ARTICLE IN PRESS

Contact Lens and Anterior Eye xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Contact Lens and Anterior Eye

journal homepage: www.elsevier.com/locate/clae

Temporal considerations in contact lens discomfort

Eric B. Papas*, Annie Chiem, George Zhang, Rabia Mobeen, Ling Lee

School of Optometry & Vision Science, University of New South Wales, Sydney, Australia

ARTICLE INFO

Keywords:
Contact Lens
Discomfort
Remote data capture
Contact time
Wear start time
Visual analogue scale

ABSTRACT

Purpose: To determine the relative contributions to perceived discomfort during contact lens wear of contact time with the lens and the time of day at which wear begins, using a wearing framework similar to that of regular users.

Methods: Twenty-three participants reported ocular discomfort using a 1–100 visual analogue rating scale, when prompted by email, during one day without contact lenses and on three other days while wearing soft contact lenses for twelve hours. Contact lens wear began at a different time on each day. The effect of start time on the change in discomfort during the wearing period was evaluated.

Results: The average (± 95 % CI) change in discomfort over 12 h without contact lenses was -0.3 ± 3.5. The corresponding values during contact lens wear were 23.5 ± 14.6 when starting wear before 8am, 16.8 ± 11.0 when starting between 8am & 10am and 22.7 ± 8.4 when starting after 10am. While the increased discomfort was significant irrespective of start time ($p < 0.01$), there were no statistically significant differences between start times ($p = 0.98$).

Conclusion: Discomfort during contact lens wear is associated with the length of time lenses are on-eye but not with the time of day when lenses are placed on-eye. This relationship is variable in the population and does not, of itself, explain why contact lenses become uncomfortable during wear. Active monitoring of participant compliance should be a consideration in all studies involving time critical responses.

1. Introduction

Discomfort associated with soft contact lenses has long been recognized as a hindrance to successful wear. [1] The significance of the problem historically, is indicated by a survey reporting that almost one in four wearers drop out of wear at some point, with discomfort being the main cause [2]. Not only is this an obvious detriment for individual wearers, but discomfort related drop-outs have also been blamed for the more general malaise of stagnation in global contact lens markets [3,4].

Whether this view continues to be a reasonable one is unclear. The supporting information is over ten years old and there has been a lack of relevant studies in the meantime. In addition, recent work has shown that excellent levels of comfort are available from several modern, daily-disposable lenses [5] and it has been observed that year-on-year revenues for contact lenses and related products are currently growing again [6]. Has the problem of discomfort then been solved?

This seems unlikely on the evidence provided by a recent UK poll which suggested that 50 % of practitioners still report discomfort to be an issue for at least a quarter of their contact lens wearers. [7]. So far as the turn-around in commercial markets is concerned, there are probably several influential factors and it is noteworthy that considerable time and effort continues to be directed towards finding effective discomfort treatments [8–13]. Taken together, all these elements indicate that discomfort remains a significant complication of contact lens wear and therefore, the need to understand the phenomenon persists.

Among the more lightly studied aspects of the discomfort cascade is the influence that temporal aspects of wear have on the subjective experience. Only two studies have looked at this question previously and their conflicting results have created a small controversy concerning the relative importance of, time in the lens vs the time of day when lenses are worn. While in one report, contact time emerged as the dominant factor, [14] the other suggested that both time of day and the period when lenses are in the eyes are relevant. [15] Scrutiny of these experiments shows that, in both cases, the chosen study designs were rather artificial, in terms of replicating a normal lens wearing scenario and this may be the reason for their conflicting outcomes.

The current study was conceived as an attempt to resolve this problem. Its aim was to determine the relative contributions to perceived discomfort of, contact time with the lens and time of day but using a wearing framework similar to that of regular contact lens user. Experimentally, this involved having participants wear lenses continuously, for 12 h, on consecutive days but starting at different times

* Corresponding author at: School of Optometry & Vision Science, L3 Rupert Myers Building, UNSW, Kensington, NSW, 2052, Australia.
E-mail address: e.papas@unsw.edu.au (E.B. Papas).

https://doi.org/10.1016/j.clae.2020.08.007
Received 19 June 2020; Received in revised form 11 August 2020; Accepted 15 August 2020

Please cite this article as: Eric B. Papas, et al., Contact Lens and Anterior Eye, https://doi.org/10.1016/j.clae.2020.08.007

each day.

2. Methods

Procedures were conducted in accordance with the Declaration of Helsinki and approved by the Human Research Ethics Advisory Panel at the University of New South Wales. All participants gave written informed consent prior to enrolment.

The study was conducted as a four-phase, open-label, cross-over design.

To be eligible for inclusion, potential participants had to be:

- Aged 18–40 years
- Healthy individuals with no significant, pre-existing ocular or medical issues
- Either current soft contact lens wearers, or previous soft contact lens wearers who had discontinued wear due to discomfort symptoms
- Willing to wear spectacles (if needed) on non-contact lens days
- Able to meet the driving standard for vision (6/12), with spectacles or contact lenses

The following exclusion criteria were also applied:

- Significant pre-existing ocular conditions that would prevent contact lens wear, e.g. Sjögren's Syndrome, severe dry eye disease, current ocular infections, including microbial keratitis or recurrent corneal erosion.
- Rigid contact lens wearers
- Astigmatism > 0.99DC
- Neophytes to contact lens wear

After satisfying the requirements for enrolment, participants completed each of the following phases on a separate day, in random order:

- Phase A: (Control) No lenses, i.e. spectacle wear
- Phase B: Contact lens wear from 7am – 7pm
- Phase C: Contact lens wear from 9am – 9pm
- Phase D: Contact lens wear from 11am – 11pm

All participants wore the same type of contact lens (1-Day ACUVUE® MOIST®, Johnson & Johnson Vision Care), appropriate fitting and back vertex power having been determined during a preliminary visit. A fresh pair of lenses was used for each phase (B–D) and participants were instructed to refrain from using any eye drops during wear.

At regular intervals on each day, as shown in Table 1, participants received an SMS text message containing a link to a short questionnaire which used branched logic to verify that they were compliant with the lens wear modality relevant to the study phase, before presenting a 1–100 visual analogue scale on which to indicate the current level of ocular discomfort. The anchors of the scale were 1 = No discomfort, 100 = Extreme discomfort, Intolerable. To allow time for lens insertion, the first message of the day was sent 10 min ahead of the scheduled start time.

Measurements time points were arranged to occur at 4 -h intervals from lens insertion (Start Time) with an additional event added, at 19:00 in phase C, to ensure there was a common time point in all phases. For the non-wearing phase (A), it was necessary to cover the whole period of lens wearing, so measurements began at 07:00 and were repeated every two hours until 23:00.

Participant responses, together with an associated timestamp, were collected and managed using REDCap electronic data capture tools [16,17] hosted at the University of New South Wales.

Based on detecting a difference in discomfort of 7 points [18] with a standard deviation of 18 points [19], at the 95 % confidence level and 80 % power, a sample size of about 18 participants was required to complete all four phases of the study.

Table 1
Lens assignments and discomfort measurement timepoints.

Study Phase	Start Time	Lens Wear (Y/N)	Measurement Time Points
A	07:00	N	07:00, 11:00, 13:00, 15:00, 17:00, 19:00, 21:00, 23:00
B	07:00	Y	07:00, 11:00, 15:00, 19:00
C	09:00	Y	09:00, 13:00, 17:00, 19:00, 21:00
D	11:00	Y	11:00, 15:00, 19:00, 23:00

3. Data analysis

Prior to analysis, standard checks indicated that one subject had incorrectly interpreted the VAS scale and their data were removed. It was also noted that significant variance between the design timepoint (i.e. start time and/or measurement time) and the actual timestamp recorded with each event, often occurred, as can be seen from Fig. 1.

One advantage of electronic data collection methods is that they permit instances of non-compliance to be more easily identified [20] and in this case, deviations were sufficiently common to prompt a re-evaluation of the approach to data analysis. While the original intention had been to conduct repeated measures analysis of variance with Start time and Measurement time as within-subject factors, it was evident that these factor levels were not well enough defined in reality, to permit that approach. Consequently, two alternative treatments were applied.

In the first, timestamp data were used to re-classify lens wear according to the recorded start time, into three groups, i.e. Before 8am, Between 8am and 10am and Between 10am and 12 pm. Further, only participants providing a full 12 (± 1) hours wear in all three categories were included, to permit an analysis of variance with repeated measures. This gave a reasonable approximation to the original plan but was wasteful of data, as only ten participants were fully compliant with the stated criteria. Hence, a second approach attempted a more complete use of data by considering Recorded Start Time and Contact Time[1] to be continuous variables in a linear mixed model. For both analyses, the initial choice of Discomfort as the dependent variable proved to be unacceptable, due to the non-normality caused by the high number of unit scores (i.e. No discomfort), recorded during the study. As an alternative, the change in discomfort over 12 h (Discomfort change) was calculated and as this proved to be normally distributed (p = 0.2, Kolmogorov- Smirnov) it was taken as the dependent variable in both cases. This manipulation also removed Contact Time from the model. All analyses were conducted using IBM SPSS v.26 at the 95 % level of confidence.

4. Results

Twenty-two participants, with a mean age of 22.0 (range 18–27) years, provided data for the analysis. Fifteen were female and seven male. Twenty were current lens wearers and two had previously worn lenses but were not regularly doing so at the time of enrolment.

4.1. No Lens

Fig. 2 shows how discomfort evolved during the day during the phase when lenses were not worn. Considerable variation is evident across a response that ranged between scores of -24 and 37, but there

[1] Contact Time = Recorded Measurement Time – Recorded Start Time. Time units are Decimal days, where 24 hours = 1.0, 12 hours = 0.5 and 1 hour = 0.0417 etc.

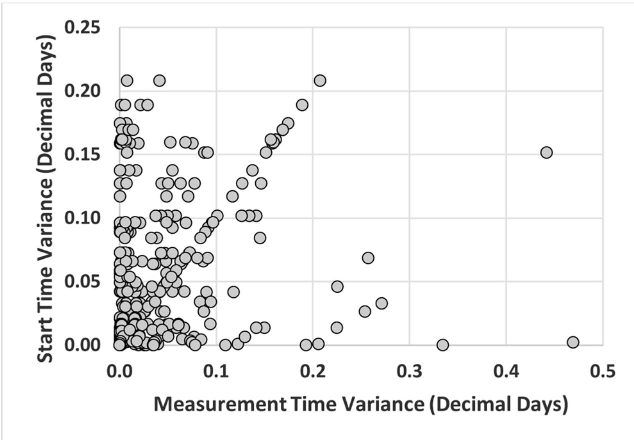

Fig. 1. Temporal variance from designed start and measurement points, for all participants and phases. Units are Decimal days (24 h = 1.0 day).

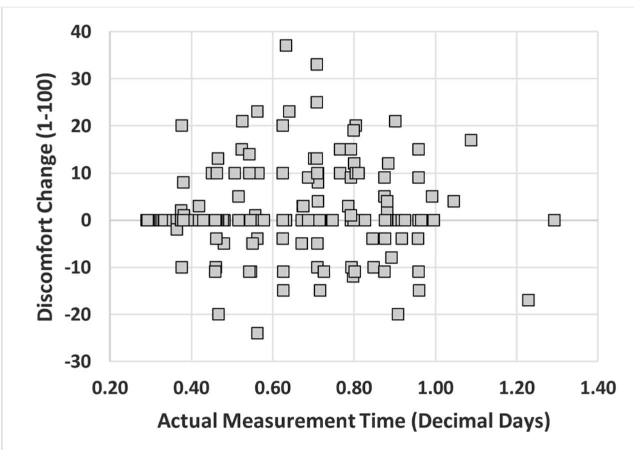

Fig. 2. No lens, change in discomfort (1-100) relative to start time, during the day. Positive values indicate increased discomfort. Actual Measurement Times > 1.0 day correspond to participants responding after midnight on the day of the study.

appears to be no clear pattern. Discomfort change did not correlate significantly with measurement time ($R^2 = 0.0003$). After 12 h (0.5 days), the mean Discomfort change score (± 95 %CI) was -0.3 ± 3.5.

4.2. Lens wear - compliant data

As mentioned above, only ten participants were considered to have fully complied with the original study design. For these individuals, Discomfort change over 12 h of lens wear is summarized in Table 2. While for each start time, the increases in discomfort over 12 h were significant ($p < 0.02$), repeated measures analysis of variance did not show a significant difference between start times (Df = 2, F = 0.42, Partial Eta^2 = 0.04, p = 0.67).

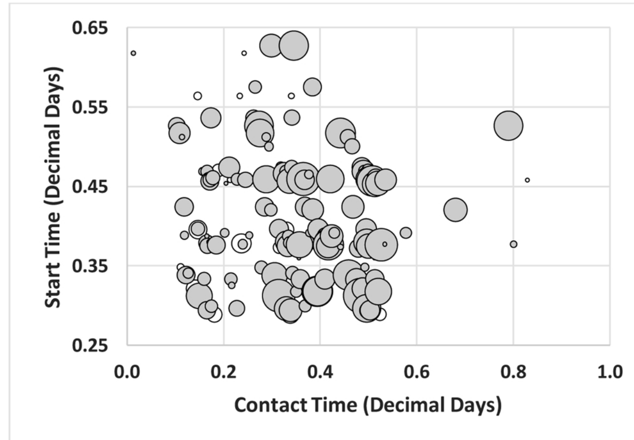

Fig. 3. Bubble plot showing change in discomfort (1-100) during lens wear, as a function of Recorded Start Time and Contact Time. Bubble area is proportional to the magnitude of discomfort change. Filled circles indicate increased discomfort, unfilled circles indicate decreased discomfort.

4.3. Lens wear - all data

In an effort to show graphically how discomfort evolved during the days of lens wear,

Fig. 3 plots the actual wear start time against contact time with the lens. The associated change in discomfort, relative to the start time, is indicated by the area of the bubble at each location. All available data are included in this plot and on visual inspection, it is difficult to discern any clear pattern in either the Y (Start time) or X (Contact time) directions.

However from Table 3, which summarises the Discomfort change over 12 h of lens wear, it can be seen that increases in discomfort relative to the start of wear were significant ($p < 0.01$) but the linear mixed model indicated that the effect of Recorded Start Time was not significant (Df = 52, t = 0.031, p = 0.98).

Overall, the average rate of discomfort increase was 2.0 ± 0.7 units per hour.

5. Discussion

The study outcomes support the view that, during lens wear, contact time has a greater influence on discomfort than the time at which lenses are inserted. This is evident from Table 2 and Table 3, which indicate that the rate of Discomfort increase over 12 h did not differ across the starting times. In other words, discomfort increased at roughly the same rate, whatever time lenses were placed on-eye. The strength of response

Table 2
Group mean Discomfort change (1-100) over 12 h of contact lens wear beginning at various times, including only fully compliant participants, providing data at all time points. Positive values indicate increased discomfort.

	Recorded Start Time		
	Before 8am	8am to 10am	10am to 12 pm
Mean	19.4	23.8	20.5
95 % CI	13.8	18.3	14.3
Min	−10	−21	−4
Max	50	68	60
n	10	10	10
p	0.67		

Table 3
Group mean Discomfort change (1-100) over 12 h of contact lens wear beginning at various times for all participants. Positive values indicate increased discomfort.

	Recorded Start Time		
	Before 8am	8am to 10am	After 10am
Mean	23.5	16.8	22.7
95 % CI	14.6	11.0	8.4
Min	−10	−21	−4
Max	78	68	60
n	13	20	21
p	0.98		

varied between participants, as shown by the large range in Table 3. This probably reflects the existence of both symptomatic and asymptomatic individuals in the sample, as is typical of the contact lens wearing population in general. [19] While the possibility exists that a sample consisting of only symptomatic individuals would produce a different outcome, there was no evidence for this in the current cohort. Start Time remained a non-significant factor even after removing from the analysis those whose discomfort did not increase during wear (Df = 43, t = 0.0, p = 1.0).

While this result is consistent with an earlier study using a similar design but with shorter wear periods (four hours) [14], it is at odds with other work that had a more complex structure. [15]. This second study, which involved interrupting wear, for varying periods, at different times during the day, concluded that contact time and time of day influenced the discomfort response. It has already been observed that regular contact lens wearers would not recognize either of these previous paradigms as a reasonable way to wear lenses and it was a specific aim of the current work to avoid this artificiality by having participants follow a continuous, 12 -h, wearing schedule. This approach replicated the normal experience of most wearers and gives confidence that the results can be generalized to the real world.

In terms of practical application, the data are consistent with the suggestion that wearers whose discomfort increases to an intolerable level at some point, can chose when to begin wear on any given day. Doing this means that the period of comfortable wear can be moved back and forth to coincide with whatever activities are most important for the individual.

There were, of course, deviations from the intended study protocol. That participants often did not follow their designated wearing schedule was pointed out earlier and perhaps it is not so surprising that individual lifestyles affected compliance, given that the study cohort were all university students. It was an option, during set-up, to limit the time-window for responses, so that only those falling within a pre-determined tolerance would have been accepted. On the evidence of Fig. 1 however, this enforced compliance would have come at the expense of considerable data loss. Analysis would then have been limited to a small subset of participants, fewer in number than intended and with an accompanying reduction in power. With hindsight, it appears that not curtailing responses, but taking note of the timestamp information and associating it with the key variables, was a preferable approach for two main reasons. First, it alerted researchers to the fact of deviations from the intended design. Without this insight, the precise temporal positions of events which in reality are unknown, would have been assumed to be accurate. Subsequent data analysis would then be conducted under a set of erroneous or flawed assumptions, leading to potentially incorrect interpretation and misleading conclusions. This leads logically to the second advantage which is that knowing the exact time of response permits remedial action to be taken during the analytical phase.

In the present case, two alternative approaches to achieving an accurate analysis were used and encouragingly, both delivered the same result; giving confidence that the interpretation of the available data as presented is a reasonable one. While it is possible that the power of either, or both, of these treatments was reduced compared to the intended analysis, the observed treatment effect for time of day (Partial $Eta^2 = 0.04$), was small enough to render misinterpretation of the outcomes unlikely.

Nevertheless, while contact time emerges as the dominant temporal factor in the development of discomfort, it should not be thought of as an independent entity. Discomfort is the manifestation of an interaction between the ocular surface/eyelid/tear film and at least one feature of the contact lens. In general, lengthening contact time prolongs this interaction, with the consequence that discomfort increases. [21] It is the rate of this increase that is the important issue for wearers and clinicians however and obviously, the lower this is, the better. What determines the rate is the mechano-biology at the interface between the lens and the ocular environment. It remains critical to understand the specific details of this interaction so that ways to eliminate, or reduce, the potency of activity at the interface can be developed. Success in that direction will reduce the slope of the discomfort increase curve and diminish the importance of contact time.

6. Conclusion

Discomfort during contact lens wear is associated with the length of time lenses are on-eye but not with the time of day when lenses are placed on-eye. This relationship is variable in the population and does not, of itself, explain why contact lenses become uncomfortable during wear. Active monitoring of participant compliance should be a consideration in all studies involving time critical responses.

References

[1] C.W. McMonnies, A. Ho, Marginal dry eye diagnosis: history versus biomicroscopy, in: F.J. Holly (Ed.), The preocular tear film in health, disease and contact lens wear, Dry Eye Institute, Lubbock, Tx, 1986, pp. 32–40.
[2] K. Dumbleton, C.A. Woods, L.W. Jones, D. Fonn, The impact of contemporary contact lenses on contact lens discontinuation, Eye Contact Lens 39 (1) (2013) 93–99.
[3] P.B. Morgan, Is the UK contact lens market healthy? Optician 221 (2001) 22–26.
[4] G. Young, J. Veys, N. Pritchard, S. Coleman, A multi-centre study of lapsed contact lens wearers, Ophthalmic Physiol Opt 22 (6) (2002) 516–527.
[5] P. Lazon de la Jara, J. Diec, T. Naduvilath, E.B. Papas, Measuring daily disposable contact lenses against non-wearer benchmarks, Optom Vis Sci 95 (12) (2018) 1088–1095.
[6] J.J. Nichols, L. Starcher, Contact lenses 2019, Cont Lens Spect 18 (19) (2020) 21–25 35(January).
[7] E.B. Papas, BCLA Annual Clinical Conference, Live Polling: contact Lens discomfort; is it as good now as it will ever be? British Contact Lens Association, Courtesy, 2019.
[8] L.E. Downie, A. Gad, C.Y. Wong, J.H.V. Gray, W. Zeng, D.C. Jackson, et al., Modulating contact Lens discomfort with anti-inflammatory approaches: a randomized controlled trial, Invest Ophthalmol Vis Sci 59 (8) (2018) 3755–3766.
[9] T. Igarashi, M. Kobayashi, C. Yaguchi, C. Fujimoto, H. Suzuki, H. Takahashi, Efficacy of rebamipide instillation for contact Lens discomfort with dry eye, Eye Contact Lens 44 (Suppl 2) (2018) S137–S142.
[10] A.D. Pucker, G. McGwin Jr., Q.X. Franklin, A. Nattis, C. Lievens, Evaluation of systane complete for the treatment of contact Lens discomfort, Cont Lens Anterior Eye (2019).
[11] J.S. Siddireddy, J. Tan, A.K. Vijay, M.D.P. Willcox, The effect of microblepharon exfoliation on clinical correlates of contact Lens discomfort, Optom Vis Sci 96 (3) (2019) 187–199.
[12] A.A. Tichenor, S.M. Cox, J.F. Ziemanski, W. Ngo, P.M. Karpecki, K.K. Nichols, et al., Effect of the Bruder moist heat eye compress on contact lens discomfort in contact lens wearers: an open-label randomized clinical trial, Cont Lens Anterior Eye 42 (6) (2019) 625–632.
[13] E.B. Papas, J.B. Ciolino, D. Jacobs, W.L. Miller, H. Pult, A. Sahin, et al., T.I.W.o.C.L.D. Members of the, the TFOS International Workshop on Contact Lens discomfort: report of the management and therapy subcommittee, Invest Ophthalmol Vis Sci 54 (11) (2013) TFOS183-203.
[14] E. Papas, D. Tilia, J. McNally, P.L. de la Jara, Ocular discomfort responses after short periods of contact lens wear, Optom Vis Sci 92 (6) (2015) 665–670.
[15] U. Stahl, N.J. Keir, A. Landers, L.W. Jones, Effect of short recovery periods on ocular comfort during daily Lens Wear, Optom Vis Sci 93 (8) (2016) 861–871.
[16] P.A. Harris, R. Taylor, B.L. Minor, V. Elliott, M. Fernandez, L. O'Neal, et al., The REDCap consortium: building an international community of software platform partners, J Biomed Inform 95 (2019) 103208.
[17] P.A. Harris, R. Taylor, R. Thielke, J. Payne, N. Gonzalez, J.G. Conde, Research electronic data capture (REDCap)–a metadata-driven methodology and workflow process for providing translational research informatics support, J Biomed Inform 42 (2) (2009) 377–381.
[18] E.B. Papas, L. Keay, B. Golebiowski, Estimating a just-noticeable difference for ocular comfort in contact lens wearers, Invest Ophthalmol Vis Sci 52 (7) (2011) 4390–4394.
[19] C.A. Woods, S.A. Bentley, D. Fonn, Temporal changes in contact lens comfort over a day of wear, Ophthalmic Physiol Opt 36 (6) (2016) 643–648.
[20] C.A. Woods, K. Dumbleton, L. Jones, D. Fonn, Patient use of smartphones to communicate subjective data in clinical trials, Optom Vis Sci 88 (2) (2011) 290–294.
[21] E.B. Papas, D. Tilia, D. Tomlinson, J. Williams, E. Chan, J. Chan, et al., Consequences of wear interruption for discomfort with contact lenses, Optom Vis Sci 91 (1) (2014) 24–31.