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Treatment, Material, Care, and Patient-Factors in Contact Lens-Related Dry Eye

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Abstract

PURPOSE—To examine the effect of general contact lens and material characteristics, care solutions, treatment and patient-related factors on contact lens-related dry eye.

METHODS—The data were derived from the Contact Lens and Dry Eye Study, designed as a cross-sectional and nested case-control study including 360 subjects. In separate statistical models, logistic regression was used to examine general contact lens characteristics, specific hydrogel lens materials, care solutions, and patient-related factors associated with dry eye status (controlled for age, gender, and current treatments).

RESULTS—Several factors were significantly associated with dry eye, including treatment factors such as a recent contact lens refitting (OR = 5.75, 95% CI = 2.14 to 15.46) and use of artificial tears/rewetting drops (OR = 1.09, 95% CI = 1.02 to 1.16), and currently worn materials including FDA group II (OR = 2.98, 95% CI = 1.14 to 6.19) and IV (OR = 1.87, 95% CI = 1.08 to 3.24). Significant patient-related factors included decreased overall satisfaction (OR = 3.57, 95% CI = 2.08 to 5.88), dry eye in the absence of contact lens wear (OR = 6.54, 95% CI = 2.57 to 16.62), reduced daily lens wear duration (OR = 1.16, 95% CI = 1.06 to 1.26), and reduced ability to wear lenses as long as desired (OR = 2.44, 95% CI = 1.30 to 4.54). Care solutions were not significant.

CONCLUSIONS—The strong association of common treatment factors with dry eye status in contact lens wearers suggests that these treatments are not entirely effective. The use of high water content materials was strongly related to dry eye in lens wearers, while care solutions were not. Contact lens-related dry eye was also associated with several patient-related factors such as greater ocular discomfort (without lenses), dissatisfaction, and inability to wear lenses for desired durations.

Keywords

dry eye disease; contact lenses; symptoms; treatments; care solutions

Several recent studies estimate that the frequency of contact lens related dry eye is about 50%, suggesting that about 17 million of the 35 million contact lens wearers in the United States alone are affected.^{1–6} Contact lens-related dry eye is also associated with other correlates including alterations in functional visual acuity^{7, 8}, reductions in wearing time⁹, and an increased risk of ocular surface desiccation, bacterial binding and infection.^{10, 11} The primary

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reason for contact lens intolerance and discontinuation has been observed to be discomfort and dryness symptoms.^{12–14}

It has been suggested that potential mechanisms of contact lens-related dry eye include increased evaporation of the tear film¹⁵, inflammation^{16–18}, reduced ability to produce adequate tears with concurrent increased osmolality^{19, 20}, dewetting related to lack of biocompatibility of the lens surface^{21–25}, or any above mentioned combination. In the current study's cohort, we previously reported that high water content contact lenses, rapid pre-lens tear film thinning, limbal injection, and an increased tear film osmolality were significant factors associated with contact lens-related dry eye.²⁶ Other clinical factors (e.g., contact lens material dehydration, tear volume/production, meibomian gland dropout) were not found to be related.

To date, little has been done to address the role of specific contact lens materials, wear schedules, care systems, and treatments associated with contact lens-related dry eye. The aims of this report are to examine the aforementioned characteristics relative to their association with contact lens-related dry eye.

MATERIALS AND METHODS

Study Overview

This research was approved by the Biomedical Institutional Review Board, in accordance with the tenets of the Declaration of Helsinki. The study (The Contact Lens and Dry Eye Study (CLADES)) has been extensively described previously.²⁶ Briefly, it was a two-phase, cross-sectional survey with a nested case-control design. The aims in Phase I (the cross-sectional survey) were to determine the distribution of contact lens-related dry eye, in addition to serving as a screening and recruiting vehicle for Phase II (the nested case-control/examination phase).²⁷ Specific details including recruitment and sampling, enrollment, inclusion/exclusion, sample size, dry eye classification, and survey and clinical outcomes have been extensively detailed elsewhere.^{1, 26–28} As previously described, the Contact Lens and Dry Eye Questionnaire was used to classify contact lens wearers with (DE) and without dry eye (NDE).^{1, 26}

Data Collection and Outcome Measures

Data collection for cases and controls was performed in an identical manner without examiner knowledge of dry eye status. Safeguards were used to protect against the clinician becoming unmasked relative to disease status (i.e., study coordinator performed scheduling, the ophthalmic history survey was self-administered by the patient at the completion of the examination). Clinical tests and questionnaire outcomes and their order have been described elsewhere.^{1, 26} As part of the battery of outcomes assessed during the examination (Phase II), subjects were asked to complete a socio-demographic survey to assess things such as age, gender, race, marital status, education status, occupation, and economic status (age and gender information are used in the statistical analyses described below). Particularly germane to the present analyses, subjects were also asked to complete a contact lens and ocular history survey. This survey assessed information with regard to age at starting lens wear, total years of lens wear, general types of contact lenses previously and presently worn (i.e., soft, rigid, both), years of wear of each general type, present wearing time (both days per week and hours per day), factors associated with reduced wearing time, current overall perception of comfort, current overall perception of satisfaction, current overall perception of vision, current treatments for contact lens-related dry eye (i.e., artificial tears/rewetting drops and their frequency, ointment use and frequency, contact lens refitting, punctal occlusions, lid compresses/scrubs, humidifier, others), present modality (i.e., overnight, daily disposable,

planned replacement, conventional), specific type of contact lens and care system currently being used, and ocular health history (general ophthalmic conditions and conditions related to contact lens wear).

Statistical Analyses

All statistical analyses described below were performed with Statistical Analysis Software (SAS), Version 9.1 (SAS Institute, Carey, North Carolina). Descriptive statistics were used to compare the distributions of study variables in those with and without dry eye (the dichotomous outcome). For continuous variables, means were used to characterize central tendency and standard deviations were used to characterize dispersion. For categorical variables, contingency tables were used to characterize the distribution of variable values.

Logistic regression was used to model the relation between self-reported dry eye disease and independent variables. There were five general themes regarding statistical models including: 1) current treatments associated with contact lens-related dry eye (from which relevant information would be used to control for confounding effects in the other models), 2) contact lens-related factors (e.g., rigid vs. soft, FDA grouping, silicone hydrogel vs. non-silicone hydrogel, modality), 3) hydrogel lens material-specific factors (materials were included if there were 10 or more sampled individuals wearing the lens material), 4) care solution-related factors (individual care solutions and type of preservative), and 5) patient-related descriptors (e.g., age at starting lens wear, years of wear, days per week, hours per day, satisfaction with wearing time, overall perceived satisfaction, overall perceived vision, previous eye infections with lens wear, dry eyes when not wearing lenses, eye sensitivity to smog, forced air, alcohol). The process began with a “core” analysis of each possible factor for each major theme as described above. For continuous and categorical patient-related and ophthalmic data, core logistic regression models were produced to describe the relation between each individual predictor variable and the group (dry eye or not dry eye), controlling for age, gender and significant treatments (from the first model as described above). Odds ratios, p-values and 95% confidence intervals are reported. The p-values are associated with Wald chi-square tests and assess whether a variable, whether continuous (e.g., duration of lens wear) or categorical (e.g., lens material), is associated with the odds of dry eye.

After construction of the core models, model building was performed in several stages to arrive at the final model for each of the five themes. All variables in the core models that were associated with contact lens-related dry eye at the $\alpha \leq 0.25$ level were considered candidates for multiple logistic regression, except for those categorical variables with small numbers (less than 5) within strata of the categorical/dry eye status factors. Age, gender, and relevant current treatments were included as control variables in all models fit for analyses 2 through 5 (above).

The initial multiple regression model was the result of a stepwise procedure, with entry and exit criteria set at $\alpha \leq 0.25$. A second stepwise multiple regression model was fitted using the variables selected by the first stepwise procedure. The second stepwise procedure used a stricter criterion of $\alpha \leq 0.10$ for inclusion, after which, selected predictors and their interactions were examined in a new model with selection criterion set at $\alpha \leq 0.05$. This concluded the model building steps and led to final models (for each theme) that best predicted self-reported dry eye status. As with the core models, odds ratios (OR), 95% confidence intervals, and p-values associated with Wald chi square tests are reported for the final models.

For final models (rather than core models, or steps in the modeling process), the Hosmer-Lemeshow goodness-of-fit test was used to examine the model calibration.²⁹ When the chi-square value for this test is small (larger p-value), the model is considered well calibrated. The discriminative ability of the model was evaluated using the area under the Receiver Operating Characteristic (ROC) curve (i.e., can the model accurately discriminate between those who

self-report dry eye disease and those who do not?). Discrimination was assessed using the following guidelines for area under the ROC curves: 0.5 indicates no discrimination, between 0.7 and 0.8 indicates acceptable discrimination, between 0.8 and 0.9 indicates excellent discrimination, and greater than 0.9 indicates outstanding discrimination.²⁹

RESULTS

Patient Sample

As previously described, 360 patients were included in the analysis pool. The average age of patients in the sample was 31.1 ± 11.5 years and 245 (68%) were female. Overall, 327 (90.8%) were hydrogel lens wearers and 33 (9.2%) were gas permeable lens wearers with an overall average length of wear of 8.6 ± 6.4 years. As reported previously, there were 199 (55.3%) classified with dry eye by self-report on the CLDEQ and 161 (44.7%) participants classified without dry eye by self-report.

Treatments Associated with Contact Lens-Related Dry Eye

Table 1 displays the categorical treatment variables stratified by dry eye status, in addition to results from the core models for each variable (note that continuous variables are not found in the Table). The total number of treatments for dry eye, treated as a continuous variable, was significantly associated with DE status (OR = 2.03; 95% CI = 1.45 to 2.83; $p < 0.0001$), wherein the DE group was more likely to currently use more total treatments than the NDE group (average $\pm$ SD = 0.80 ± 0.74 and 0.48 ± 0.59 treatments, respectively). A recent contact lens refitting was also associated with DE status, whereby 16% of the DE group had recently been refitted in contrast to 3% of the NDE group (OR = 6.10, 95% CI = 2.28 to 16.33, $p = 0.0003$). Other variables significantly associated with DE status included the average number of weekly applications of rewetting drops/artificial tears (OR = 1.10, 95% CI = 1.03 to 1.17, $p = 0.003$) and the use of artificial tears/rewetting drops; those in the DE group were more likely to report their use compared to the NDE group (OR = 1.57, 95% CI = 1.02 to 2.41, $p = 0.04$) in addition to those in the DE group reporting more applications per week (2.96 ± 5.05 and 1.46 ± 3.21 drops per week, respectively).

The final multiple logistic regression model showed that contact lens refitting (OR = 5.75, 95% CI = 2.14 to 15.46, $p = 0.0005$) and the average number of artificial tears/rewetting drops used per week (OR = 1.09, 95% CI = 1.02 to 1.16, $p = 0.01$) were significant predictors of DE when controlled for gender (OR = 2.68, 95% CI = 1.65 to 4.36, $p < 0.0001$) and age (OR = 0.99, 95% CI = 0.97 to 1.01, $p = 0.44$). No other factors were found to be statistically significant in the multiple logistic setting. The Hosmer-Lemeshow goodness-of-fit test indicated excellent calibration ($\chi^2 = 3.17$, $p = 0.92$), while the area under the curve (auROC = 0.69) indicated marginal discrimination.

General Contact Lens Factors Associated with Contact Lens-Related Dry Eye

Frequency and the core model estimates (controlled for age, gender, a recent contact lens refitting, and the total number of treatments currently used) for contact lens-related factors stratified by dry eye status are displayed in Table 2. The FDA grouping of the current contact lens worn was associated with DE status ($p = 0.008$), with 71% of those wearing FDA group II materials in the DE group, 56.3% of those wearing FDA group IV materials in the DE group, and 42.9% of those in FDA group I materials in the DE group. Compared to FDA group I wearers, those wearing FDA group II materials were the most likely to be associated with dry eye (OR = 2.98, 95% CI = 1.14 to 6.19), followed by those in FDA Group IV materials (OR = 1.87, 95% CI = 1.08 to 3.24). Silicone hydrogel lens wear (versus non-silicone hydrogel lens wear) was the only other factor significantly associated with dry eye status in the core analyses (OR = 0.46, 95% CI = 0.25 to 0.84, $p = 0.01$). These two factors were included in a multiple

logistic regression model (controlled for age, gender, a recent contact lens refitting, and the number of weekly applications of artificial tears/rewetting drops). FDA grouping remained significantly associated with DE status while silicone hydrogel lens wear (versus non-silicone hydrogel lens wear) was not selected. The odds ratios, confidence intervals, and p-value remained unchanged given the model's similarity to the core model. The Hosmer-Lemeshow goodness-of-fit test indicated moderate calibration ($\chi^2 = 6.24$, $p = 0.62$), while the area under the curve (auROC = 0.72) indicated marginal discrimination of the final model.

Individual Contact Lens Materials Associated with Contact Lens-Related Dry Eye

Table 3 displays frequency estimates and findings from the core analysis for specific contact lens materials in relation to dry eye status. The overall contact lens material effect was not statistically associated with DE status ($p = 0.08$). Consistent with this finding, none of the material comparisons were statistically significant (with each material compared to etafilcon, the most commonly used material). The Hosmer-Lemeshow goodness-of-fit test indicated excellent calibration ($\chi^2 = 0.44$, $p = 0.99$), while the area under the curve (auROC = 0.73) indicated marginal discrimination for the final model.

Individual Care Solutions and Preservatives Associated with Contact Lens-Related Dry Eye

Neither specific contact lens care solutions, nor care solutions grouped on preservative showed a relation with contact lens-related dry eye (Table 4). Likewise, no individual pair-wise comparisons (compared to Opti-Free Express or PHMB, the most frequent within the groups) showed a relation with DE status.

Patient-Specific Factors Associated with Contact Lens-Related Dry Eye

Lastly, Tables 5 (categorical variables) and 6 (continuous variables) show the results for patient-related factors in relation to DE status. In the core models, dry eye symptoms/diagnosis in the absence of contact lens wear was a statistically significant factor associated with DE status (OR = 6.29, 95% CI = 2.67 to 14.79, $p < 0.0001$). Twenty-five percent of the DE group had a dry eye diagnosis or symptoms without lens wear in comparison to only 4% of the NDE group. Overall satisfaction with current contact lenses was also statistically significant, whereby subjects satisfied with their lenses were less likely to be in the DE group (OR = 0.21, 95% CI = 0.13 to 0.34, $p < 0.0001$). Increased sensitivity to heating and cooling was also significantly associated with DE status (OR = 1.63, 95% CI = 1.24 to 2.14, $p = 0.0005$) as was satisfaction with contact lens-corrected vision (OR = 0.56, 95% CI = 0.39 to 0.81, $p = 0.002$).

Many aspects of contact lens wearing time were associated with DE status. Subjects wearing lenses overnight (OR = 0.18, 95% CI = 0.07 to 0.45, $p = 0.0002$) and longer each day (OR = 0.85, 95% CI = 0.79 to 0.91, $p < 0.0001$) were more likely to be in the NDE group. On average, those in the NDE group were able to wear their lenses for about two hours longer daily than those in the DE group. Further, the average number of days lenses were worn each week was associated with DE status (OR = 0.75, 95% CI = 0.63 to 0.88, $p = 0.0006$), whereby those in the NDE group reported an average weekly lens wear duration of 6.60 ± 1.14 days (about a half a day greater than the DE group). Dry eye subjects were also much more likely to remove their lenses more frequently than those in the NDE group (OR = 7.28, 95% CI = 1.56 to 33.88, $p = 0.01$). Lastly, subjects who were able to wear their lenses as long they desired/needed were less likely to be in the DE group (OR = 0.21, 95% CI = 0.12 to 0.37, $p < 0.0001$). The only significant factor associated with a reduction in wearing time was discomfort/symptoms ($p = 0.02$).

The aforementioned significant factors in the core models were considered in developing a final model (controlled for age, gender, a recent contact lens refitting, and number of weekly applications of artificial tears/rewetting drops). The following factors were retained: decreased

overall satisfaction (OR = 3.57, 95% CI = 2.08 to 5.88, $p < 0.0001$), dry eye in the absence of contact lens wear (OR = 6.54, 95% CI = 2.57 to 16.62, $p < 0.0001$), reduced daily lens wear duration (hours per day) (OR = 1.16, 95% CI = 1.06 to 1.26, $p = 0.0007$, and reduced ability to wear lenses as long as desired (OR = 2.44, 95% CI = 1.30 to 4.54, $p = 0.005$). The Hosmer-Lemeshow goodness-of-fit test indicated excellent calibration ($\chi^2 = 9.18$, $p = 0.33$), while the area under the curve (auROC = 0.84) indicated excellent discrimination of the final model.

DISCUSSION

Treatment Factors

The use of an increased number of contact lens-related dry eye treatments was associated with dry eye status. These variables included a recent contact lens refitting, the use of artificial tears/rewetting drops (in addition to the total number of drops used), and the total number of treatments used. Treatments less frequently used included lid scrubs/warm compresses, humidifiers, and punctal occlusion. It is interesting to consider the fact that despite the use of these treatments, most of these subjects were still classified as having dry eye. This suggests that current treatment options for dry eye in contact lens wearers are not completely efficacious in treating the condition. Numerous previous reports have shown that the primary reason for contact lens dissatisfaction and discontinuation was ocular symptoms including dryness and discomfort, and in order to facilitate continued comfortable and safe contact lens wear, new treatment options for the clinical care of these patients is paramount.^{12, 30, 31}

Contact Lens Characteristics

The FDA material classification was found to be a very strong predictor of contact lens-related dry eye when examining general contact lens characteristics, whereas other variables showed no relation (e.g., rigid versus soft lens, lens replacement modalities). Specifically, the odds of dry eye for FDA group IV and II contact lens materials were two-to-three times greater than that associated with FDA group I lens wear. Interestingly, silicone hydrogel lens wear was found to be significantly protective in the core model, but dropped out in the final model with FDA group (which is probably because silicone hydrogels are low in water content and correlated with FDA grouping); further discussion pertaining to this is found below. The nonionic high water content (group II) lens materials were more associated with dry eye than the ionic high water content (group IV) lens materials, although wear of either increased the probability of dry eye status. Previously, we showed in this same cohort that high water content materials increase the probability of contact lens-related dry eye when controlling for various tear film factors, age, and gender.²⁶ We are now reporting a similar finding (the use of high water content materials increases the probability of contact lens-related dry eye) when controlling for the use of treatments for dry eye in these lens wearers. It was previously thought that these high water content materials lead to dry eye due to polymer dehydration, although evidence from our prior work, in addition to that of others, suggests that dehydration does not play a role in the process.^{13,26,32–34}

Several factors might be considered in explaining the relation between water content and dry eye in contact lens wearers. Differences in deposition patterns of materials may impact wearer comfort and dry eye symptoms by altering the lens surface wettability and potentially tear stability/evaporation characteristics. High water content materials have been shown to be associated with significant tear film deposition.^{35–39} Group II lenses have been shown to be particularly prone to lipid deposition, while group IV lenses have been shown to attract more protein than lipid species.³⁶ We recently proposed that the more polar lipids from the tear film may be attracted to the additional water in these polymers (as water is polar itself and hydrogen bonds are a stronger attractive force than electrostatic bonds that might be associated with lipids binding to the polymer itself). The resultant altered pre-lens tear film lipid layer and altered

contact lens surface may lead to increased evaporation and/or reduced wettability, respectively. These ideas are somewhat substantiated by our previously reported data showing reduced lipid layer thicknesses and faster thinning rates of the pre-lens tear film in the dry eye cohort from the sample.²⁶

Another potential consideration is the argument that traditional HEMA-based low water content lenses with lower oxygen permeability could lead to partial neural desensitization of the cornea and result in reducing symptoms. However, silicone hydrogel lenses (with the low water content and high oxygen permeability) were associated with reductions in dry eye in core model analyses. Thus, it seems unlikely that the comfort benefits associated with low water content lens wear are due to any sort of neural desensitization or oxygen permeability characteristics of the materials.

Care Solutions and Preservatives

No specific individual care solution, in addition to those when grouped by preservative, were found to be generally associated with DE status. At present, there is significant interest in understanding the potential impact of care solutions on comfort during lens wear with the addition of wetting/lubricating agents and the role of care systems in ocular surface staining. However, the presence of lubricating agents in care solutions does not appear to have a long-lasting effect on lens wettability and wearer comfort (as shown here). In a previous report, we showed an overall thicker pre-lens tear film associated with use of Complete MoisturePlus (Advanced Medical Optics, Inc) which contains a thickness-enhancing agent compared to Opti-Free Express (Alcon Laboratories, Inc).⁴⁰ While the ~15 minute solution-specific pre-lens tear film thickness decay constant was still twice that of the use of no care solution (~ 7 minutes) there was no impact on comfort during lens wear. There were also no differences in post-lens tear film thickness when comparing these care solutions. This suggests that these lubricative components in care solutions may offer some comfort benefits during lens insertion and settling, but may not necessarily be associated with improved overall comfort.

Patient-Related Factors

In the final model, four main patient-related factors were found to be highly predictive of DE status including dry eye while not wearing contact lenses, reduced overall satisfaction with current contact lenses, reduced daily wear-time, and inability to wear lenses as long as desired. Dry eye symptoms have been cited as the most frequently reported reason for dissatisfaction and discontinuation from contact lens wear.¹² The ability to wear lenses for prolonged hours was also significantly associated with CLDE; a majority of dry eye patients responded that they were unable to wear their lenses as long as they desired. Correspondingly, the quantitative variable on daily lens wear duration reflected that subjects with dry eye wore their lenses for 12.6 hours on an average, which was 2 hours less than those without dry eye. Previous reports have also identified shorter lens wear duration among dissatisfied and discontinued contact lens wearers.^{9,12}

Knowledge about the precise mechanisms of contact lens-related dry eye is still lacking. While large cross-sectional studies like ours help in identifying some key associated factors, it is difficult to draw any causal relations from such data. Longitudinal studies are warranted to more powerfully analyze causal associations between the disease and related factors.

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Table 1

Frequency distributions of categorical treatment variables associated with contact lens-related dry eye. The percentages presented sum for each outcome variable by row within each variable subclass. NA indicates that too few cells were available to conduct this analysis. All analyses are controlled for age and gender.

Variable	DE Frequency (%)		NDE Frequency (%)		Odds Ratio (95% CI)	p-value
Recent Contact Lens Refitting	No	168 (51.9%)		156 (48.1%)	6.1 (2.28 to 16.33)	0.0003
	Yes	31 (86.1%)		5 (13.9%)		
Artificial Tears/Rewetting Drops	No	93 (49.5%)		95 (50.5%)	1.57 (1.02 to 2.41)	0.04
	Yes	106 (61.6%)		66 (38.4%)		
Lids Scrubs/Compresses	No	183 (54.1%)		155 (45.9%)	2.49 (0.93 to 6.67)	0.07
	Yes	16 (72.7%)		6 (27.3%)		
Humidifier	No	191 (54.4%)		160 (45.6%)	4.66 (0.54 to 40.09)	0.16
	Yes	6 (85.7%)		1 (14.3%)		
Punctal Occlusion	No	197 (55%)		161 (45%)	NA	NA
	Yes	1 (100%)		0 (0%)		
Ointment	No	192 (54.5%)		160 (45.5%)	NA	NA
	Yes	1 (100%)		0 (0%)		

Frequency distributions of categorical contact lens variables associated with contact lens-related dry eye. As stated in the results, there were 360 individuals total (including both rigid and soft lenses). Analyses other than a comparison of rigid vs. soft are specific to the soft lens wearing group only (n = 327). The percentages presented sum for each outcome variable by row within each variable subclass. All analyses are controlled for age, gender, recent contact lens refitting, and total treatments utilized.

Table 2

Variable	DE Frequency (%)	NDE Frequency (%)	Odds Ratio (95% CI)	p-value
FDA Group ¹	1	45 (42.9%)	2 vs 1: 2.98 (1.44 to 6.19) 4 vs 1: 1.87 (1.08 to 3.24)	0.008
	2	44 (71%)		
	4	89 (56.3%)		
Silicone Hydrogel	No	151 (58.8%)	0.46 (0.25 to 0.84)	0.01
	Yes	28 (40%)		
Modality ²	Daily Disposable (DD)	14 (63.6%)	DD vs TW: 1.59 (0.59 to 4.24) M vs. TW: 0.71 (0.42 to 1.22) Q+ vs. TW: 0.54 (0.19 to 1.58)	0.28
	Two Week (TW)	97 (55.1%)		
	Monthly (M)	59 (54.1%)		
	Quarterly+ (Q+)	9 (47.4%)		
Rigid vs. Soft	Rigid	20 (60.6%)	0.73 (0.32 to 1.66)	0.45
	Soft	179 (54.7%)		

¹There were insufficient individuals wearing a Group III lens (n = 7) and thus, they were excluded from analyses.

²There were insufficient individuals wearing yearly-replaced lenses and thus, they were grouped with those wearing quarterly-replaced lenses.

Univariate regression analyses and frequency distributions of individual contact lens materials associated with contact lens-related dry eye. Analyses are limited to hydrogel lens wearers and the percentages presented sum for each outcome variable by row within each variable subclass. Analyses presented below are controlled for age, gender, recent contact lens refitting, and weekly application of artificial tear/rewetting drops. Pair-wise comparisons are made to etafilcon A (the most commonly used lens in the overall cohort).

Table 3

Contact Lens Material	DE Frequency (%)	NDE Frequency (%)	Odds Ratio (95% CI) *All versus etafilcon A	p-value
Etafilcon A	52 (51.5%)	49 (48.5%)	Reference	0.08
Galvafilcon A	7 (41.2%)	10 (58.8%)	0.76 (0.24 to 2.37)	
Lotrafilcon A	21 (39.6%)	32 (60.4%)	0.48 (0.23 to 1.02)	
Methafilcon A	9 (69.2%)	4 (30.8%)	1.21 (0.28 to 5.25)	
Nelfilcon A	7 (70%)	3 (30%)	1.71 (0.38 to 7.72)	
Ocufilcon D	10 (58.8%)	7 (41.2%)	1.27 (0.40 to 4.02)	
Onafilcon A	22 (73.3%)	8 (26.7%)	1.51 (0.56 to 4.08)	
Other	27 (71.1%)	11 (28.9%)	2.49 (1.07 to 5.83)	
Polymacon	13 (61.9%)	8 (38.1%)	1.41 (0.49 to 4.09)	
Tetrafilcon A	4 (30.8%)	9 (69.2%)	0.31 (0.08 to 1.25)	
Vifilcon A	7 (53.8%)	6 (46.2%)	1.21 (0.36 to 4.06)	

Table 4

Univariate regression analyses and frequency distributions of individual contact lens care solutions, and when grouped by preservative, associated with contact lens-related dry eye. Analyses are limited to hydrogel lens wearers and the percentages presented sum for each outcome variable by row within each variable subclass. Analyses presented below are controlled for age, gender, recent contact lens refitting, and weekly application of artificial tear/rewetting drops. Pair-wise comparisons are made to Opti-Free Express and PHMB (the most commonly used individual care solution and preservative in the overall cohort).

Care Solution or Preservative	DE Frequency (%)	NDE Frequency (%)	Odds Ratio (95% CI) *Reference = OFX or PHMB	p-value
Care Solution	23 (62.2%)	14 (37.8%)	1.01 (0.44 to 2.31)	0.99
Complete MoisturePlus (CMP) (Advanced Medical Optics, Inc)				
Generic	14 (53.8%)	12 (46.2%)	0.94 (0.37 to 2.38)	
None (e.g., daily disposable or extended wear)	15 (55.6%)	12 (44.4%)	1.01 (0.40 to 2.57)	
Opti-Free Express (OFX) (Alcon Laboratories, Inc)	61 (57.5%)	45 (42.5%)	Reference	
Other	15 (53.6%)	13 (46.4%)	0.81 (0.33 to 1.97)	
Renu Multiplus (RMP) (Bausch and Lomb, Inc)	51 (50.5%)	50 (49.5%)	0.84 (0.46 to 1.53)	
Generic	14 (53.8%)	12 (46.2%)	1.09 (0.44 to 2.70)	
Hydrogen Peroxide (H ₂ O ₂)	11 (57.9%)	8 (42.1%)	1.10 (0.40 to 3.06)	0.99
None (e.g., daily disposable or extended wear)	15 (55.6%)	12 (44.4%)	1.16 (0.47 to 2.86)	
PHMB	77 (53.5%)	67 (46.5%)	Reference	
Poliquad	61 (56.5%)	47 (43.5%)	1.11 (0.64 to 1.91)	

Table 5

Univariate regression analysis results and frequency distributions of categorical patient-related factors associated with contact lens-related dry eye. The percentages presented sum for each outcome variable by row within each variable subclass. Analyses presented below are controlled for age, gender, recent contact lens refitting, and weekly application of artificial tear/rewetting drops.

Variable	DE Frequency (%)	NDE Frequency (%)	Odds Ratio (95% CI)	p-value
Dry eye diagnosis/symptoms without lens wear	Yes	50 (87.7%)	6.29 (2.67 to 14.79)	<0.0001
	No	149 (49.3%)		
Overall satisfaction with current contact lenses	Very dissatisfied	5 (83.3%)	0.21 (0.13 to 0.34)	<0.0001
	Dissatisfied	19 (95.0%)		
	Satisfied	134 (67.7%)		
	Very satisfied	41 (30.1%)		
Wear lenses as long as desired/needed	Yes	110 (44.4%)	0.21 (0.12 to 0.37)	<0.0001
	No	89 (79.5%)		
Overnight lens wear	Yes	8 (21.1%)	0.18 (0.07 to 0.45)	0.0002
	No	190 (59.2%)		
Eye sensitivity to heating and cooling	Not at all	48 (40.7%)	1.63 (1.24 to 2.14)	0.0005
	Occasionally	82 (55%)		
	Often	52 (73.2%)		
	All the time	17 (77.3%)		
Factors that reduce lens wearing time ^a	Inconvenience	9 (64.3%)	NA	0.16
	Symptoms/comfort	82 (82.8%)		0.02
	Poor CL fit	1 (50.0%)		0.37
	Cost	2 (50.0%)		0.19
	Doctor recommended reduction of wearing time for eye health reasons	9 (75.0%)		0.71
	Very dissatisfied	4 (80%)		0.002
	Dissatisfied	18 (81.8%)		
Frequency of needing to remove of lenses (due to lenses bothering the eyes) ^a	Satisfied	114 (59.7%)	Several times per week vs Weekly: 7.28 (1.56 to 33.88)	0.01
	Very satisfied	63 (44.4%)		
	Never	2 (66.7%)		
	Less than once per week	17 (53.1%)		
	Weekly	27 (87.1%)		
	Several times per week	25 (92.6%)		
	Once per day	15 (100%)		
	Several times per day	3 (100%)		
	Not at all	94 (50.8%)		
	Occasionally	53 (57.6%)		
Dryness and irritation on the day after alcohol consumption	Often	8 (61.5%)	1.34 (0.93 to 1.93)	0.11
	All the time	7 (87.5%)		
	Not applicable	36 (60%)		
	Not at all	34 (52.3%)		
Eye sensitivity to smoke	Occasionally	90 (50.3%)	1.17 (0.90 to 1.51)	0.24
	Often	41 (60.3%)		
	All the time	34 (70.8%)		
	Yes	32 (52.5%)		
Infection associated with lens wear	No	167 (55.9%)	0.71 (0.39 to 1.3)	0.26
	Not at all	122 (50.8%)		
Eye sensitivity to smog	Occasionally	62 (66%)	1.20 (0.83 to 1.74)	0.34
	Often	13 (59.1%)		
	All the time	2 (66.7%)		
	Yes	71 (55.5%)		
Doctor recommended discontinuation of lens wear	No	123 (54.4%)	0.90 (0.56 to 1.45)	0.65
		103 (45.6%)		

^d Out of all lens wearing subjects considered, 112 subjects answered 'No,' when asked if they were able to wear their contact lenses as long as they liked. This item was not considered in the multivariate model as it represents a different sub-sample of patients given that not all patients responded to these questions. The p-values are derived from Fisher's exact test (due to the small samples found in several of the cells)

Table 6

Univariate regression analysis results and frequency of continuous patient-related factors associated with contact lens-related dry eye. The average and standard deviations are reported by DE status. Analyses presented below are controlled for age, gender, recent contact lens refitting, and weekly application of artificial tear/rewetting drops.

Variable	DE Ave $\pm$ SD	NDE Ave $\pm$ SD	Odds Ratio (95% CI)	p-value
Daily lens wear duration (hours)	12.56 $\pm$ 3.61	14.45 $\pm$ 3.31	0.85 (0.78 to 0.91)	<0.0001
Weekly lens wear duration (days)	5.89 $\pm$ 1.91	6.56 $\pm$ 1.14	0.75 (0.63 to 0.88)	0.0006
Total years lenses worn (years)	8.27 $\pm$ 6.04	8.99 $\pm$ 6.83	0.98 (0.95 to 1.02)	0.40
Age when started lens wear (years)	18.05 $\pm$ 8.24	17.79 $\pm$ 8.06	1.01 (0.98 to 1.05)	0.48