Original Article

The Impact of Advanced Surface Moisturizing Technologies on Contact Lens Comfort in Digital Platform Users

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Abstract

Objectives: To evaluate and compare the on-eye performance and comfort of two lotrafilcon B contact lenses, each manufactured using different surface moisturizing technologies, in individuals who use digital platforms for more than 3 hours daily.

Materials and Methods: Twenty-nine asymptomatic habitual contact lens wearers participated in a randomized, double-masked crossover study. Each subject wore either Air Optix Aqua or Air Optix Plus HydraGlyde contact lenses for a month before switching to the other lens type for another month. Contact Lens Dry Eye Questionnaire 8 (CLDEQ-8) scores, biomicroscopic examination, tear function tests, and blink rates were recorded at baseline and at the end of each month. The patients were asked to complete a Likert-type questionnaire evaluating vision and comfort, along with first-impression ratings for visual clarity, comfort, and dryness with each lens.

Results: The mean age of patients was 25.5±7.2 years. Tarsal papillary grade was significantly lower, and tear-film break up time was higher with Air Optix Plus HydraGlyde lenses compared to Air Optix Aqua lenses ($p<0.05$). There were no significant differences between the two lenses in terms of slit-lamp findings, Schirmer's test, blink rate, or CLDEQ-8 scores ($p>0.05$). Air Optix Plus HydraGlyde lenses provided significantly better end-of-day comfort and less blurred vision, dryness, and eye tiredness ($p<0.05$).

Conclusion: Air Optix Plus HydraGlyde lenses with advanced surface moisturizing technology were superior in terms of end-of-day comfort, end-of-month comfort, and visual clarity. Technological advances in silicone hydrogel lens surface treatments seem to be helpful in improving contact lens comfort in lens wearers with moderate daily exposure to digital devices.

Keywords: Surface moisturizing technologies, contact lens comfort, lens surface modification, silicone hydrogel, digital eye strain

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Introduction

Contact lenses (CLs) are effective and reliable optical devices for correcting refractive errors. They have been widely used since the introduction of soft lens materials. Despite the increase in the global population, the number of CL wearers has remained more or less stable over the years because of constant CL discontinuation reported in the range of 12% to 51% globally.[1] One of the leading causes for discontinuation is CL discomfort, which accounts for 30% to 50% of all discontinuations.[2,3,4]

For years, CL practitioners and scientists have questioned the influence of polymer chemistry, design, and other quantifiable material attributes as possible determinants of CL discomfort.[5] These attributes include the bulk (e.g., water content, dehydration, ionicity, oxygen transmissibility, modulus, and mechanical factors) and surface properties (e.g., friction, wettability, surface modification) of CL materials. Although the exact cause

of CL discomfort remains unclear, it is known to be multifactorial and complex.[6] In 2013, the Contact Lens Materials, Design, and Care Subcommittee of TFOS International Workshop on Contact Lens Discomfort[7] classified the factors underlying CL discomfort as CL-related and environmental factors. Among CL-related factors, lens material and design, lens care, and/or wear pattern have been extensively evaluated from the available literature. However, the specific parameters influencing CL discomfort could not be determined, as existing studies could not isolate other confounding factors.[1] Nevertheless, considering the relevance of pre-lens tear film stability in CL discomfort, the workshop recommended that future studies focus on developing novel materials or surface treatments to resist tear evaporation during CL wear.[1] The surface characteristics of CLs include friction, wettability, lubricity, and surface water contact.[5] Wettability and lubricity are two important predeterminants of the frictional forces between the lens and the ocular/palpebral surfaces.[5] Among the material properties of CLs, only friction was correlated with *in vivo* comfort scores according to previous studies.[1,8,9] Frictional forces have also been linked to CL discomfort-related conditions such as lid-wiper epitheliopathy.[7,10]

While silicone hydrogel soft CL materials effectively reduce hypoxia-related adverse events, the wettability/lubricity issues of these CLs still present challenges for the CL industry. Recognizing the impact of frictional forces on comfort, the CL industry has made significant efforts to enhance surface properties through intrinsic wettability agents, surface modifications, or water-gradient technologies. This study aims to evaluate and compare the impact of advanced moisturizing technology with lotrafilcon B lenses on patient comfort.

Materials and Methods

The study was approved by the Ethics Committee of Ankara University Faculty of Medicine Clinical Research Ethics Committee (number: 07-362-17; date: 10 April 2017) and was conducted according to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment.

Twenty-nine consecutive participants with myopic refractive errors (from -0.75 to -5.00 diopters [D]) who reported more than 3 hours of daily digital device use (desktop, laptop, tablet, or smartphone) and wore CLs for at least 8 hours per day, 6 days a week were included in the study. Habitual CL wearers who had signs of ocular disease, were using systemic or topical medication that could affect the ocular surface, or had CL-related discomfort were excluded. Following a 1-week washout period, participants were randomly assigned to wear either Air Optix Aqua (lotrafilcon B, Alcon, Fort Worth, TX, USA) or Air Optix Plus HydraGlyde (lotrafilcon B, Alcon, Fort Worth, TX, USA) lenses (Table 1). Randomization was performed by simple random sampling using a random number list from Excel. Both participants and observers were blinded to the lens allocation, and all CLs were applied by a CL nurse. CL fitting characteristics including centration, movement, and tightness were evaluated using slit-lamp biomicroscopy. Participants wore the assigned lens type on a daily wear basis for one month. At the end of the first month, the lenses were removed by the participants one day before the follow-up visit. At the follow-up visit, participants were assigned the alternate lens type. CL fit was reassessed at the slit-lamp, and the participants continued wearing the second lens type for another month. Throughout the study, all participants used the same lens solution (OptiFree Express, Alcon, Fort Worth, TX, USA).

At baseline and follow-up visits (at month 1 and month 2), a detailed slit-lamp biomicroscopic examination of the cornea and adnexa was performed, including blink rates, Schirmer-I test, fluorescein staining of the ocular surface, and tear break-up time (TBUT). The blink rate was recorded through direct observation of the participants. This observation was conducted while participants were calmly awaiting the examination to ensure natural blinking behavior. The Schirmer-I test was performed without topical anesthesia. On slit-lamp biomicroscopy, the tarsal papillary reaction was assessed using the grading system of Bonini et al.[11]: grade 0 (no papillary reaction), grade 1 (few papillae, 0.2 mm widespread over the tarsal conjunctiva or around the limbus), grade 2 (papillae of 0.3-1 mm over the tarsal conjunctiva or at the limbus), grade 3 (papillae of 1-3 mm all over the tarsal conjunctiva or for 360° around the limbus), and grade 4 (papillae of more than 3

Table 1. Physical properties of the contact lenses studied

	Air Optix Aqua	Air Optix Plus HydraGlyde
Material	Lotrafilcon B	Lotrafilcon B
Lens design	Aspherical	Aspherical
Water content (%)	33	33
Diameter (mm)	14.2	14.2
Base curve (mm)	8.6	8.6
Dk/t (@-3.00D)	138	138
Center thickness (mm)	0.08	0.08
Modulus (MPa)	1.0	1.0
Surface	SmartShield Technology	SmartShield Technology Moisture Matrix Technology

mm over the tarsal conjunctiva or gelatinous appearance at the limbus covering the peripheral cornea). Superficial punctate keratitis was graded based on corneal staining as grade 0 (no staining), grade 1 (mild staining with a few disseminated dots and limited to less than one third of the cornea), grade 2 (moderate staining with severity between 1 and 3), or grade 3 (severe confluent staining and occupying half or more of the cornea).[12] Both the tarsal papillary reaction and superficial punctate staining were graded by the same examiner (M.A.E.). TBUT was measured three times after fluorescein application and the mean value was recorded.

Following routine ophthalmic examination, all participants were asked to complete the Contact Lens Dry Eye Questionnaire 8 (CLDEQ-8), which has been validated in the Turkish language (Supplementary File 1).[13,14]

At follow-up visits, the participants were asked to report their CL experience in the past month. Firstly, they were asked to score each question regarding visual clarity, comfort, dryness, weariness, etc. on a scale from 1 (very poor) to 10 (excellent). Additionally, they responded to seven statements regarding their vision and comfort with the CL on a 5-point Likert-type scale (strongly agree, agree, undecided, disagree, strongly disagree) (Supplementary File 2). Lastly, the participants were asked if they would continue wearing this CL and requested to pick from the options of "definitely wear", "wear", "not wear", "probably not wear", or "definitely never wear".

Statistical Analysis

The sample size was calculated based on a two-tailed paired t-test, assuming an alpha level of 0.05, a power of 80%, and an expected effect size (Cohen's d) of 0.67. This yielded a required sample size of 24 participants. To account for potential dropouts, we planned to include a total of 29 participants. Data were described as mean and standard deviation for numerical variables and frequency and percentage for categorical variables. Normality of the data was tested using the Kolmogorov-Smirnov test/Shapiro-Wilk test and histogram and probability graphs. Nominal variables were compared with chi-square or Fisher's exact test, whereas numerical variables were compared with independent samples t-test or Mann-Whitney U test as appropriate. Responses to the Likert-type items were converted to binary format (strongly agree/agree: favorable [1], undecided/disagree/strongly disagree: unfavorable [0]) and compared using a binomial generalized linear mixed model. Statistical analyses were performed with SPSS version 26.0 (IBM Corp., Armonk, NY, USA). The level of statistical significance was set at $p<0.05$.

Results

Twenty-nine consecutive asymptomatic CL wearers were included in this study. The mean age was 25.5±7.2 years (range, 16-45 years) and 24% of them were male. The mean spherical refractive error was -3.01±1.80 D (range, -0.75 to -5.00 D). Among the participants, 65% wore their CLs for over 10 hours a day, and 52% wore their CLs 7 days a week. The mean daily duration of digital device use was 4.9±2.3 hours (range, 3-10 hours). Baseline clinical data of the participants are presented in Table 2.

Functional Parameters

The clinical characteristics of the eyes in each CL group are presented in Table 3. There were no statistically significant differences between the two groups in terms of mean CLDEQ-8 score, superficial punctate keratitis grade, blink rate, or Schirmer-I test score ($p>0.05$). The mean TBUT was significantly higher ($p=0.02$) and tarsal papillary grade ($p=0.003$) was lower with the Air Optix Plus HydraGlyde compared to the Air Optix Aqua.

Table 2. Demographic and clinical data of the participants

Age (years)		25.5±7.2
Sex (female:male)		22:7
BCVA (logMAR)		0.0±0.0
MR spherical (D)		-3.0±1.8
Schirmer I test (mm)		24.6±8.0
TBUT (s)	<10 ≥10	0 (0%) 57 (100%)
SPK grade	0 1 2 3 4	56 (98.2%) 1 (1.8%) 0 (0%) 0 (0%) 0 (0%)
Tarsal papillary grade	0 1 2 3 4	20 (35.1%) 29 (50.9%) 8 (14.0%) 0 (0%) 0 (0%)
Blink rate (blinks/min)		12.0±4.5
Digital platform use (hours/day)		4.9±2.3
Lens wear (hours/day)	8-10 10-12 12-14 ≥14	10 (17.5%) 10 (17.5%) 19 (33.4%) 18 (31.6 %)
CLDEQ-8 score		14.1±6.5

Numerical variables are presented as mean ± standard deviation, categorical variables as frequency and percentage
BCVA: Best corrected visual acuity, logMAR: Logarithm of the minimum angle of resolution, MR: Manifest refraction, D: Diopter, TBUT: Tear break-up time, SPK: Superficial punctate keratitis, CLDEQ-8: Contact Lens Dry Eye Questionnaire

Subjective Parameters

Out of 12 questions rated on a scale of 1 to 10, the Air Optix Plus HydraGlyde showed significantly better performance in alleviating blurred vision, dryness, and tiredness during the day, and provided better end-of-day comfort ($p<0.05$) (Table 4). Regarding Likert-type questionnaire responses, more than 80% of the participants agreed or strongly agreed that both lenses provided excellent visual acuity and handling (Figure 1). Most of the participants (>60%) agreed or strongly agreed that the Air Optix Plus HydraGlyde provided greater comfort and less tiredness, dryness, visual fluctuations, and lens awareness. However, according to the binomial generalized linear mixed model, there was no statistically significant difference between the two lenses (odds ratio: 1.27, 95% confidence interval: 0.64-2.51, p=0.488).

Overall, 79.3% of participants reported they would "definitely wear" or "probably wear" the Air Optix Plus HydraGlyde, while 76% expressed the same preference for the Air Optix Aqua.

Discussion

In this study, the Air Optix Plus HydraGlyde CL with advanced surface moisturizing technology was statistically significantly superior to the Air Optix Aqua CL in terms of end-of-day and end-of-month comfort and lower frequency of tiredness, dryness, and blurred vision, which are the common symptoms of CL discomfort. In addition to subjective outcomes, TBUT was significantly longer, and tarsal papillary grade was significantly lower with the Air Optix Plus HydraGlyde lens compared to the Air Optix Aqua. Outcomes of this preliminary study indicate that the incorporation of surface modifications to improve lubrication or decrease friction over silicone hydrogel CL surfaces does translate to improved patient comfort.

Despite developments in lens designs, material properties, and care regimens, CL discomfort remains a challenge for CL wearers, eye care practitioners, and the industry. Typically, ocular discomfort is minimal or absent immediately after lens insertion but tends to increase as the day progresses.[15,16,17] Management strategies often include rewetting drops, switching to lenses with alternative designs or materials, changing care solutions, altering the replacement schedules, or in more severe cases, prescribing topical medications.[18] Nevertheless, the prevalence of discomfort among CL wearers is as high as 75%, and it is one of the leading causes of CL discontinuation.[6,19]

CL-related factors influencing discomfort include lens material, fit, design, surface characteristics, and care solutions.[20] To date, studies investigating comfort with silicone hydrogel CLs have yielded controversial results,[20] with some studies reporting improved comfort with silicone hydrogel lenses compared to traditional hydrogel lenses[13,15,21,22,23] and others reporting no added benefit.[5,24,25,26] These discrepancies may be due to methodological variations, differences in outcome measures, and/or limited follow-up durations. Moreover, comfort also varies between different silicone hydrogel CL materials, indicating the influence of additional confounding variables. In addition to lens material, other CL-related factors associated with greater comfort include a tighter fit, steeper base curve, lower CL power,

Table 3. Subjective and objective ocular surface measurements

	Air Optix Aqua	Air Optix Plus HydraGlyde	p
CLDEQ-8 score	12.9±6.6	11.6±6.7	0.42
Blink rate (blinks/min)	14.0±4.9	13.2±4.5	0.91
SPK grade	0.15±0.3	0.03±0.1	0.050
TBUT (s)	8.8±2.0	9.4±1.2	0.02
Tarsal papillary grade	0.8±0.6	0.6±0.5	0.003
Schirmer I test (mm)	25.2±8.1	23.8±6.5	0.42

Values are presented as mean ± standard deviation. p: Independent samples t-test or Mann-Whitney U test
CLDEQ-8: Contact Lens Dry Eye Questionnaire, SPK: Superficial punctate keratitis, TBUT: Tear break-up time

Table 4. Comparison of participants' subjective scores on the questionnaire

	Air Optix Aqua	Air Optix Plus HydraGlyde	p
Initial visual clarity	8.3±1.2	8.6±1.4	0.18
Day-long visual clarity	8.3±1.2	8.4±1.3	0.19
End-of-day visual clarity	7.6±1.7	8.0±1.5	0.16
Initial comfort	8.2±1.6	8.3±1.5	0.14
Day-long comfort	8.0±1.5	8.2±1.2	0.42
End-of-day comfort	7.0±2.3	7.7±1.7	**0.02**
Blurred vision	7.4±2.1	8.1±2.1	**0.03**
Fluctuation in vision	8.1±1.6	8.2±1.6	0.59
End-of-day dryness	7.3±2.5	7.9±2.1	**0.04**
End-of-day tiredness	7.1±2.1	7.8±2.3	**0.04**
Lens awareness	8.1±1.9	8.6±1.6	0.09
Lens handling	8.4±1.7	8.7±1.5	0.25

Values are presented as mean ± standard deviation. p: Independent samples t-test or Mann-Whitney U test

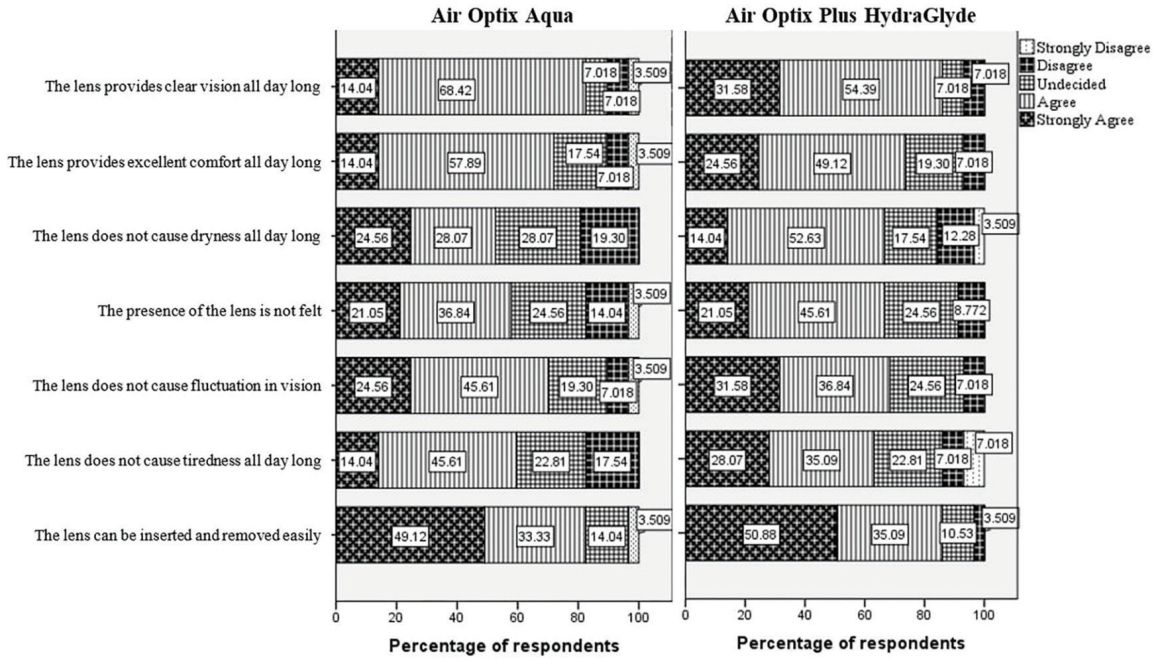

Figure 1. Likert-type responses regarding vision and comfort for the Air Optix Aqua and Air Optix Plus HydraGlyde contact lenses

knife-edge design, as well as a smooth and wettable lens surface with minimal deposits.[20]

In the present study, both types of lenses were covered with SmartShield® technology, a consistent protective plasma layer covering the outer surface of the lens which improves smoothness, wettability, and resistance to deposits.[27] Air Optix Plus HydraGlyde lenses also incorporate an additional surface modification, the HydraGlyde® Moisture Matrix. This technology utilizes a block copolymer (polyoxyethylene-polyoxybutylene, EOBO) that integrates into the lens surface, creating a long-lasting moisture envelope around the lens.[28,29] The EOBO moisture matrix acts as a surfactant that helps reduce frictional forces on the CL by maintaining extra hydration throughout the day, emphasizing the role of surface treatments in enhancing wearer comfort.[29,30] Recently, a prospective, contralateral eye study conducted with 30 novice CL users compared two CLs with different materials and surface treatments: the Bausch&Lomb ULTRA (samfilcon A with MoistureSeal® technology, Bausch&Lomb Inc., Rochester, NY, USA) and Air Optix Plus HydraGlyde (lotrafilcon B with HydraGlyde® Moisture Matrix and SmartShield® technology, Alcon, Fort Worth, TX, USA).[31] The authors reported good compliance with both lenses and similar CLDEQ-8 scores (5.1 and 6.8, respectively), which highlights the importance of surface treatment in providing patient comfort. However, despite their shared emphasis on surface treatment technologies, these lenses differ in other critical parameters that may influence comfort levels, such as water content, oxygen transmission, lens thickness, and design.[31] Another study seeking to eliminate these differences used a randomized cross-over design with 19 habitual CL wearers to evaluate the impact of an ultrathin surface coating on the comfort and wettability of a standard silicone hydrogel CL.[32] The patients wore formofilcon B monthly disposable soft CLs with and without a surface-modifying coating (Bettervision Pty, Keller, TX, USA) for one month each. The coated lenses provided superior subjective lens comfort, improved perceived visual quality, and reduced CL-related dry eye symptoms, as assessed by CLDEQ-8. The authors concluded that changing the physical properties (lubricity) of the surface of a soft CL positively impacts subjectively rated comfort.[32] Similarly, the present study compared two commercially available CLs from the same manufacturer, both made from identical bulk material, with the same water content, design, oxygen transmissibility, and modulus. The only variable between the two lenses was the addition of the surface moisturizing technology in the Air Optix Plus HydraGlyde lens. The results of this study support the findings of aforementioned study, with statistically significant improvements in end-of-day comfort ratings, as well as other subjective parameters such as blurred vision, end-of-day dryness, and end-of-day tiredness. Although CLDEQ-8 scores were also better

with the Air Optix Plus HydraGlyde lenses compared to their predecessor, the difference did not reach statistical significance in this study.

Enhanced surface wettability through surface modifications (coatings or moisturizing agents) is expected to decrease frictional forces over the CL and thereby improve wearer comfort.[8] Today, improved comfort is particularly important for CL wearers due to the increased daily exposure to digital platforms such as computers, tablets, and smartphones. Digital device use is associated with decreased blink rate and increased percentage of incomplete blinks, which lead to adverse ocular sensations and reductions in TBUT, mucin expression, and Schirmer scores—a.k.a., "digital eye strain" (DES) or "computer vision syndrome".[33,34,35] Studies have demonstrated that CL wearers using video display terminals for more than 4-6 hours per day are more likely to suffer from DES compared to non-wearers.[36,37,38] In a prospective comparative study conducted with 232 intensive digital device users with myopia, Uçakhan et al.[39] evaluated a samfilcon A lens with surface treatment (Bausch&Lomb ULTRA, MoistureSeal® Technology, Bausch&Lomb Inc., Rochester, NY, USA) compared to a senofilcon A lens (Acuvue Oasys, HydraClear® Plus, Vistakon, Jacksonville, FL, USA) and lotrafilcon B lens (Air Optix Aqua, SmartShield® Technology, Alcon, Fort Worth, TX, USA). The authors reported high overall ratings from both patients and clinicians for samfilcon A lenses. Among habitual wearers of lotrafilcon B or senofilcon A lenses, samfilcon A was rated significantly higher for comfort and visual performance than their habitual CLs.[39] In the present study, both lotrafilcon B lenses provided high levels of comfort, with Air Optix HydraGlyde outperforming Air Optix Aqua. These differing outcomes may be attributed to variations in study design and differences in daily screen time exposure. The mean duration of digital device use was not mentioned in the previous study. However, in the current study, participants reported a mean usage of 5 hours per day, during which the Air Optix Aqua still yielded satisfactory performance. Still, DES remains a challenge for the CL industry, highlighting the need to meet increased patient requirements and provide better CL material and surface technologies to overcome end-of-day comfort issues.

The effect of lens care solutions on ocular signs and symptoms has been previously evaluated in the literature.[20] Vidal-Rohr et al.[32] observed a low incidence of bulbar and limbal redness regardless of whether the lenses were coated or uncoated. They attributed the lack of a difference to the use of hydrogen peroxide disinfection systems, arguing that this might have masked any possible consequence of the frictional forces between the lens surface and lid margin.[32] In the present study, all participants used Polyquad/Aldox-preserved OptiFree Express, yet similarly low rates of objective signs were observed with both lens types. Even ocular surface staining, which is commonly cited as a frequent CL-related adverse event,[40] was minimal with both lens types in this study, despite previous findings that it occurs least often with peroxide-based care systems.[41]

Study Limitations

This study has some limitations. Firstly, the small sample size and limited follow-up duration reduce the generalizability of our results. Secondly, the absence of a wash-out period between lens switches could influence clinical outcomes by allowing residual effects from the first lens to carry over, potentially confounding the results. However, our study design was consistent with the existing literature, where similar crossover designs have been employed without the inclusion of a wash-out period between different lens types.[42,43,44] Additionally, our study employed randomization of lens wear sequence to minimize systematic bias. This random allocation ensures that any potential residual effects are evenly distributed across the study groups, thereby reducing the risk of confounding. Lastly, using different questionnaires to assess CL comfort might lead to confusion and redundancy. However, this approach allowed participants to more fully express their perceived comfort and symptom burden in a way that a single questionnaire may not have captured as effectively. Besides, based on our previous clinical experience, certain questions within each questionnaire were particularly effective to assess CL comfort. Rather than fragmenting the questionnaires, we opted to administer them together in a unified format.

Conclusion

In conclusion, the incorporation of a surfactant-based surface technology to enhance wettability and lubricity led to improved comfort scores in this study. Therefore, the efforts made by the CL industry to improve silicone hydrogel CL material, design, and surface characteristics may help alleviate CL discomfort and reduce discontinuation rates. However, larger-scale, longitudinal studies are necessary to confirm the long-term benefits of surface modifications on CL tolerance and dropout.

Ethics

Ethics Committee Approval: The study was approved by the Ethics Committee of Ankara University Faculty of Medicine Clinical Research Ethics Committee (number: 07-362-17; date: 10 April 2017) and was conducted according to the tenets of the Declaration of Helsinki.

Informed Consent: Written informed consent was obtained from all participants prior to enrollment.

Declarations

Authorship Contributions

Surgical and Medical Practices: M.A.E., Ö.Ö.U-G., Concept: M.A.E., Ö.Ö.U-G., Design: M.A.E., Ö.Ö.U-G., Data Collection or Processing: M.A.E., T.Ç.B., Analysis or Interpretation: M.A.E., T.Ç.B., Literature Search: T.Ç.B., Writing: M.A.E., T.Ç.B., Ö.Ö.U-G.

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