laser in situ keratomileusis; PRK = photorefractive keratectomy; MSE = manifest spherical equivalent; D = diopters
[a]Number of patients who reported mild symptoms prior to surgery reported moderate to severe symptoms at 3 months postoperatively. Denominator represents the number of patients with mild dry eye symptoms preoperatively.
[b]Number of patients who reported moderate to severe symptoms preoperatively and mild symptoms postoperatively. Denominator represents the number of patients with moderate to severe symptoms preoperatively.

ing the worst possible dry eye frequency and severity. For the preoperative to postoperative dry eye change, the scale was normalized to -100 to +100, with 0 representing no change, +100 representing no preoperative dry eye symptoms and the worst possible postoperative symptoms, and -100 being the worst possible preoperative symptoms and no postoperative symptoms.

RESULTS

A total of 13,319 patients (25,886 eyes) met the inclusion criteria. Of these patients, 7,141 (53.6%) were women. The median age was 33.0 years (range: 18 to 74 years, IQR: 26 to 44). Women were more likely to have preoperative myopia and to undergo LASIK (**Table 1**) than men.

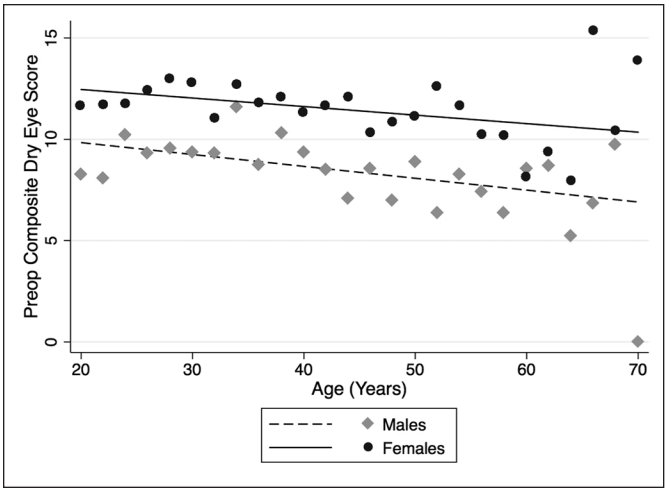

Figure 1. Relationship between age, gender, and preoperative dry eye score. The scattergram shows the mean preoperative composite dry eye score in 2-year age intervals for men and women. The solid line (men) and dashed line (women) represent the linear regression.

A subset of patients (n = 5,869, 44%) provided information regarding their preoperative habitual spectacle or contact lens wear. Of those who provided this information, 2,517 (43%) wore contacts and 3,352 (57%) wore spectacles for optical correction. Contact lens wearers were more likely to be women (47.7% of women vs 37.1% of men). Contact lens wearers also tended to be younger, with a median age of 33 years (IQR: 25 to 39) among contact lens wearers and a median age of 37 years (IQR: 27 to 47) among spectacle wearers ($P < .001$).

Preoperative Dry Eye Symptoms

Prior to surgery, women were more likely to report higher levels of dry eye symptoms than men (**Table 1**). Overall, the majority of patients (58.5%; n = 7,793) reported zero dry eye frequency and severity prior to surgery. Overall, the degree of preoperative dry eye frequency and severity decreased with increasing age for both men and women ($P < .001$, **Figure 1**).

In the univariate analysis (**Table 2**), female gender, decreasing age, season, preoperative contact lens use, and a hyperopic correction were associated with greater preoperative dry eye symptoms. Because contact lens use was such a significant factor in the univariate model and contact lens data were not available for the entire population, the multivariate model (**Table 3**) was constructed using the subset of patients for whom preoperative habitual correction use was available. In this model, contact lens use (vs spectacles) and women (vs men) were associated with more dry eye symptoms before surgery. Overall, the model was poorly predictive and accounted only for 1.1% of the variance in preoperative dry eye symptoms ($r^2 = 0.011$). Similar results were obtained for the group without the inclusion of contact lens use.

Change in Dry Eye Symptoms

Patient-reported dry eye frequency and severity increased after surgery for men and women in all age groups. In the univariate regression model, age, preoperative hyperopia, degree of preoperative dry eye symptoms, preoperative contact lens wear, and procedure type were significantly related to dry eye symptom change (**Table 2**). Although gender was not significant in the univariate model, it was included given its potential as a confounder because it had interactions with procedure type, refraction, and contact lens use.

In patients who had mild dry eye symptoms before surgery, 20.5% (n = 1,361) of women and 17.5% (n = 1,008) of men reported moderate to severe symptoms 3 months after surgery (**Table 1**). Of the patients who reported moderate to severe symptoms before surgery, 73.5% (n = 515) of women and 78.9% (n = 312) of men reported mild symptoms 3 months after surgery.

In a multivariate model, gender, preoperative dry eye symptoms, and procedure type were significantly related to the dry eye symptom change from preoperatively to postoperatively (**Table 3**). A sensitivity analysis conducted with patients without available preoperative, habitual correction data yielded similar results.

Patients who underwent PRK were more likely to report an increase, although small, in dry eye symptoms (mean difference: 3.99; 95% CI: 1.64 to 4.82, $P < .001$). Because the dry eye composite scale was normalized to a range from 0 to 100, this can be interpreted as patients who underwent PRK, on average, reported postoperative dry eye symptoms that were 3.99% worse than those reported for LASIK. Women were more likely to report an increase in dry eye symptoms, with a mean difference of 1.76 (95% CI: 0.68 to 2.84, $P = .001$). Overall, the model was able to account for 31% of the variance in dry eye symptoms ($r^2 = 0.31$).

There was a negative correlation between preoperative and postoperative dry eye symptoms, indicating that patients with worse dry eye symptoms before surgery tended to have an improvement after surgery (**Figure 2**). As with procedure type, the mean difference was small (-0.93, 95% CI: -0.97 to -0.90, $P < .001$). Age, preoperative refraction, contact lens use, and ablation pattern (wavefront-guided vs conventional) were not associated with dry eye symptoms.

A sensitivity analysis was conducted to see if there was any interaction between procedure type and preoperative dry eye symptoms, and no significant interaction was found ($P = .20$), indicating that preoperative patient dry eye symptoms did not affect the

TABLE 2

Univariable Regression Analysis[a]

	Preoperative			Preoperative to Postoperative Change		
Variable	**Coefficient**	**95% CI**	***P***	**Coefficient**	**95% CI**	***P***
Age (per year)	-0.056	-0.079 to -0.032	< .001	0.040	0.0019 to 0.0077	.039
Female (vs male)	2.91	2.37 to 3.44	< .001	-0.44	-1.29 to 0.41	.30
Contact lens wear[b]	2.64	1.87 to 3.40	<.001	-3.17	- 4.46 to -1.88	<.001
Season						
Winter	ref			ref		
Spring	-0.67	-1.43 to 0.83	.081	0.20	-1.00 to 1.41	.75
Summer	-0.81	0.63 to 1.57	.034	0.63	-0.57 to 1.83	.30
Fall	0.39	0.39 to 0.37	.28	0.049	-1.10 to 1.20	.93
Hyperopia (vs myopia)	-1.80	- 2.61 to -0.88	< .001	2.04	0.74 to 3.33	.002
Preoperative CDVA[c]	0.96	-4.08 to 5.99	.71	-0.64	- 1.46 to 0.17	.26
Average K[c]	0.065	-0.14 to 0.27	.53	0.060	- 0.26 to 0.38	.71
Pachymetry[c]	0.0028	-0.012 to 0.018	.70	-0.0028	- 0.018 to 0.012	.79
Preoperative dry eye score	–	–	–	-0.88	- 0.90 to -0.85	< .001
PRK (vs LASIK)	–	–	–	3.39	2.16 to 4.61	< .001
Wavefront-guided ablation (vs standard)	–	–	–	-0.94	- 2.00 to 0.12	.083

CI = confidence interval; ref = reference; CDVA = corrected distance visual acuity; K = keratometry; PRK = photorefractive keratectomy; LASIK = laser in situ keratomileusis
[a]Factors influencing the preoperative and preoperative to postoperative change in dry eye symptoms. A negative correlation indicates a decrease in dry eye symptoms after surgery and a positive correlation indicates an increase in dry eye symptoms from before to after surgery.
[b]Analysis was conducted with the subset of patients for whom preoperative correction type was available.
[c]For patients who had both eyes treated, the value from the eye for the analysis were: worse corrected distance visual acuity (CDVA), higher average keratometry, and thinner pachymetry, respectively.

TABLE 3

Multivariable Regression Analysis of Factors[a]

	Preoperative			Preoperative to Postoperative Change		
Variable	**Coefficient**	**95% CI**	***P***	**Coefficient**	**95% CI**	***P***
Age (per year)	8.91×10^{-5}	-0.037 to 0.38	.99	-0.0098	-0.063 to 0.043	.72
Female (vs male)	2.13	1.37 to 2.89	< .001	1.76	0.68 to 2.84	.001
Contact lens wear[b]	2.43	1.64 to 3.21	< .001	-0.82	-1.94 to 0.29	.15
Hyperopia (vs myopia)	2.04	0.74 to 3.33	.002	1.23	- 0.61 to 3.07	.19
Preoperative dry eye score	–	–	–	-0.93	-0.97 to -0.90	< .001
PRK (vs LASIK)	–	–	–	3.99	1.64 to 4.83	< .001
Wavefront-guided ablation (vs standard)	–	–	–	0.48	-0.93 to 1.89	.51

CI = confidence interval; PRK = photorefractive keratectomy; LASIK = laser in situ keratomileusis
[a]Analysis of factors influencing the preoperative and preoperative to postoperative change in dry eye symptoms using variables that were found to be significant in the univariable analysis. For the postoperative analysis, a negative correlation indicates a decrease in dry eye symptoms after surgery and a positive correlation indicates an increase in dry eye symptoms from before to after surgery.
[b]Analysis conducted with the subset of patients for whom preoperative correction type was available.

decision for procedure type. To evaluate for the effect of ablation depth in myopia, an analysis looking specifically at the correlation between preoperative manifest spherical equivalent and change in dry eye symptoms in myopic patients to discern if there was any effect of ablation depth yielded no correlation (P = .31).

A total of 373 (2.8%) patients had severe dry eye (composite score > 66) 3 months postoperatively. Of the 373 patients, 3.3% (n = 236) were women, 2.2% (n

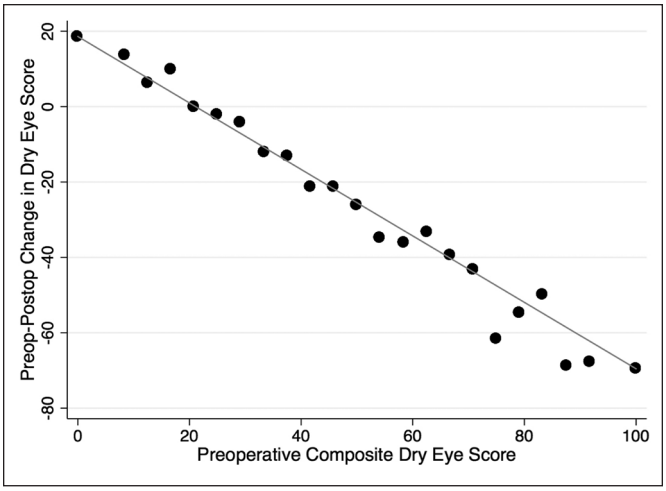

Figure 2. Relationship between the preoperative dry eye composite score and the change in the preoperative to postoperative dry eye score. Each marker represents the average change from preoperative to postoperative for patients with the corresponding preoperative composite score. The line is the linear regression for the correlation between the preoperative composite dry eye score and the change from preoperative to postoperative for all patients.

= 143) were men ($P < .001$), and they represented 4.1% (n = 70) of patients who underwent PRK and 2.6% (n = 30) of patients who underwent LASIK ($P < .001$).

We conducted a logistic regression analysis of this subset to see if there were any unique characteristics about this population. This revealed that the patients who had severe symptoms after surgery were more likely to be women (OR: 1.47, 95% CI: 1.19 to 1.83, $P < .001$) and have had PRK (OR: 1.66, 95% CI: 1.30 to 2.15, $P < .001$). There was a weak effect of severe preoperative dry eye symptoms (OR: 1.01 per one-unit increase in dry eye symptoms, 95% CI: 1.00 to 1.02, $P < .001$). Age was not a significant factor (OR: 1.00, $P = .90$), nor was degree of preoperative myopia (OR: 1.01, $P = .70$).

DISCUSSION

The incidence of dry eye syndrome in the normal population ranges between 8% and 34%, with an increasing incidence with age, and is reported more frequently in women than in men.[9,10] We found greater preoperative dry eye symptoms in women than in men, but in contrast to the available literature, we found no correlation between age and preoperative dry eye symptoms in this patient cohort. Likewise, as has been reported,[11,12] contact lens wear was also associated with higher reported preoperative dry eye symptoms.

This study group included a population of patients who were found suitable for laser vision correction, and any patients with significant clinical dry eye findings on the preoperative examination were excluded, which may have affected the influence of age on preoperative dry eye in this study. Although patients with clinically significant dry eye were excluded from undergoing surgery, there were still a small number of patients in the cohort who indicated they had moderate to severe dry eye symptoms on the preoperative questionnaire (**Table 1**). Because patients were informed of the confidentiality of this questionnaire, it is possible that they reported dry symptoms on the questionnaire but did not share these with their clinician, which we believe explains this discrepancy.

Also, we did not see an influence of age on the preoperative to postoperative change in dry eye symptoms. This indicates that older patients with healthy, stable ocular surfaces were likely able to withstand LASIK or PRK similar to younger patients. Although tear film quality has been reported to deteriorate with age,[13,14] older patients with a healthy ocular surface should not be considered at high risk for developing postoperative dry eye symptoms in the 3-month postoperative period. Over a longer time period, Price et al.[4] found that older patients were more likely to report some dry eye symptoms at 3 years after LASIK than younger patients. This study did not examine a longer time point, and it is possible that older patients could experience a deterioration in their ocular surface at longer time points.

On average, we found an increase in patient-reported dry eye symptoms 3 months after surgery. An increase in dry eye symptoms is commonly reported for the first 1 to 3 months after laser vision correction and, in many patients, returns to the preoperative level between 6 and 12 months.[1,15] In contrast, the PROWL studies found that patients had an average improvement in ocular surface discomfort at the 3-month time point. However, nearly one-third of the cohort who had a normal ocular surface disease index score initially developed dry eye symptoms and 4% to 6% developed severe dry eye symptoms.[6] This is similar to our findings because 20.5% of women and 17.5% of men with mild symptoms preoperatively developed moderate or severe symptoms postoperatively. We also found that the majority of patients who reported moderate to severe symptoms preoperatively experienced symptom resolution postoperatively, regardless of gender.

Several studies have examined risk factors associated with development of dry eye symptoms after laser vision correction.[15-23] The majority of these suggest that the main risk factors for dry eye after laser vision correction are attempted refractive correction[17-20] and preoperative dry eye level.[24-26] Five studies considered age as a possible risk factor for dry eye after laser vision correction.[4,15,17,20,23] Of the five studies, two

concluded that age had no effect on dry eye development,[15,23] and two found that older age was associated with a postoperative decrease in corneal sensitivity, although not necessarily with an increase of dry eye symptoms.[17,20] Four studies concluded that women are at higher risk for the development of chronic dry eye[16,18,20] or reduced corneal sensitivity after laser vision correction.[17]

We did find that women were associated with an overall increase in dry eye symptoms after laser vision correction. Overall, the relative increased risk was small. Women reported symptoms that were on average 1.76% greater than in men. Additionally, women had a greater risk of developing severe dry eye symptoms after surgery (OR: 1.47).

In this study, the procedure type was the greatest factor influencing the preoperative to postoperative change in dry eye symptoms. Patients who underwent PRK were more likely to report an increase in dry eye symptoms at the 3-month follow-up. Given the relatively short follow-up period, it is possible that differences between the two procedures could disappear at later times. In a randomized trial of LASIK versus PRK by Murakami and Manche,[15] no statistically significant differences in dry eye or foreign body sensation between PRK and LASIK were found at 12 months. The fact that patients who underwent PRK had a greater increase in dry eye symptoms than patients who underwent LASIK is interesting in light of the greater damage to corneal nerves with LASIK than PRK. It is possible that the neurotrophic effect induced by LASIK results in greater comfort than PRK, because the recovery of corneal sensation to preoperative levels is longer in LASIK.[24,27] Based on these findings, at least in the near postoperative term, LASIK, rather than PRK, should be considered the procedure producing less dry eye discomfort. This may be an artifact of reduced sensation from a degree of postoperative reduced sensation from delayed corneal nerve healing after LASIK, or it may be due to the potential epithelial instability causing a dryness sensation after PRK.

We found no correlation between the preoperative refractive error and change in dry eye symptoms. Additionally, a sensitivity analysis looking specifically at the amount of intended correction in myopic eyes found no correlation. We can conclude that deeper ablations do not induce more dry eye symptoms in our cohort. Our findings are in contrast to previous studies that report ablation depth and higher preoperative refractions are associated with increased dry eye symptoms.[19,20]

Another significant predictor of change in dry eye symptoms was the preoperative dry eye level. Surprisingly, the correlation was negative, meaning patients with more dry eye symptoms before surgery were more likely to report fewer symptoms after surgery, but the size of the effect was small. One explanation is that all of the patients may have been more attentive to using artificial tears after surgery, which also may have aided their comfort. Although patients with contact lens use had more dry eye symptoms preoperatively, contact lens use versus spectacle use in the final postoperative multivariate model was not associated with a significant change in dry eye symptoms.

The main limitations of our study are the retrospective design and relatively short follow-up period. The literature suggests that dry eye symptoms typically improve a few months after surgery.[1,2] From our dataset, we were unable to establish which patients were at risk of developing long-term, chronic dry eye. Another limitation of this study was the brief questionnaire used. The questions used in this study have not undergone psychometric evaluation. However, they are similar in terminology and construction to brief dry eye questionnaires used in previous large epidemiology studies.[12,25,28] We additionally did not have data on the frequency of artificial tear use, allergy history, or medication use, such as antihistamines or antidepressants, that may affect tear production and therefore act as confounders.

We did not include dry eye findings in our evaluation, which may be a limitation in this study. However, clinical examination dry eye findings have been shown to not be correlated with patient-reported dry eye symptoms after LASIK,[6] and have been shown in multiple studies to not be repeatable or predictive of patient dry eye complaints.[26,28,29] For this reason, this study focused on patient-reported dry eye symptoms as an outcome instead of the objective findings of dry eye signs. Patients do not present to clinics after undergoing refractive surgery complaining of corneal epitheliopathy, but they do complain of a persistent sensation of dryness. Patient-reported dry eye symptoms, not clinical findings, are what affect patients in their day-to-day life, and the patient experience of ocular dryness is a major concern for potential refractive surgery patients. The results of this study should help clinicians counsel patients on the risk of dry eye symptoms after refractive surgery.

AUTHOR CONTRIBUTIONS

Study concept and design (JMS, MP, SCS), data collection (MP); analysis and interpretation of data (CO, DT, SJH); writing the manuscript (JMS, MP); critical revision of the manuscript (JMS, CO, DT, SJH, SCS); statistical expertise (JMS, SCS); administrative, technical, or material support (DT, SJH)

REFERENCES

1. Shtein RM. Post-LASIK dry eye. *Expert Rev Ophthalmol*. 2011;6:575-582.
2. Gomes JAP, Azar DT, Baudouin C, et al. TFOS DEWS II iatrogenic report. *Ocul Surf*. 2017;15:511-538.
3. Ambrosio R Jr, Tervo T, Wilson SE. LASIK-associated dry eye and neurotrophic epitheliopathy: pathophysiology and strategies for prevention and treatment. *J Refract Surg*. 2008;24:396-407.
4. Price MO, Price DA, Bucci FA Jr, Durrie DS, Bond WI, Price FW Jr. Three-year longitudinal survey comparing visual satisfaction with LASIK and contact lenses. *Ophthalmology*. 2016;123:1659-1666.
5. Nettune GR, Pflugfelder SC. Post-LASIK tear dysfunction and dysesthesia. *Ocul Surf*. 2010;8:135-145.
6. Eydelman M, Hilmantel G, Tarver ME, et al. Symptoms and satisfaction of patients in the patient-reported outcomes with laser in situ keratomileusis (PROWL) studies. *JAMA Ophthalmol*. 2017;135:13-22.
7. Hallak JA, Tibrewal S, Jain S. Depressive symptoms in patients with dry eye disease: a case-control study using the beck depression inventory. *Cornea*. 2015;34:1545-1550.
8. Kim KW, Han SB, Han ER, et al. Association between depression and dry eye disease in an elderly population. *Invest Ophthalmol Vis Sci*. 2011;52:7954-7958.
9. Gayton JL. Etiology, prevalence, and treatment of dry eye disease. *Clin Ophthalmol*. 2009;3:405-412.
10. Stapleton F, Alves M, Bunya VY, et al. TFOS DEWS II Epidemiology Report. *Ocul Surf*. 2017;15:334-365.
11. Caffery BE, Richter D, Simpson T, Fonn D, Doughty M, Gordon K. CANDEES. The Canadian Dry Eye Epidemiology Study. *Adv Exp Med Biol*. 1998;438:805-806.
12. Paulsen AJ, Cruickshanks KJ, Fischer ME, et al. Dry eye in the beaver dam offspring study: prevalence, risk factors, and health-related quality of life. *Am J Ophthalmol*. 2014;157:799-806.
13. Maissa C, Guillon M. Tear film dynamics and lipid layer characteristics: effect of age and gender. *Cont Lens Anterior Eye*. 2010;33:176-182.
14. Ozdemir M, Temizdemir H. Age- and gender-related tear function changes in normal population. *Eye (Lond)*. 2010;24:79-83.
15. Murakami Y, Manche EE. Prospective, randomized comparison of self-reported postoperative dry eye and visual fluctuation in LASIK and photorefractive keratectomy. *Ophthalmology*. 2012;119:2220-2224.
16. Albietz JM, Lenton LM, McLennan SG. Effect of laser in situ keratomileusis for hyperopia on tear film and ocular surface. *J Refract Surg*. 2002;18:113-123.
17. Michaeli A, Slomovic AR, Sakhichand K, Rootman DS. Effect of laser in situ keratomileusis on tear secretion and corneal sensitivity. *J Refract Surg*. 2004;20:379-383.
18. Albietz JM, Lenton LM, McLennan SG. Chronic dry eye and regression after laser in situ keratomileusis for myopia. *J Cataract Refract Surg*. 2004;30:675-684.
19. De Paiva CS, Chen Z, Koch DD, et al. The incidence and risk factors for developing dry eye after myopic LASIK. *Am J Ophthalmol*. 2006;141:438-445.
20. Shoja MR, Besharati MR. Dry eye after LASIK for myopia: incidence and risk factors. *Eur J Ophthalmol*. 2007;17:1-6.
21. Konomi K, Chen LL, Tarko RS, et al. Preoperative characteristics and a potential mechanism of chronic dry eye after LASIK. *Invest Ophthalmol Vis Sci*. 2008;49:168-174.
22. Salomão MQ, Ambrósio R Jr, Wilson SE. Dry eye associated with laser in situ keratomileusis: Mechanical microkeratome versus femtosecond laser. *J Cataract Refract Surg*. 2009;35:1756-1760.
23. Golas L, Manche EE. Dry eye after laser in situ keratomileusis with femtosecond laser and mechanical keratome. *J Cataract Refract Surg*. 2011;37:1476-1480.
24. Bower KS, Sia RK, Ryan DS, Mines MJ, Dartt DA. Chronic dry eye in photorefractive keratectomy and laser in situ keratomileusis: manifestations, incidence, and predictive factors. *J Cataract Refract Surg*. 2015;41:2624-2634.
25. Schaumberg DA, Buring JE, Sullivan DA, Dana MR. Hormone replacement therapy and dry eye syndrome. *JAMA*. 2001;286:2114-2119.
26. Sullivan BD, Crews LA, Messmer EM, et al. Correlations between commonly used objective signs and symptoms for the diagnosis of dry eye disease: clinical implications. *Acta Ophthalmol*. 2014;92:161-166.
27. Lee HK, Lee KS, Kim HC, Lee SH, Kim EK. Nerve growth factor concentration and implications in photorefractive keratectomy vs laser in situ keratomileusis. *Am J Ophthalmol*. 2005;139:965-971.
28. Vehof J, Kozareva D, Hysi PG, Hammond CJ. Prevalence and risk factors of dry eye disease in a British female cohort. *Br J Ophthalmol*. 2014;98:1712-1717.
29. Nichols KK, Nichols JJ, Mitchell GL. The lack of association between signs and symptoms in patients with dry eye disease. *Cornea*. 2004;23:762-770.
30. Nichols KK, Mitchell GL, Zadnik K. The repeatability of clinical measurements of dry eye. *Cornea*. 2004;23:272-285.