OPEN

Clinical Investigation of Flat Pack Toric Contact Lenses and Wearer Attitudes to Environmental Impact

Neema Ghorbani-Mojarrad, Ph.D., Lindsay Rountree, Ph.D., Louise Terry, Ph.D., Heather Bruce, B.Sc. (Hons), Emily Hallam, B.Sc. (Hons), Louise Jolly, B.Sc. (Hons), Neil Retallic, B.Sc. (Hons), and Katharine Evans, Ph.D.

Objectives: To investigate the performance of a novel flat pack toric daily disposable contact lens compared with traditionally packaged toric lenses in a randomized, crossover study. Environmental attitudes to contact lens wear were also explored.

Methods: Habitual contact lens wearers were recruited to wear a hioxifilcon A (Miru 1 day Flat Pack Toric, Menicon, Nagoya, Japan) test lens and a control lens: either nelfilcon A (Dailies AquaComfort Plus, Alcon, Geneva, Switzerland) or etafilcon A (1-Day Acuvue Moist, Johnson & Johnson, New Brunswick, NJ). Objective lens performance was assessed at fitting, and participants wore lenses in a randomized order for three consecutive days. Subjective measures of lens performance (comfort, vision, and handling) were then assessed by a questionnaire, with further questions on overall lens preference and environmental perceptions.

Results: Objective measures of lens fit were similar for the test and control lenses, except for distance VA which was better with the control lenses ($P<0.05$; difference of two logMAR letters). End of day comfort was greater with the test lens, but this did not reach significance. Both lenses demonstrated similar scores for overall satisfaction. 87.5% of participants indicated the environmental impact of contact lenses to be important/extremely important to them, with 100% of participants identifying the flat pack packaging as having a smaller environmental impact.

Conclusion: Overall, the lenses used in the study performed to similar levels. Environmental credentials are important to contact lens wearers, which may contribute to overall lens preference.

Key Words: Toric contact lenses—Contact lens comfort—Soft contact lenses—Environmental awareness.

(*Eye & Contact Lens* 2023;49: 475–482)

A systematic review conducted in 2018 estimated a global prevalence of astigmatism in adults (typically defined as ≥ -0.75DC in at least one eye) of 40%.[1] Within the United Kingdom population, this seems to be slightly higher, estimated to be 47% monocularly and 24% binocularly.[2] An international survey revealed that there has been a continuous increase in toric contact lens prescribing over the past 20 years, likely because of the increased accessibility and increased parameter ranges in soft toric contact lenses.[3] This trend is also apparent in the United Kingdom; this increase in toric lens fitting is accompanied by a decline in the proportion of soft spherical-only fits, leading to the number of toric contact lens fits overtaking spherical ones in 2020.[4] This is beneficial to patients as studies indicate improved visual acuity and contrast sensitivity when fitted with toric contact lenses.[5–7] More recently, a study comparing subjective and objective measures of visual performance with digital devices in astigmatic patients trialing toric and spherical lenses of the same material found that participants preferred the comfort and vision with the toric contact lenses.[8]

Dumbleton et al.[9] investigated contact lens drop out in a retrospective sample of over 4,000 lapsed wearers, and while discomfort was cited as the most common cause, poor vision and issues with lens handling were also common causes of lens discontinuation. Toric contact lens wearers are more likely to discontinue lens wear compared with spherical lens wearers, with comfort and vision problems being factors in discontinuation.[10]

Despite this, most contact lens studies examine spherical contact lenses only, and there are very few that look at the relationship between vision and comfort in soft toric contact lenses.[11] One such study found that any reduction in visual acuity may increase the symptoms of ocular discomfort, and both were related to overall satisfaction in lens wear.[11]

In addition, the environmental impact of contact lens wear has started to draw interest from the contact lens industry, because of the use of predominantly synthetic plastic materials. Initially, environmental impact was explored in the academic literature with differences in lens modalities that is, daily versus monthly disposable,[12] and the

From the School of Optometry and Vision Sciences (K.E., L.T.), Cardiff University, Cardiff, United Kingdom; School of Optometry and Vision Science (H.B., E.H., L.J., L.R., N.G.-M.), University of Bradford, Bradford, United Kingdom; Menicon UK Ltd (N.R.), Northampton, United Kingdom; and Wolfson Centre for Applied Health Research (N.G.-M.), Bradford, United Kingdom.

N. Retallic is an ex-employee of Menicon UK Ltd. The remaining authors have no funding or conflicts of interest to disclose.

Supported by Menicon UK Ltd. Creation of the protocol, analysis of the data, and drafting of the manuscript was performed by K. Evans, L. Terry, L. Rountree, and N. Ghorbani-Mojarrad only, with the funders having no input into the collection of data, data analysis, or presentation of results within the article.

Concept and design: K. Evans, N. Ghorbani-Mojarrad, and L. Terry. Data collection and analysis: K. Evans, N. Ghorbani-Mojarrad, H. Bruce, L. Jolly, and E. Hallam. Drafting of the manuscript: N. Ghorbani-Mojarrad. Critical revision of the manuscript: all authors. Statistical analysis: K. Evans and N. Ghorbani-Mojarrad.

Address correspondence to School of Optometry and Vision Science, University of Bradford, Bradford BD7 1DP, United Kingdom; e-mail: n.ghorbanimojarrad@bradford.ac.uk

Accepted July 27, 2023.

DOI: 10.1097/ICL.0000000000001031

potential impact that perceived environmental impact could hypothetically have on patient lens choice.[13,14] Reports stated that the overall environmental impact of contact lenses is relatively small compared with other sources of domestic waste; however this report did not take into account manufacturing and distribution.[12] Recent interest has accelerated due to more frequent news and media reports relating to the environment. This, coupled with the increase in daily disposable lens use, and subsequent increased single use plastic in blister packaging, has brought this matter to the fore.[3] Although daily disposable lenses produce more waste, and have a greater potential environmental impact,[12,13] it has been reported that reusable contact lenses do not substantially reduce the relative environmental burden of contact lens wear as much as initially expected when peripheral factors and their accompanying lens care systems are accounted for.[15,16]

In light of the greater public interest in environmental affairs, contact lens manufacturers have begun to implement new strategies to reduce their environmental impact. This includes contact lens recycling schemes within the United Kingdom and United States[15,17,18] and plastic-neutral partnerships.[19]

One manufacturer has developed packaging that removes the need for plastic casing within blister packs. Miru 1 Day Menicon Flat Pack (hioxifilcon A) comes in a bifoil "flat pack" design, made of polypropylene-covered foil on both sides, with minimal plastic and saline in comparison with typical lens blister packs. The design allows the packaging to be just over 1 mm thick, flattening the lens within the blister and resulting in an 80% reduction in packaging on average.[15]

Although this design may be more environmentally friendly, it is unknown whether it impacts on lens performance or lens handling when compared with contact lenses supplied in traditional blister packs. In this study, the performance of the Miru 1 Day Menicon Flat Pack Toric (hioxifilcon A) contact lens was evaluated both through objective and subjective means, in comparison with similar lenses available on the market. In addition, ease of lens handling and participants' opinions on the importance of the environmental impact of contact lens packaging were also evaluated.

METHODS

Study Protocol and Study Lenses

The study was approved by both the School of Optometry and Vision Sciences Research Ethics and Audit Committee at Cardiff University and The Research Ethics Committee at The University of Bradford and followed the tenets of the Declaration of Helsinki. Informed consent was obtained from all participants before enrolment in the study.

This was a prospective, single-masked (participant-masked), randomized, crossover study over two sites in England and Wales. Participants were asked to wear the Miru 1 Day Menicon Flat Pack Toric lens (Menicon) and either a 1-Day Acuvue Moist for Astigmatism lens (Johnson & Johnson) or a Dailies Aqua Comfort Plus Toric lens (Alcon), in both eyes for a period of three consecutive days. The control lens was selected at random, unless the participant habitually wore one of the control lens options—they were then assigned the other control lens. No participant habitually wore the test lens, ensuring that both study lenses were new to the participant. Wear order was randomized (determined by coin toss). A minimum 24-hr wash-out period, where no contact lenses were worn, was required before wearing each study lens.

Lens specifications for the lenses used in this study are summarized in Table 1. Contact lens packaging was over labeled to mask participants from the brands of each lens.

Participants were recruited using email lists and posters placed around Cardiff University and University of Bradford campuses, inviting anyone interested in participating to contact the study team directly. Where possible, notices were placed in locations to try and recruit from the wider community, in addition to the university populations. A participant information sheet was sent to those who were interested, inviting them to contact the study team again once they had read and understood the information. Potential participants were encouraged to ask any questions they may have, which were fully answered before recruitment to the study. If a potential participant chose to volunteer, written informed consent was provided before the commencement of any study tests.

Data collection occurred between February and August of 2021. Owing to the ongoing COVID-19 pandemic at the time, in person attendance was kept to a minimum; participants attended one appointment to assess the fit of both lenses and receive study instructions. All subsequent communication with participants took place remotely, unless symptoms were experienced which required further examination.

Study Procedure

The initial screening appointment was undertaken remotely, where a series of questions were asked to assess general and ocular health to ensure study eligibility. Participants were aged between 18 and 40 and did not have any systemic disease and/or medication known to affect visual performance. They were experienced soft contact lens wearers who wore contact lenses at least 5 days per week, and at least 8 hour per day. Participants had no history of significant ocular problems. Participants were asked to provide their most recent spectacle (within the past 2 years) and contact lens (within the past year) prescriptions. Participants' refractive errors were within the range +2.00DS to −6.00DS, with cylindrical component between −0.75DC and −1.75DC (axis 180°±25° or 90°) in each eye. Study lenses were selected in the nearest available prescription to the participant's habitual lenses and in accordance with the manufacturers' fitting guidance.

At the fitting appointment, distance visual acuity was confirmed as +0.10 logMAR or better in each eye, with a difference of ≤0.20 logMAR between right and left eyes. Ocular health was confirmed by slit lamp biomicroscopy and corneal topography before lens fitting. Participants then inserted a randomly selected pair of over labeled contact lenses (lens A). Participants were not given any instructions regarding the orientation of the lens on insertion. The fit of the lenses was assessed on the eyes using slit-lamp biomicroscopy and the simplified recording scheme to quantify aspects of lens fit.[20] The simplified recording scheme allows for quantification of the contact lens fit, with negative and positive integers ranging from −2 to +2, with 0 being the optimal lens fit, to describe lens position, movement on blink and the push up test. After these fitting measures were collected, lens orientation was measured 5 min after insertion and time to reorientation was assessed after manually rotating the lens 45° nasally and temporally in the right eye. Distance and near visual acuity were assessed after 10 min of wear. After these measures were collected, the lenses were removed and the same procedure was repeated for lens B.

TABLE 1. *Summary of Lens Specifications (Parameters Listed are Those Available at Commencement of Study)*

	Miru 1 Day Menicon Flat Pack Toric	Johnson & Johnson 1-Day Acuvue Moist for Astigmatism	Alcon Dailies Aqua Comfort Plus Toric
Material	Hioxifilcon A Hydrogel	Etafilcon A Hydrogel	Nelfilcon A Hydrogel
Water content (%)	57	58	69
UV absorber	None	Class 2	None
Center thickness (mm)	0.10	0.09	0.10
BOZR (mm)	8.6	8.5	8.8
TD (mm)	14.5	14.5	14.4
Power range (D)	S: +2.00 to −6.00 (0.25) −6.00 to −8.00 (0.50) C: −0.75, −1.25 A: 180±15 (15), 90 C: −1.75 A: 180	S: +4.00 to −6.00 (0.25) C: −0.75, −1.25, −1.75 A: 10 to 180 (10) C: 2.25 A: 180±20 (10), 90±20 (10) S: +0.25 to +4.00 (0.25) −6.50 to −9.00 (0.50) C: −0.75, −1.25, −1.75 A: 180±20 (10), 90±20 (10)	S: +4.00 to −6.00 (0.25) −6.50 to −9.00 (0.50) C: −0.75, −1.25, −1.75 A: 10 to 180 (10) S: Plano to −6.00 (0.25) C: −2.25 A: 180±20 (10), 90±20 (10) S: +4.00 to +0.25 (0.25) −6.50 to −8.00 (0.50) C: −2.25 A: 180±20 (10)
Orientation mark	Vertical circular markings at 6 o'clock	Vertical single line at 6 and 12 o'clock	Horizontal single line at 3 and 9 o'clock
Design	Biaspheric dynamic asymmetric stabilisation system	Back surface toric eyelid stabilised design	Toric back surface, dual thin zone design

S, sphere; C, cylinder; A, axis in relation to parameter availability.

If the fit of both lenses was deemed acceptable, participants were given three pairs of lens A and three pairs of lens B. If the fit of the control lens was deemed unacceptable, the fit of the other control lens was also assessed. If the fit of the test lens or the fit of both control lenses was deemed unacceptable, the participant was withdrawn from the study. Participants were instructed to wear lens A over three consecutive days, for at least 8 hr on each day, following their usual pattern of wear. If any nontolerance issues occurred, participants were advised to cease wear and contact a study investigator. Participants who habitually wore reusable contact lenses were advised not to store or reuse any of the study contact lenses.

At the end of the 3-day lens trial, participants completed a short questionnaire by Jisc online surveys (www.onlinesurveys.ac.uk), recording their experiences of comfort, quality of vision, and lens handling on a 10-point Likert scale, where 1 indicated the worst possible score and 10 indicated the best possible score, that is, the higher the score given for the question, the better the overall experience. Participants also recorded their wearing times, and at the end of each questionnaire, an optional, free text box was available for participants to add any comments that they wished to, about any aspect of the lens.

After a wash-out period of at least 24 hr, where no contact lenses were worn, participants were instructed to wear lens B following the same instructions. At the conclusion of the study, participants were asked to indicate their overall preference for lens A or B and state their preference for lens packaging. These questions had response options of "strongly prefer lens A," "prefer lens A," "prefer lens B," and "strongly prefer lens B."

After participants had submitted their answers regarding lens preference, they were asked four supplementary questions regarding their opinion of the environmental impact of contact lenses in general and of the study lenses in particular:

"In your opinion, the environmental impact of contact lens wear is"

Low Medium High

"In your opinion, what priority should contact lens manufacturers give for the environmental impact of their products?"

Low Medium High

"How important to you is the environmental impact of contact lens wear?"

Very Unimportant Not Important Important Very Important

"In your opinion, which of the lenses you trialed would have the smaller impact on the environment in terms of waste produced?"

Lens A Lens B

Environment-related questions were asked after submission of all other questionnaires to avoid biasing participant responses with other questions about lens packaging. For the same reason, participants were not made explicitly aware that their opinions of environmental impact were to be asked as part of this study in any of the communications. In contrast to previous questions, these responses were not associated with the participant's study ID and as such were anonymous. It was anticipated that this would encourage participants to be completely honest in their responses. Participants were advised of this before submitting their responses.

Participants received a token payment after completion of the study as compensation for their time.

Statistical Analysis

Data were analyzed with IBM SPSS Statistics v27. The Kolmogorov–Smirnov test indicated that all outcome measures were not normally distributed; thus, data were analyzed using the Wilcoxon signed-rank test. Significance was indicated by a P value less than 0.05. As participants only wore two lenses, one of which was the Miru 1 Day Menicon Flat Pack toric and the other was either a randomly determined Johnson & Johnson 1-Day Acuvue Moist for Astigmatism or the Alcon Dailies Aqua Comfort Plus Toric contact lens, data referring to the Miru 1 Day Menicon Flat

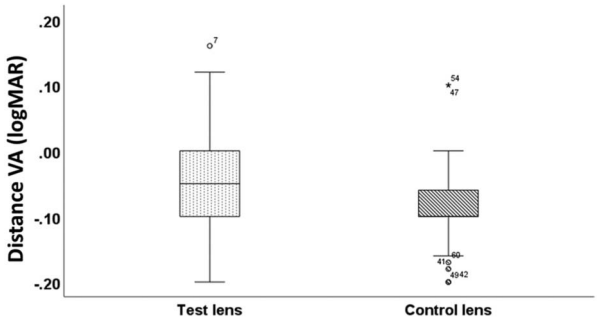

FIG. 1. Distribution of distance visual acuity for the test and control lenses. Open circles indicate outliers extending more than 1.5 box lengths, and asterisks indicate outliers extending more than three box lengths.

Pack Toric is referenced as the study's "test" lens, and the other lenses were combined for comparison and referred to as the study's "control" lens.

RESULTS

Forty participants (67% female) with a mean age of 25.8 years (±6.5 years) were enrolled and completed the study. Daily disposable contact lenses were habitually worn by 85% of participants, and the remaining six participants habitually wore monthly reusable soft contact lenses. These six participants were not outliers in the data, and their inclusion did not affect the statistical significance outcomes of any analyses.

The mean spherical refractive power of the participants was −2.43DS (±0.87DS), and the mean cylindrical power was −0.97DC (±0.31DC). Twenty-seven participants had with the rule astigmatism, and 13 participants had against the rule astigmatism. No participant was required to withdraw due to unacceptable contact lens fit, although one participant was refitted with the alternative control lens for this reason.

Objective Measures

Lens Fit and Vision

Clinical measures of lens fit (movement on blink, push-up test, and lens centration) were similar for the test and control lenses. Any differences were statistically insignificant, with identical median measures of all fit parameters. Distance visual acuity was better with the control lens compared with the test lens, with a median and interquartile range (IQR) logMAR acuity of −0.10 (−0.06, −0.10) versus −0.06 (0.00, −0.10) (P=0.037). This equates to a difference of approximately two logMAR letters (Fig. 1), so although this was statistically significant (P=0.037), it is clinically inconsequential.

Lens Orientation and Recovery

In 80% of test lenses and 95% of control lenses, the orientation mark was in a position 10° or less of their optimal position 5 minutes after insertion. For both lens types, the median recovery times were faster after nasal rotation compared with temporal rotation, with the fastest correction seen nasally for the test lens. However, the recovery times were not significantly different between the test and control contact lenses (Table 2).

Subjective Measures

Comfort and Wearing times

Wearing times for the two lens types were very similar, with a median wear time of 8.0 hr per day (Table 3). All subjective measures of comfort (overall comfort, comfort on insertion, end of day comfort, and eye fatigue) were higher for the test lens compared with the control lens. Overall comfort scores are shown in Figure 2. The magnitude of difference was greatest for the end of day comfort (median difference of 1.0); however, none of these differences achieved the statistical significance threshold. Within the free text comments at the end of the questionnaire, twice as many participants (eight vs. four) mentioned favorable comfort with the test lens compared with the control lens.

Visual Performance

All subjective measures of visual performance were higher for the control lens compared with the test lens (Table 4). These differences were all statistically significant, with the exception of night vision. Ten participants mentioned poor, unstable, or variable vision with the test lenses in the free text comments.

Lens Handling

Subjective measures regarding ease of insertion, ease of removal, ease of packaging use, and overall handling were similar between the test and the control lenses (Table 5). No differences were statistically significant. Five participants recorded positive comments about the test lens packaging, with no additional comments about the traditional blister packaging of the control lenses given.

Overall Satisfaction

Numerical values for the median overall satisfaction score with the different lens types were identical at 8.00 for the test and control lens, respectively (Fig. 3).

Correlations of Vision and Comfort Against Overall Satisfaction

Spearman rank correlation was performed for subjective scores of vision and comfort against overall satisfaction scores for each instance it was measured (Fig. 4). Both vision and comfort scores positively correlated with overall satisfaction, with r scores of 0.50

TABLE 2. *Recovery Time After Manual Rotation for the Test and Control Lenses Expressed as Median and IQR*

Recovery	Test Lens (sec)	Control Lens (sec)	P*
After 45° nasal rotation	60.00 (IQR 38.00–116.00)	88.00 (IQR 40.00–137.00)	0.252
After 45° temporal rotation	103.00 (IQR 53.00–167.00)	100.00 (IQR 49.00–190.00)	0.936

*Statistically significant result with the Wilcoxon signed-rank test.

IQR, interquartile range.

TABLE 3. *Wearing Time, Comfort, and Fatigue Scores for the Test and Control Lenses Expressed by Median and IQR*

Subjective Measures	Test Lens	Control Lens	*P**
Wearing time	8.00 (IQR 7.00–9.00)	8.00 (IQR 8.00–9.00)	0.939
Comfort on insertion	8.00 (IQR 7.00–9.00)	7.50 (IQR 6.00–8.25)	0.350
Comfort at end of day	8.00 (IQR 7.00–9.00)	7.00 (IQR 5.75–8.00)	0.070
Comfort (overall)	8.00 (IQR 7.00–9.00)	8.00 (IQR 6.00–8.00)	0.242
Eye fatigue	7.00 (IQR 4.00–9.00)	7.00 (IQR 5.00–8.00)	0.789

*Statistically significant result with the Wilcoxon signed-rank test.

IQR, interquartile range.

and 0.63, respectively. This suggests that, of the two scores, comfort was more strongly correlated with overall satisfaction.

Overall Lens and Packaging Preference

On completing the study, participants were asked to indicate their overall preference for the two trial lenses. Sixty percent (n=24) indicated that they preferred the test lens, with four of those participants indicating a strong preference. Furthermore, 70% of participants (n=28) indicated that they preferred the test lens packaging, with 17 of those participants indicating a strong preference.

Participant Attitudes to Environmental Impact of Contact Lenses

When asked their opinion on the environmental impact of contact lens wear, 95% of participants (n=38) reported they believed there was a medium (50%) or high (45%) environmental impact from daily contact lens wear. A similar proportion indicated lens manufacturers should give medium (52.5%) or high (45%) priority to environmental impact in their contact lens design. When asked which of the study lenses had the smaller impact on the environment for waste produced, all participants indicated the test lens for their answer.

DISCUSSION

In this study, we compared the performance of the Miru 1 Day Menicon Flat Pack Toric (hioxifilcon A, Menicon) contact lens against the 1-Day Acuvue Moist for Astigmatism (etafilcon A, Johnson & Johnson) and Dailies Aqua Comfort Plus Toric (nelfilcon A, Alcon) contact lenses. Overall, all three lenses performed to a similar standard, with a comparable level of overall satisfaction given for both the lenses after wear. As a novel assessment within peer-reviewed literature, questioning the importance participants placed on environmental impact revealed that this should be a high priority among contact lens manufacturers.

Although distance visual acuity was significantly better with the control lens compared with the test lens, the magnitude of the difference (2 letters on the logMAR chart) suggests that this is not clinically meaningful. However, given that subjective quality of vision was better with the control lens compared with the test lens, and that these differences between the lenses were often statistically significant, it may be that high contrast distance visual acuity is not the best clinical measure when evaluating vision with contact lenses. Other studies have suggested considering subjective visual quality with more weight than objective measures of visual acuity for this reason,[21] as the subjective visual loss appears greater than any high contrast visual acuity loss found. Interestingly, this difference in vision quality was not sufficient to influence participants' overall lens choice, with similar overall satisfaction scores, and an overall preference for the test lens.

Blink dynamics and lens-lid interaction are reportedly the most influential factors in determining toric lens stability.[22] Although the toric stabilization design differs between the lenses used in this study, there was remarkably little difference in the fitting characteristics. Lens orientation recovery after a 45° nasal displacement was quicker for all lenses compared with the temporal displacement. This may reflect altered blink dynamics and lens lid interaction between the two displacement directions.[23] It is worth noting that the BCLA CLEAR report on evidence-based practice recommends that soft toric lens rotational stability should be assessed 10 min after lens insertion to provide adequate time for the lens to settle.[24] This was not published at the time of study commencement, and therefore, this recommendation was not followed. However, the results for all lenses used in this study suggest that these lenses generally stabilized within the 5 min. This result may be different with silicone hydrogel lens materials, which have a higher lens modulus than the hydrogel lens materials used in this study.

Although differences did not reach statistical significance, all subjective measures of lens comfort were higher with the test lens when compared with the control lens. Although several different lens properties are likely to influence comfort, very few clinical assessment properties have been found to reliably predict discomfort in the published literature.[25] This limits the ability to make direct comparisons between lenses, as these confounding factors are inseparable. It is likely that the factors influencing comfort for each lens in this study are multifactorial, and can include edge profile differences influencing fitting characteristics,[26] material differences, and differences in stabilization design and thickness profiles[27] and identifying the most influential feature is beyond the scope of this study. Nevertheless, it is worth noting that the flattening of the contact lens due to the packaging design did not seem to negatively affect subjective comfort or average fitting on initial fit assessment.

Although superior comfort was suggested with the test lens, superior visual performance was indicated with the control lens. As already noted, scores of overall satisfaction were remarkably similar for the test and control lenses. Interestingly, comfort

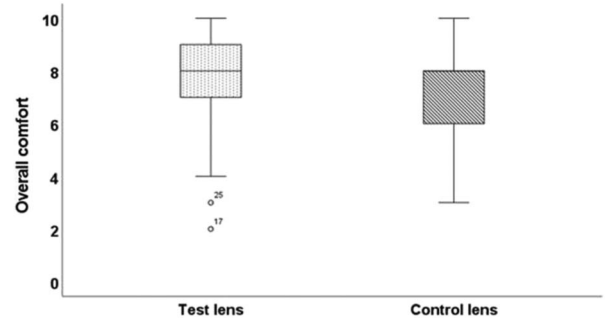

FIG. 2. Distribution of overall comfort scores of the test and control lenses. Open circles indicate outliers extending more than 1.5 box lengths.

TABLE 4. *Subjective Likert Scores Expressed With Median and IQR of the Visual Performance of the Test and Control Lenses*

Subjective Measures	Test Lens	Control Lens	P*
Vision (overall)	7.00 (IQR 5.00–9.00)	9.00 (IQR 7.00–9.00)	**0.002**
Distance vision	8.00 (IQR 6.00–9.00)	8.50 (IQR 8.00–9.00)	**0.011**
Near vision	8.00 (IQR 6.00–9.00)	9.00 (IQR 8.00–10.00)	**0.010**
Night vision	8.00 (IQR 6.00–9.00)	8.00 (IQR 7.00–9.00)	0.227
Stability of vision	7.00 (IQR 5.00–8.00)	8.00 (IQR 6.00–9.00)	**0.008**

*Statistically significant result ($P < 0.05$) with the Wilcoxon signed-rank test.

IQR, interquartile range.

presented with a stronger correlation to overall satisfaction than visual quality (Fig. 4). This has also been seen in data from Guthrie et al.,[21] where the correlation of comfort and overall satisfaction was higher than that of subjective vision and supports data suggesting that comfort is the primary reason for contact lens drop out.[10] This may partly explain why 60% of participants selected the test lens as their lens of choice when asked for their preference. It should be noted, however, that overall satisfaction is a multifactorial measure that takes into account visual performance, comfort, and lens handling. Further research exploring the relationships between vision and comfort in toric contact lens designs would help explore this relationship in greater detail.

Ease of insertion and removal showed a slight preference for the test lens compared with the control lens, although this was not statistically significant. Interestingly, although the ease of packaging scored slightly higher with the control lens, 70% of participants indicated that they preferred the flat pack packaging when asked to make a direct comparison. This preference may reflect the lower effort required to open the foil blister and/or the need to touch only the back surface of the test lens to remove it from the packaging.[28] Free text comments from participants that favored the flat pack stated that their preference was due to more convenient packaging, less mess (presumably due to the reduced volume of saline), and reduced waste.

This study indicated that patients see environmental impact of contact lens wear as a high priority, with 95% of participants believing that daily contact lens wear has a moderate or high environmental impact. This is an interesting observation, as studies have previously indicated that the environmental impact of contact lens wear is comparatively small.[12] Participants were habitual contact lens wearers with different prior experiences, lenses worn, and different wearing patterns, in two different cities. These responses may indicate a distortion in the perception of environmental impact, and/or a lack of awareness of the recycling and plastic-neutral initiatives established by contact lens manufacturers,[17–19] suggesting that more needs to be done to promote these. Given that 39 of 40 participants indicated that manufacturers should consider the environmental impact of their products to be a medium or high priority, it is likely that they would approve of these activities and encourage further initiatives. Therefore, it is important that patients and practitioners are both made more aware of, and encouraged to take part in, available contact lens recycling schemes, as not all contact lens materials or packaging can be recycled in typical domestic recycling collections.[16] Current schemes likely do not address some of the less conspicuous environmental detriments associated with contact lenses, such as the impact of shipping lenses with bulkier and/or heavier packaging. It may be more effective to reduce the amount of material used and transported, compared with recycling the materials once used. Of additional note is the importance of perception. This study indicates that contact lens wearers may overestimate the environmental impact of contact lenses. As such, the perceived lower environmental impact of some contact lenses and/or manufacturers in comparison with others may influence consumer choice, irrespective of the true environmental impact.

There are a number of strengths and limitations associated with this study. The randomization and masking of the lenses provided to the patient and the completion of questionnaires without the presence of the researchers may be considered as strengths. Although this decision was related to the COVID-19 pandemic, participants may be less inclined to feel pressure to respond with any particular answers. Recruiting over two separate sites with different demographics also allowed the study to capture the opinions of a greater range of contact lens wearers within the United Kingdom, providing a more representative sample.

Limitations of this study include the single in-person appointment, due to the need to minimize in-person contact. This meant that assessment of contact lens fit was limited to a single day, with no opportunity to evaluate lens fit and condition after significant wear time. It is possible that surface wettability issues and/or deposition were not captured as a result. In addition, although attempts were made to mask participants to the contact lens names and brands by over labeling, it should be acknowledged that this does not always guarantee full masking. It could have been possible for participants to identify the lenses if they made the effort to peel away the over labeling tape. Care was taken to ensure

TABLE 5. *Subjective Likert Scores of Lens Handling of the Test and Control Lenses Expressed as Median and IQR*

Subjective Measures	Test Lens	Control Lens	P*
Overall handling	9.00 (IQR 7.00–10.00)	9.00 (IQR 8.00–10.00)	0.733
Ease of insertion	9.00 (IQR 8.00–10.00)	9.00 (IQR 7.75–10.00)	0.413
Ease of removal	10.00 (IQR 8.00–10.00)	9.00 (IQR 7.75–10.00)	0.507
Ease of packaging use	10.00 (IQR 8.00–10.00)	9.00 (IQR 8.00–10.00)	0.693

*Statistically significant result with the Wilcoxon signed-rank test.

IQR, interquartile range.

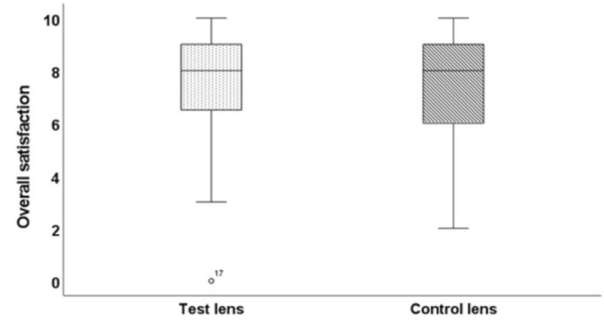

FIG. 3. Distribution of overall satisfaction Likert scores for the test and control lenses. Open circles indicate outliers extending more than 1.5 box lengths.

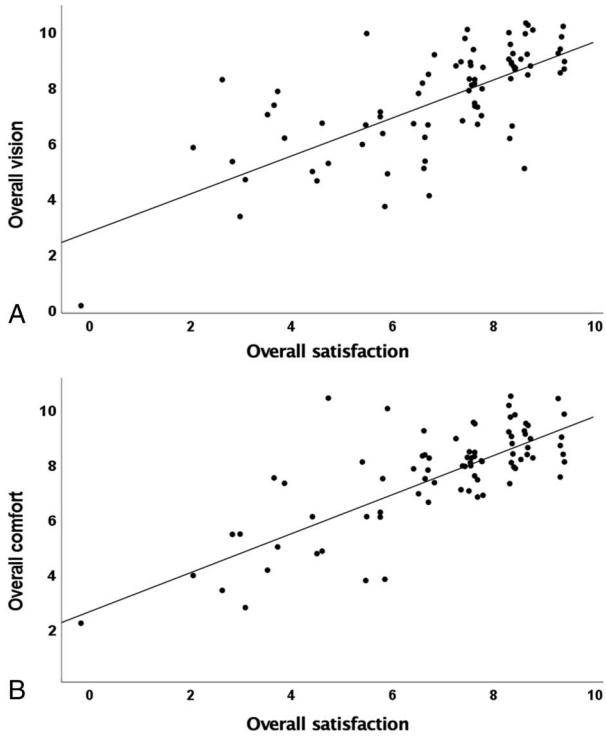

FIG. 4. Correlation of subjective vision and comfort scores against overall satisfaction. (a) The correlation between overall vision and overall satisfaction scores. (b) The correlation between overall comfort and overall satisfaction scores. To avoid overlapping data points, random jitter was applied to each of the data points in both x and y directions (80 observations in total).

that overlabels were difficult to remove, and there would have been minimal incentive for the participants to attempt this as any participants interested in the brands trialed were advised they would be unmasked at the end of the study after collecting their responses. Nevertheless, previous studies have found that participants can identify contact lenses by their packaging, even where over labeling has been used.[29]

To mitigate potential bias from answers to the supplementary questions relating to environmental aspects, participants were advised that their responses would be completely anonymous. Nevertheless, the phrasing of the questions or optional answers may have predisposed participants' answer choices. Further investigation into contact lens wearers' expectations regarding production of contact lenses and manufacturers' environmental responsibilities would be beneficial.

Participants were primarily those without significant contact lens symptoms, for example, severe dry eye. Asymptomatic contact lens wearers are less likely to experience changes in lens comfort throughout the day, whereas symptomatic contact lens wearers are more likely to experience a decline in their comfort.[30] The aim of this study was to evaluate lens performance in a typical, healthy cohort of contact lens wearers. Further investigation, with the inclusion of more symptomatic contact lens wearers, is recommended and may reveal subtle differences in comfort between lenses that the current study was unable to identify. Moreover, it may have been beneficial for participants to trial all three contact lenses, rather than only one control.

To the best of the authors' knowledge, this is the first study that has investigated the environmental attitudes of participants wearing contact lenses. It is likely that our demographic of younger contact lens wearers has influenced these findings, as environmental concern seems to be more common in younger individuals.[31] However, the average age of contact lens wearers globally is 31 years old,[3] which is within our inclusion criteria and within one SD of mean age. Therefore, it is likely that the opinions observed here regarding the importance of environmental impact in contact lens wear will intensify in the future. Going forward, it may be beneficial to further examine contact lens wearers' opinions of the environmental burden of contact lens wear and how this influences their preferred choice of lens. Increasing awareness of manufacturer initiatives to reduce the environmental burden of contact lens wear is recommended.

In conclusion, fitting characteristics were similar between the Miru 1 Day Menicon Flat Pack Toric lens and the control lens. Although visual performance appeared reduced, there was a trend of improved comfort with this lens, particularly for end of day comfort. This suggests that the flattening of the contact lens due to the flat pack packaging does not negatively affect lens comfort. Most participants indicated a preference for this lens, suggesting that visual performance was not the most influential factor in this decision. Overall satisfaction is a multifaceted measure of several factors, including vision, lens handling, and comfort, and further research on satisfaction in toric contact lenses would help the understanding of the relationship between these variables.

Almost all participants indicated that the environmental impact of contact lenses is of importance and that manufacturers should be concerned about the environmental impact of their products. Practitioners should be mindful of patients' attitudes to the environmental impact of daily contact lens wear and the importance they place on this, as environmental impact may be a contributing factor in patients' lens choice.

ACKNOWLEDGMENTS

The authors thank the participants that took part in this study.

REFERENCES

1. Hashemi H, Fotouhi A, Yekta A, et al. Global and regional estimates of prevalence of refractive errors: Systematic review and meta-analysis. *J Curr Ophthalmol* 2018;30:3–22.
2. Young G, Sulley A, Hunt C. Prevalence of astigmatism in relation to soft contact lens fitting. *Eye Contact Lens* 2011;37:20–25.
3. Morgan PB, Efron N. Global contact lens prescribing 2000-2020. *Clin Exp Optom* 2022;105:298–312.
4. Morgan PB, Efron N. Quarter of a century of contact lens prescribing trends in the United Kingdom (1996-2020). *Cont Lens Anterior Eye* 2022;45:101446.
5. Berntsen DA, Cox SM, Bickle KM, et al. A randomized trial to evaluate the effect of toric versus spherical contact lenses on vision and eyestrain. *Eye Contact Lens* 2019;45:28–33.
6. Cho P, Cheung SW, Charm J. Visual outcome of soflens daily disposable and soflens daily disposable for astigmatism in subjects with low astigmatism. *Clin Exp Optom* 2012;95:43–47.
7. Morgan PB, Efron SE, Efron N, et al. Inefficacy of aspheric soft contact lenses for the correction of low levels of astigmatism. *Optom Vis Sci* 2005; 82:823–828.
8. Logan AKM, Datta A, Skidmore K, et al. Randomized clinical trial of near visual performance with digital devices using spherical and toric contact lenses. *Optom Vis Sci* 2020;97:518–525.
9. Dumbleton K, Woods CA, Jones LW, et al. The impact of contemporary contact lenses on contact lens discontinuation. *Eye Contact Lens* 2013;39: 93–99.

10. Sulley A, Young G, Hunt C. Factors in the success of new contact lens wearers. *Cont Lens Anterior Eye* 2017;40:15–24.
11. Maldonado-Codina C, Navascues Cornago M, Read ML, et al. The association of comfort and vision in soft toric contact lens wear. *Cont Lens Anterior Eye* 2021;44:101387.
12. Morgan SL, Morgan PB, Efron N. Environmental impact of three replacement modalities of soft contact lens wear. *Cont Lens Anterior Eye* 2003;26: 43–46.
13. Efron SE, Efron N, Morgan PB, et al. A theoretical model for comparing UK costs of contact lens replacement modalities. *Cont Lens Anterior Eye* 2012;35:28–34.
14. Efron N, Efron SE, Morgan PB, et al. A 'cost-per-wear' model based on contact lens replacement frequency. *Clin Exp Optom* 2010;93:253–260.
15. Yeung KK, Davis R. The environmental impact of contact lens waste. *Cont Lens Spectr* 2019;34:27–30.
16. Smith SL, Orsborn GN, Sulley A, et al. An investigation into disposal and recycling options for daily disposable and monthly replacement soft contact lens modalities. *Cont Lens Anterior Eye* 2022;45:101435.
17. Terracycle. *Bausch + Lomb Launches National ONE by ONE Contact Lens Recycling Program*. NJ: Terracycle, 2016. Available at: https://s3.amazonaws.com/tc-global-prod/download_resource/us/downloads/3086/Bausch___Lomb_2016_Launch_Release.pdf. Accessed July 20, 2022.
18. Opticians B. *Boots Opticians Partners with ACUVUE® and TerraCycle® to Launch UK's First Contact Lenses Recycling Programme*. London, United Kingdom: Boots, 2019. Available at: https://www.boots-uk.com/newsroom/features/boots-opticians-partners-with-acuvue-and-terracycle-to-launch-uk-s-first-contact-lenses-recycling-programme/. Accessed July 20, 2022.
19. Optometrists Ao. *CooperVision Forms Plastic Neutral Partnership*. London, United Kingdom: Association of Optometrists, 2022. Available at: https://www.aop.org.uk/ot/industry/contact-lenses/2022/01/21/coopervision-forms-plastic-neutral-partnership. Accessed July 16, 2022.
20. Wolffsohn JS, Hunt OA, Basra AK. Simplified recording of soft contact lens fit. *Cont Lens Anterior Eye* 2009;32:37–42.
21. Guthrie S, Ng A, Woods J, et al. Exploring the factors which impact overall satisfaction with single vision contact lenses. *Cont Lens Anterior Eye* 2022; 45:101579.
22. Jurkus JM, Furman DW, Colip MK. Stability characteristics of toric soft lenses. *Int Contact Lens Clin* 1993;20:65–68.
23. Castellano CF, Myers RI, Becherer PD, et al. Rotational characteristics and stability of soft toric lenses. *J Am Optom Assoc* 1990;61:167–170.
24. Wolffsohn JS, Dumbleton K, Huntjens B, et al. BCLA CLEAR-evidence-based contact lens practice. *Cont Lens Anterior Eye* 2021;44:368–397.
25. Jones L, Brennan NA, González-Méijome J, et al. The TFOS international Workshop on Contact Lens Discomfort: Report of the contact lens materials, design, and care subcommittee. *Invest Ophthalmol Vis Sci* 2013;54: TFOS37–TFOS70.
26. Wolffsohn JS, Drew T, Dhallu S, et al. Impact of soft contact lens edge design and midperipheral lens shape on the epithelium and its indentation with lens mobility. *Invest Opthalmol Vis Sci* 2013;54:6190–6196.
27. Stapleton F, Bakkar M, Carnt N, et al. BCLA CLEAR-contact lens complications. *Cont Lens Anterior Eye* 2021;44:330–367.
28. Tan J, Siddireddy JS, Wong K, et al. Factors affecting microbial contamination on the back surface of worn soft contact lenses. *Optom Vis Sci* 2021;98: 512–517.
29. Keir N, Luensmann D, Woods CA, et al. Effect of masking on subjective responses to daily disposable contact lenses. *Optom Vis Sci* 2016;93:828–835.
30. Woods CA, Bentley SA, Fonn D. Temporal changes in contact lens comfort over a day of wear. *Ophthalmic Physiol Opt* 2016;36:643–648.
31. Reinhart RJ. *Global Warming Age Gap: Younger Americans Most Worried*. Washington, DC: Gallup News, 2018. Available at: https://news.gallup.com/poll/234314/global-warming-age-gap-younger-americans-worried.aspx. Accessed July 21, 2022.