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Optimisation of blinking exercises for dry eye disease

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ABSTRACT

Purpose: Blinking exercises can reduce the signs and symptoms of dry eye disease, but the optimum technique, repetitions and repeats/day are unclear. Hence, this study used an instructional app to assess the best routine for blinking exercises.

Method: In the optimisation stage, dryness symptoms with the Ocular Surface Disease Index (OSDI-6-item), Symptom Assessment Questionnaire iN Dry Eye (SANDE), and the time the eyes were comfortable for after a blink (the Blink Test) were assessed in 98 participants with dry eye before and after 2 weeks of blinking exercises, as well as 2 weeks after completing the blinking exercise routine. Participants were randomised between a squeeze and blink compared to blink only regimen, 2 to 4 repeats per day and 5 to 25 repetitions each time. A second efficacy study with 28 participants with dry eye disease assessed the optimum app parameters based on symptom severity and frequency, blink rate/completeness, tear film stability and volume, along with ocular surface staining over the same time period.

Results: Overall, blinking exercises reduced symptomatology ($p < 0.01$). Including a squeeze step significantly reduced symptom frequency ($p < 0.01$). Forty repetitions spread over two time a day was more effective than 10 repetitions 4x/day (SANDE frequency $p = 0.015$). Fifteen repetitions was more effective than 5 repetitions 3x/day (SANDE frequency $p = 0.008$). Using the optimum blinking exercise routine of 15 repeats, 3x/day for 2 weeks, dry eye symptom severity ($p = 0.001$), frequency ($p = 0.027$), incomplete blinks ($p < 0.001$) and conjunctival staining ($p = 0.041$) significantly decreased. These readings mostly returned to baseline levels two weeks after finishing the blinking exercises ($p > 0.05$). However, there was no significant effect on the blink rate, non-invasive tear breakup time, tear meniscus height or corneal staining ($p > 0.05$).

Conclusion: Fifteen repeats of close-squeeze-open cycles, 3x/day was the optimum blinking exercise routine, reducing symptoms, number of incomplete blinks and conjunctival staining.

1. Introduction

The blink action is vital for spreading the tear film over the ocular surface, as well as to physically squeeze the tear glands to stimulate expression. Ousler and colleagues [1], found patients with dry eye disease (DED) blinked at a similar rate, but blinks lasting more than half a second were eight times as many than with healthy-matched controls. A similar pattern of people with DED spending an increased amount of time opening and closing their eyelids, with more time spent with their eyes shut was identified by Su and colleagues [2]. However, in a paediatric population, blink rate was increased [3]. Incomplete blinking also increases in DED and appears to be a key driver in the severity of signs and symptoms [4–6]. It has been suggested that the trigeminal blink reflex is altered in DED, causing blink oscillations, resulting in multiple blinks instead of one single blink reflex [7].

When using digital devices, blink rate reduces and this can exacerbate dry eye symptoms [8]. Using blink reminder software can increase the blink rate and reduce dry eye symptomatology [9,10]. While blinking exercises are often advocated for alleviating the symptoms of eye dryness or contact lens discomfort [11], particularly with digital screen use [12], the research evidence is limited [8]. Websites are more detailed in their blinking exercise instructions, but there is no evidence-

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base for these (Table 1). One study instructed participants to perform daily blinking exercises 10x a day for 1 month as an adjunct therapy, but the effects were not independently evaluated and compliance was reported as "more than half of the subjects reported completing 10 repetitions of the exercises 5–10 times a day for 20–30 days of the month" [13].

The only quantitative study published on contact lens wearers had 10 participants who performed blinking exercises of 10 forced blinks, 3 times a day for 2 weeks (with the lids pulled taught) which resulted in an increased frequency of complete blinks, whereas the blinking patterns of the 5 soft contact lens wearers in the control group remained unchanged [14]. A small retrospective study, (n = 10), found exercises (not defined) over 8 or more weeks and a computer blinking reminder programme, decreased partial blinking, as well as improved symptomology and the number of functional meibomian glands [15].

Kim and colleagues [16] showed in 41 participants that blinking exercises can modify poor blinking patterns and improve dry eye symptomology, with modest changes in objective measures of tear film quality. However, participants were asked to perform a ten-second cycle of squeeze and blinking exercises every 20 min during waking hours for four weeks, which is a significant burden, with participants reporting completion on average of 25.6 ± 17.7 cycles per day. The authors concluded that "incorporating such routines into clinical care recommendations may improve blinking habits and help protect against the impact of digital device use on tear film quality and DED onset and evolution" [16]. Therefore, the present study evaluated the optimum technique (with or without a 'squeeze' step), repetitions and repeats/day to refine this recommendation.

2. Methods

The study was given a favourable opinion by the Aston University Research Ethics Committee and followed the tenets of the Declaration of Helsinki.

For the optimisation study, 98 participants (average age 36.1 ± 16.6 years, 63 female, 33 Caucasian, 14 Black & 49 East Asian) were recruited. Participants who had an Ocular Surface Disease Index – 6 item (OSDI-6) [17] score > 6 and the time the eyes were comfortable for after a blink was < 10 s were enrolled. The Blink Test combined with symptoms, has a sensitivity of 71 % and specificity of 90 % compared to the full Tear Film and Ocular Surface (TFOS) Dry Eye Workshop (DEWS) II dry eye disease diagnosis [18]. Inclusion criteria was otherwise healthy eyes, no planned changes in ocular surface treatment and access to a smartphone running an iOS or Android operating system. OSDI-6 score [17], Symptom Assessment Questionnaire iN Dry Eye (SANDE) scales [19], and the time the eyes were comfortable for after a blink (the Blink Test) [18] were assessed in participants before and after 2 weeks of blinking exercises, as well as 2 weeks after completing the exercise routine. The participants were randomly allocated to exercise settings (set by the researcher and checked at the end of the study) of 3 repeats per day with 5, 10, 15 or 25 repetitions of close, squeeze and open cycles (each step held for 2 s), 2 repeats per day of 20 repetitions, 4 repeats a day of 10 repetitions, or 3 repeats per day with 15 repetitions of close and open cycles (each step held for 2 s) with 14 participants in each group (Fig. 1, Table 2), which were similar in age and sex distribution ($p > 0.05$). The squeeze step involved innervating the orbicularis oculi muscle more than with a standard blink as indicated in the app animation.

Once the optimum repeats and repetitions had been established, a second efficacy study was performed on 28 participants (average age 24.5 ± 13.3 years, 22 female, 2 Caucasian, 2 Black & 24 East Asia) who met the full TFOS DEWS II diagnostic criteria [20], and had a tear meniscus height (TMH) > 0.2 mm. The median symptom level reported by participants using the OSDI questionnaire was 19, ranging from 13 to 79. Symptomatology was assessed before and after the blink exercises with the SANDE questionnaire [19]. The blink rate was observed surreptitiously over 30 s (while the patient was observing the fixation light), TMH (captured 2 s after a blink and the average of 3 measurements taken) and non-invasive tear breakup time (NIBUT; average of three measurements) were assessed using the Keratograph 5 M (Oculus, Wetzlar, Germany) under infrared light, and corneal staining (with dye applied with moistened fluorescein strips – I-DEW FLO, Mid-Optic, Derby, UK, and observed with a blue light through a yellow barrier filter)[21] and conjunctival staining (with lissamine green dye applied – GreenGlo, Sigma Pharmaceuticals, North Liberty, Iowa, USA) [22], with a slit-lamp biomicroscope at baseline, after 2 weeks of conducting blinking exercises, and again 2 weeks after completing the blinking exercises (Fig. 1). The blinking exercise app (MyDryEye – Wolffsohn Research, Lisburn, Co. Antrim, UK) was set to 3 repeats of 15 close, squeeze and open cycle repetitions (each held for 2s).

2.1. Statistics

Statistical analysis was performed using SPSS (v20.0.1.0). All the data was found to be distributed significantly differently from normal (Kolmogorov-Smirnov test: $p < 0.05$) so non-parametric statistics were applied. Related-samples Friedman's Two-Way Analysis of Variance by Rank was applied to changes with time and independent sample Mann-Whitney U tests to comparisons between blinking exercise groups. A sample size of 14 participants in each optimisation group gave 95 %

Table 1
A summary of some blinking exercise advice stated by websites (accessed Sept 2024). C = close; S = squeeze; O = open; * Hold your fingers at the corners of your eyes and blink. When you are blinking correctly, you should feel no movement under your fingers.

Website Address	Recommended Sequence	Duration of stages	Finger to sense muscle stain?*	Sequence repeats	Repetitions
http://eyedoc2020.blogspot.com/2016/09/blinking-exercises-importance-of.html#!/2016/09/blinking-exercises-importance-of.html	C–O–C–S–O	2 s	✔	5×/hour	20×
http://www.overlakeeyecare.com/dry-eye-center/blinking-exercises.html	C–O	3 s	✔	Several times	10×
https://www.davisopticians.co.uk/eyehealth/BlinkExercises.asp	C–O	1 s	✔	–	–
https://www.speakcdn.com/assets/2519/tw_blinkingexercises.pdf TearWell	C–O–C–S–O.	2 s	✔	5×/hour	–
https://www.nkcf.org/science-and-art-of-blinking/	C–O	–	✔	5×/day	10×
https://www.youtube.com/watch?v=_nvaPZZAprI	C–O–C–S–O	Undefined "pause, pause"	×	–	–
https://dryeyecentre.co.uk/treatment/blinking-exercises/ – same as Blink by Tear Science app	C–S–O	2 s	×	–	5×
https://skyvisioncenters.com/blog/dry-eye-sufferers-try-blinking-exercises-app/	C–O C–SO	2 s	×	5×/hour	20×
https://www.eyelink.com/blinking-exercises/	C–O C–SO	2 s	×	–	5× each
https://www.notadryeye.org/all-about-dry-eye-syndrome/treatments-for-dry-eye-syndrome-and-related-conditions/improve-blinking/	C–O–C	3 s	×	15×/day	10×

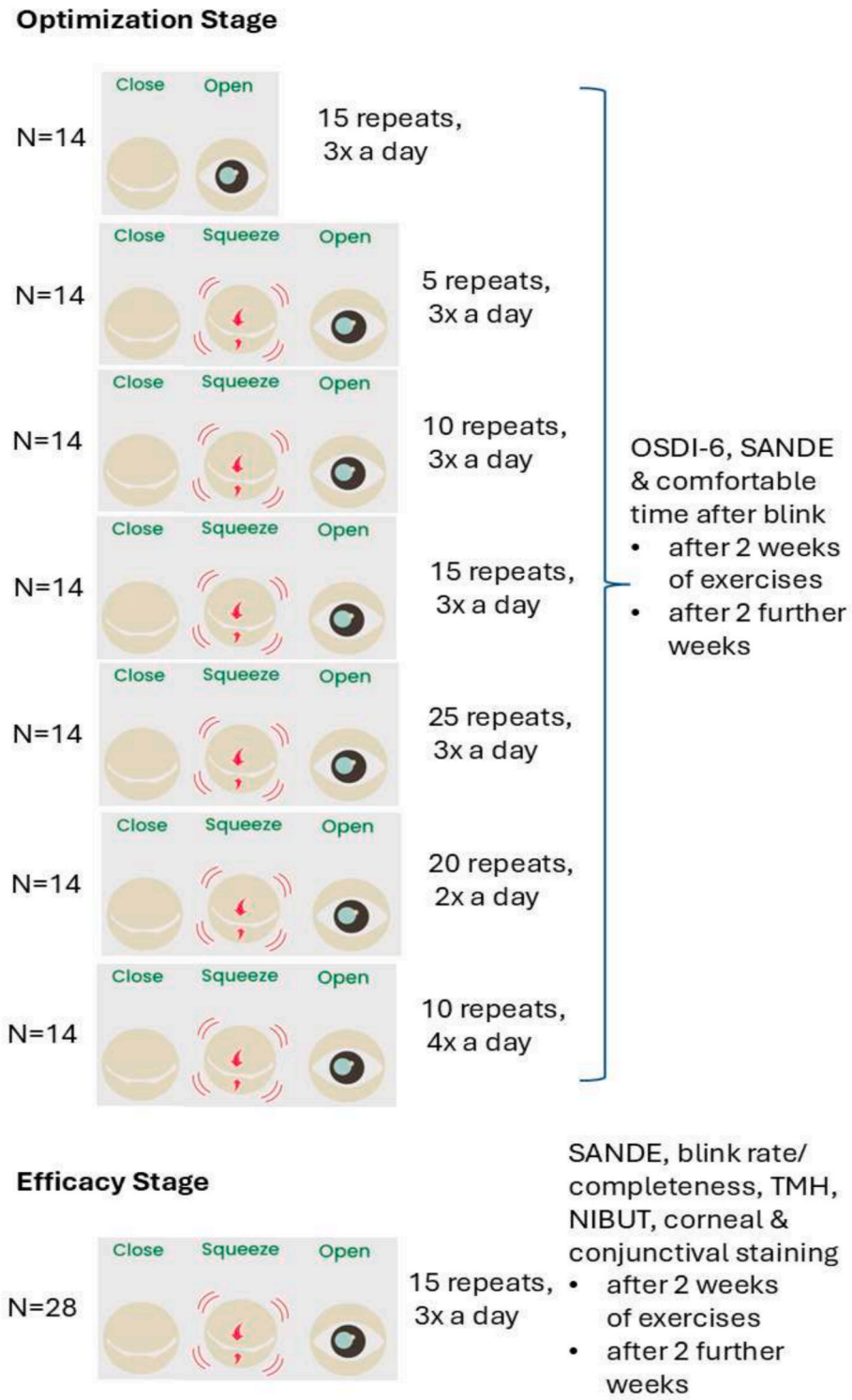

Fig. 1. Schematic of the Optimisation and Efficacy stages. NIBUT = Non-invasive Tear Breakup Time; OSDI-6 = Ocular Surface Disease Index questionnaire with 6-items; SANDE = Symptom Assessment Questionnaire iN Dry Eye; TMH = Tear Meniscus Height.

power with significance taken as $p < 0.05$ (G*Power v 3.1.9.7) to detect a 2-point difference in OSDI-6 [17] and a 20 mm difference in the SANDE scales [19] using non-parametric comparisons.

A sample size of 28 participants in the efficacy study gave 95 % power to detect 6 mm difference in the SANDE scales [19], a 1.5 s difference in NIBUT [23], a 0.04 mm difference in TMH [23] and a 0.1 grade in ocular surface staining [24] using non-parametric comparisons. No repeatability data on blinking is available to inform a sample size calculation. A statistic of $p < 0.05$ was taken as the level for significance. Bonferroni correction adjusted this to $p < 0.009$ for the optimisation study.

3. Results

In the optimisation study, overall blinking exercises reduced symptomatology (ODSI-6: $p < 0.001$) with further improvements in the 2

Table 2
Optimisation study difference from baseline after 2 weeks of blinking exercises and after a further 2 weeks following blinking exercise completion (mean ± 1 S.D.).

Exercise	Repeats/ day	Repetitions	Participants	OSDI-6 difference		SANDE frequency difference		SANDE severity difference		Comfort after blink difference (s)		Completions/ day
			n=	2 weeks	4 weeks	2 weeks	4 weeks	2 weeks	4 weeks	2 weeks	4 weeks	
Blink	3	15	14	−0.3 ± 3.4	−2.3 ± 3.2	−7.8 ± 15.9	−1.2 ± 17.1	−0.5 ± 7.1	−4.5 ± 7.2	1.4 ± 3.5	4.4 ± 7.4	1.6 ± 1.2
Squeeze/ blink	3	5	14	−2.1 ± 3.7	−0.9 ± 2.3	−12.7 ± 18.4	−2.7 ± 16.4	−7.9 ± 24.4	1.1 ± 17.5	2.3 ± 5.0	−1.1 ± 3.6	1.0 ± 1.2
Squeeze/ blink	3	10	14	−2.6 ± 4.4	−1.4 ± 2.7	−16.0 ± 15.5	−1.6 ± 13.5	−15.0 ± 12.4	−6.5 ± 11.3	5.3 ± 6.7	−1.0 ± 4.3	2.0 ± 1.1
Squeeze/ blink	3	15	14	−5.5 ± 4.1	−2.7 ± 2.8	−26.0 ± 19.7	−1.9 ± 19.7	−11.1 ± 24.8	−6.3 ± 22.8	5.1 ± 6.0	−1.0 ± 5.3	1.8 ± 1.2
Squeeze/ blink	3	25	14	−2.1 ± 3.2	−1.5 ± 3.5	−12.0 ± 17.4	−3.3 ± 9.5	−10.8 ± 20.1	−6.0 ± 10.5	4.6 ± 4.8	−1.7 ± 8.9	0.9 ± 1.3
Squeeze/ blink	2	20	14	−1.1 ± 3.6	−0.7 ± 1.4	−22.7 ± 20.1	−1.8 ± 12.7	−16.4 ± 22.9	−2.3 ± 18.9	−1.3 ± 7.5	2.2 ± 3.0	1.4 ± 1.0
Squeeze/ blink	4	10	14	−1.0 ± 2.3	−1.6 ± 2.5	−3.4 ± 13.6	−1.7 ± 21.7	−2.7 ± 15.9	−0.8 ± 16.3	3.9 ± 7.0	0.2 ± 7.9	2.4 ± 1.5
Overall	98	−2.1 ± 4.0	−1.6 ± 2.9	−14.4 ± 22.5	−2.0 ± 18.7	−9.2 ± 21.5	−3.6 ± 15.5	3.0 ± 7.5	0.3 ± 8.3			

weeks post exercises ($p < 0.01$). SANDE frequency ($p = 0.008$) and severity ($p = 0.031$) reduced only by 2 weeks after exercises. The comfortable time after a blink also increased with blinking exercises ($p = 0.004$), with no reduction 2 weeks after their cessation ($p = 0.455$).

A close, squeeze and open regimen was no better than open and close exercises alone in terms of comfort after a blink (2 weeks: $p = 0.821$; 4 weeks: $p = 0.051$) and SANDE severity (2 weeks: $p = 0.132$; 4 weeks: $p = 0.429$). However, the close, squeeze and open regimen outperformed close and open alone exercises in OSDI-6 ($p = 0.002$) and SANDE frequency ($p < 0.001$) immediately after exercises, but not by 2 weeks after exercise cessation ($p = 0.711$; $p = 0.171$ respectively).

Twenty repetitions 2x/day was more effective than 10 repetitions 4x/day in reducing the frequency of symptoms by the end of the blinking exercises ($p = 0.015$), but this was not sustained to 2 weeks after cessation ($p = 0.329$). However, the spread of the exercises did not impact the OSDI-6 (2 weeks: $p = 0.897$; 4 weeks: $p = 0.126$) or SANDE severity (2 weeks: $p = 0.515$; 4 weeks: $p > 0.999$) symptom scores or the amount of time the eyes were comfortable after a blink (2 weeks: $p = 0.203$; 4 weeks: $p = 0.429$).

Five repetitions 3x/day was less effective than 10 ($p = 0.031$), 15 ($p = 0.008$) or 25 ($p = 0.035$) repetitions in reducing SANDE frequency. However, the frequency of repetitions did not impact the OSDI-6 (2 weeks: $p = 0.0.149$; 4 weeks: $p = 0.751$) or SANDE severity (2 weeks: $p = 0.719$; 4 weeks: $p = 0.660$) symptomatology scores or the amount of time the eyes were comfortable after a blink (2 weeks: $p = 0.160$; 4 weeks: $p = 0.174$).

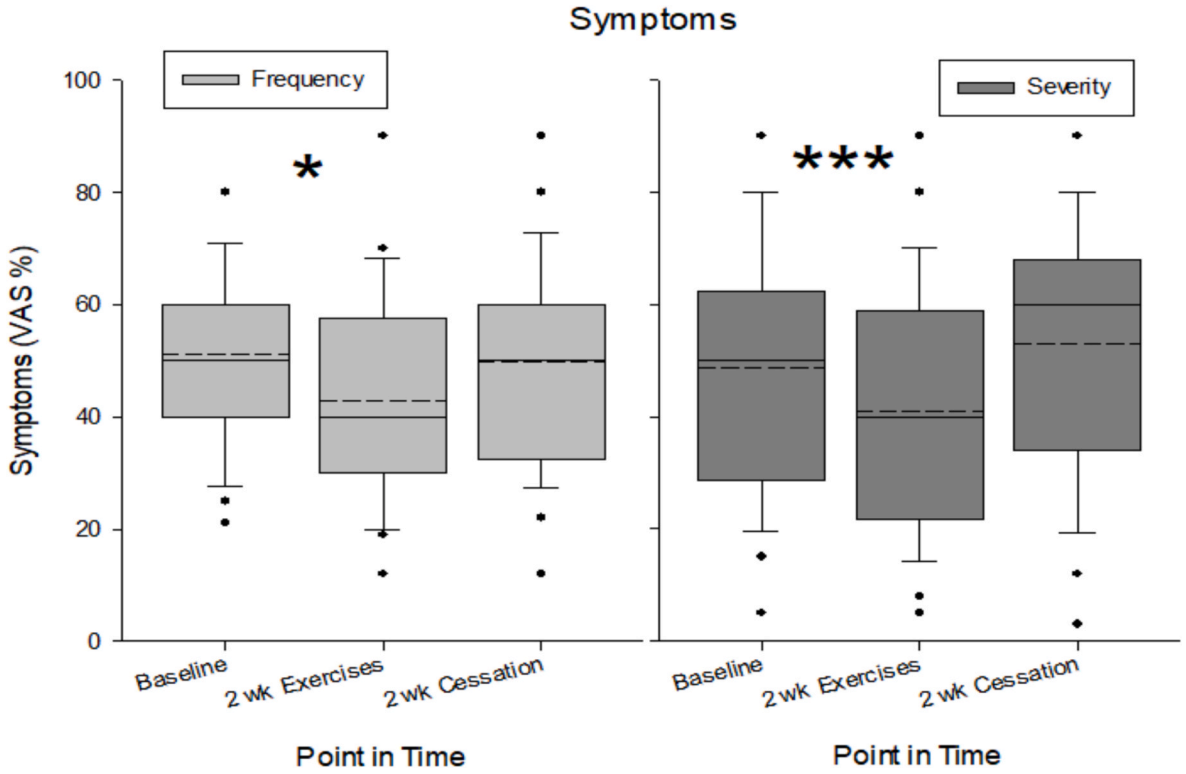

Fig. 2. Symptom Assessment Questionnaire iN Dry Eye (SANDE) symptom scale scores at baseline, after 2 weeks of blinking exercises and after a further 2 weeks following blinking exercise completion. The boxes indicate the 25th to 75th percentile range, with the solid line within indicating the mean and the dashed line the median; the whiskers indicate the 95 % confidence interval; and the dots, outlying data. * = $p < 0.05$. *** = $p < 0.001$.

In the efficacy study, the mean level of symptoms was 19 on the OSDI (range 13 to 79). Dry eye symptom frequency decreased after the use of blinking exercises ($p = 0.027$; Fig. 2), and then returned to baseline levels 2 weeks later ($p > 0.999$). Similarly, dry eye symptom severity also decreased significantly following blinking exercises ($p = 0.001$), returning to the baseline level by 2 weeks later ($p = 0.184$; Fig. 1). While, the blink rate was not significantly affected by blinking exercises ($p = 0.499$), the number of incomplete blinks reduced significantly following blinking exercises ($p < 0.001$), returning to baseline level by 2 weeks later ($p = 0.058$; Fig. 3). NIBUT ($p = 0.898$) and TMH ($p = 0.630$) were not affected by 2 weeks of blinking exercises (Fig. 4). A significant decrease occurred in the number of conjunctival (but not corneal $p = 0.368$) punctate spots stained after adopting blinking exercises ($p = 0.041$), returning to baseline 2 weeks later ($p = 0.855$; Fig. 5). On average 2.1 ± 1.1 sets of blinking exercises were fully completed each day.

4. Discussion

The aim of this study was to refine the recommendation to patients with DED with poor blinking patterns in terms of the technique (whether a squeeze step should be included), the required frequency during a day, and the optimal number of repetitions of blinking exercises each time. After this optimisation phase, the efficacy on signs and symptoms of dry eye were evaluated.

A close, squeeze and open regimen resulted in a lower frequency of symptoms as assessed by the OSDI-6 and that subscale of the SANDE than an open and close technique. The same number of repetitions (80 repeats) of this regimen was more effective over two sessions rather than spaced over four times of day, again based on the frequency rather than severity of symptoms. This is likely to be due, in part, to compliance as two scheduled sessions a day were completed on average 1.4 times giving an average of 28 repetitions, whereas four scheduled sessions a day of half the number of repeats were completed on average 2.4 times, giving an average of 24 repetitions. The pressure required to extract meibum in patients with meibomian gland dysfunction, which is highly prevalent in those with DED [25], ranges from 5 to 60 lb per square inch (3.5 to 42 g/mm)[26], so this might be aided by more repetitions within a shorter period of time, as well as the squeeze step. The frequency of symptomatology was also less if more repetitions were conducted in the same session. While there was only a statistically significant difference between 5 and 10 repeats, the peak was found to occur with 15 repetitions as beyond this amount, the significance reduced, and compliance halved. In the optimisation study, both the severity and frequency of dry eye symptoms reduced, but they were only moderately correlated ($r = 0.57$) [27], and it is not clear how the rating of one affects the other. The time the eyes remained comfortable after a blink [18] also remained similar, but both improved when the data from all groups were analysed.

While across all groups in the optimisation study, blinking exercises reduced the frequency and severity of symptoms along with the time the eyes were comfortable after a blink, it was not possible to monitor signs associated with dry eye disease during COVID-19. The efficacy study used the blinking exercise parameters identified as having the best impact in the optimisation study, being 15 repetitions of a close-squeeze-open regimen, repeated three times a day. The previous symptomology benefit of blinking exercises in the optimisation study was corroborated in the efficacy study and aligns with the findings of Kim and colleagues [16]. The blinking exercises decreased the number of incomplete blinks, but did not affect the blink rate which was a similar finding of previous studies [14–16], although one study found a reduction in blink rate as well [16]. The lack of improvement in tear film stability (as assessed with NIBUT) may have been to the relatively short duration of the exercises (2 weeks), but a previous study over 4 weeks also found no effect on tear volume (as assessed with TMH) [16]. Previous studies have not assessed the impact of blinking exercises on ocular surface staining, with this study showing a significant decrease in the number of conjunctival (but not corneal) punctate spots stained after 2 weeks. Conjunctival staining has been found to be more sensitive to dry eye changes than corneal staining in some previous studies [28] and the levels of conjunctival staining in the participants in this study were about 4 times higher than their corneal staining, making a change easier to detect. Interestingly, the change occurred over a much shorter time frame than the approximately 4 months of 4 times daily use of artificial tears required to impact both corneal and conjunctival staining in a longitudinal study [29]. Within 2 weeks of cessation of the blinking exercises, the benefits had largely dissipated, perhaps due to a longer exercise period needed to develop more persistent muscle memory. Further studies are needed to understand whether the effects are cumulative to inform the advice given to patients.

Despite reminders set on participants phones at times they selected

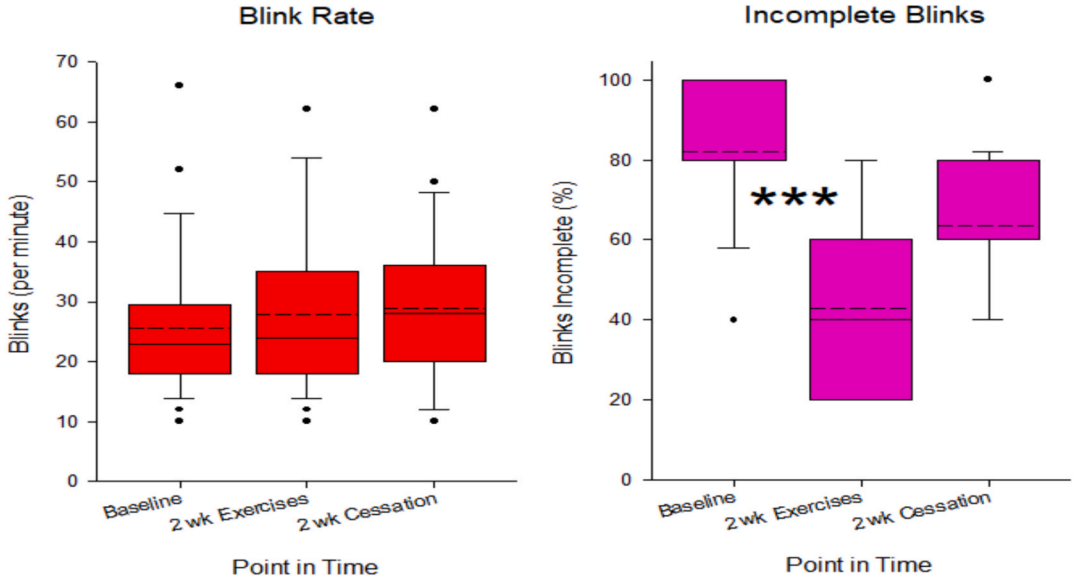

Fig. 3. Blink rate and completeness at baseline, after 2 weeks of blinking exercises and after a further 2 weeks following blinking exercise completion. The boxes indicate the 25th to 75th percentile range, with the solid line within indicating the mean and the dashed line the median; the whiskers indicate the 95 % confidence interval; and the dots, outlying data. *** = $p < 0.001$.

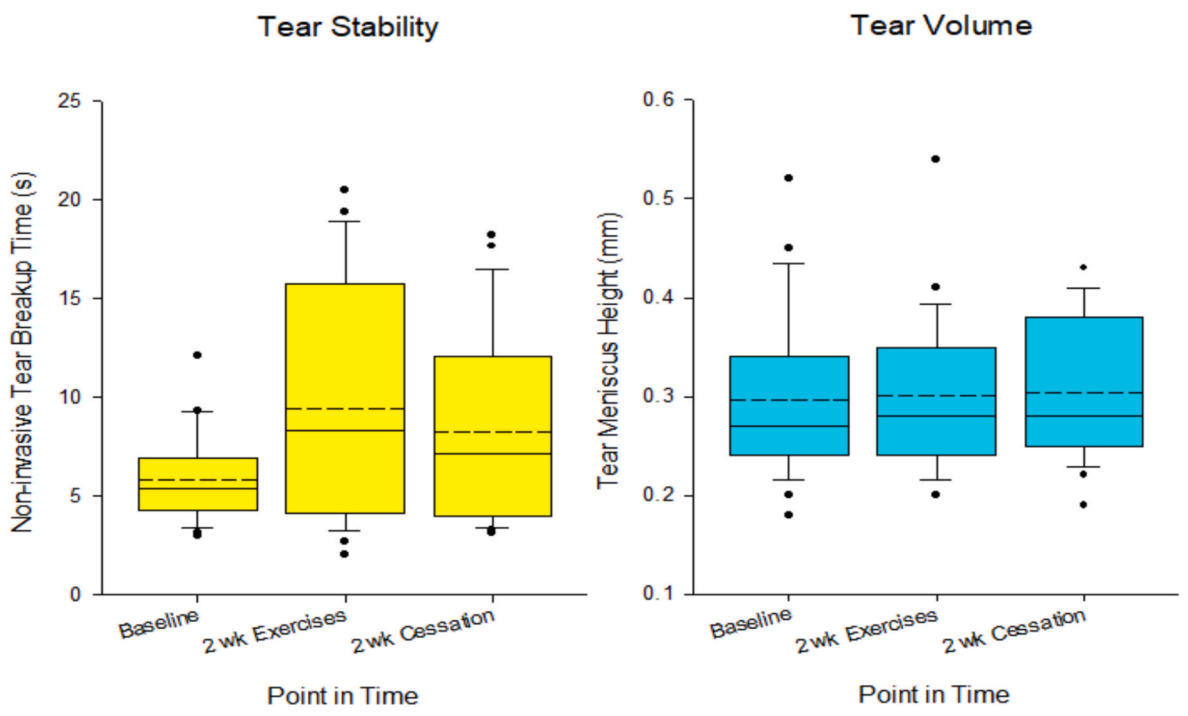

Fig. 4. Tear stability (non-invasive breakup time) and volume (tear meniscus height) at baseline, after 2 weeks of blinking exercises and after a further 2 weeks following blinking exercise completion. The boxes indicate the 25th to 75th percentile range, with the solid line within indicating the mean and the dashed line the median; the whiskers indicate the 95 % confidence interval; and the dots, outlying data.

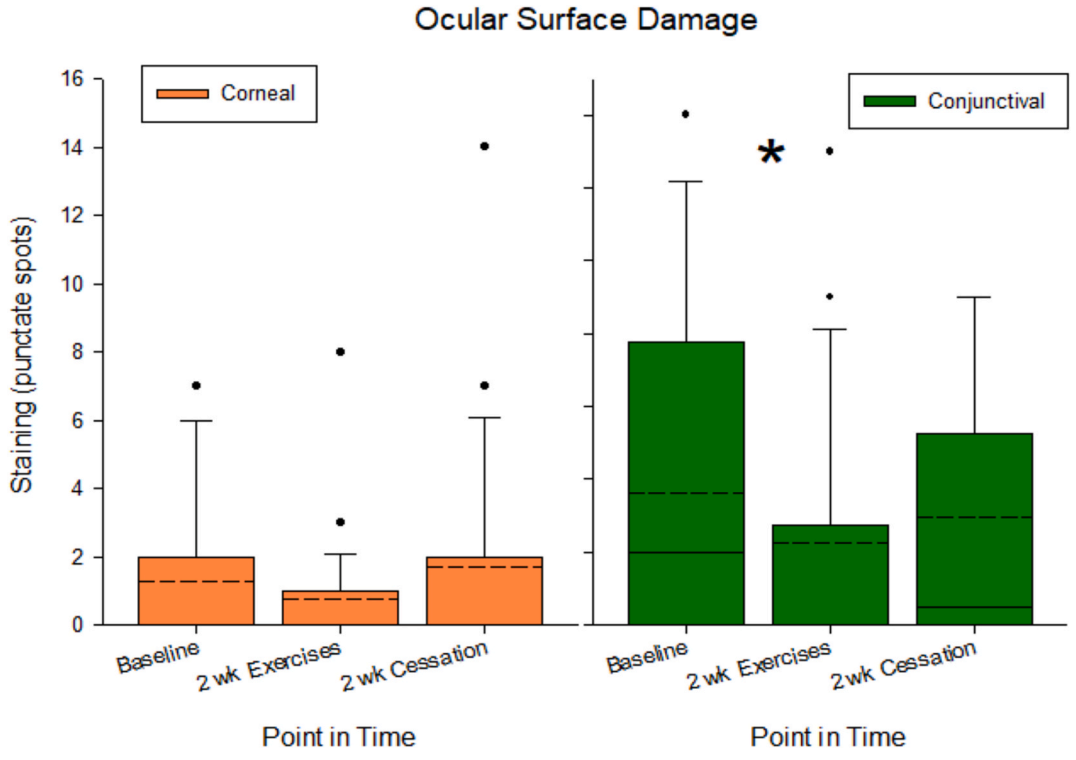

Fig. 5. Corneal and conjunctival ocular surface damage at baseline, after 2 weeks of blinking exercises and after a further 2 weeks following blinking exercise completion. The boxes indicate the 25th to 75th percentile range, with the solid line within indicating the mean and the dashed line the median; the whiskers indicate the 95 % confidence interval; and the dots, outlying data. * = $p < 0.05$.

to suit their lifestyle, on average around 2 of the 3 set repeats of blinking exercises were completed each day (based on video monitored MyDryEye app completions). In contrast, a previous study requested participants to perform 10 s of squeeze and blinking exercises (with 2 s gaps, about two close-squeeze-open cycles) 3 times an hour during waking (so about 48 repeats a day) of which they self-reported an

average of about 25 completions. Many factors affect compliance including the severity of the disease [30], so a more severe cohort could be expected to be more compliant.

Limitations of the study include the lack of a control group, but it is not possible to mask a participant from blinking exercises. While some of the symptomology benefit in the optimisation study could have resulted from the placebo effect, participants were not aware of the variation in blinking exercise parameters being explored and the lack of effect after 2 weeks cessation was consistent. The results were directly recorded on the app so any possible investigator bias was avoided. The trigeminal blink reflex changes in older age [31] and the participants in the study were only up to 40 years of age, so these finding may not be generalisable across all patients with DED and more severe disease. In addition, only patients with evaporative DED were examined. While conducting blinking exercises 3 times a day was not directly compared with the same number of cycles 2 and 4 times a day, the compliance and clinical data suggests its recommendation gave the best efficacy (Table 2).

In conclusion, recommending blinking exercises to patients with evaporative dry disease is effective and the best impact is achieved with a regimen of 15 repetitions of a close-squeeze-open sequence (each held for 2s), repeated three times a day. To enable this, the MyDryEye app for iOS and Android phones was created that allows blinking exercise reminders to be sent and compliance to be monitored https://dry-eye-association.com/dry-eye-association-app/. Such a recommendation should accompany other strategies for reducing the impact of evaporative DEDe on the patient such as meibomian gland debridement and expression, prescribing lipid based artificial tears [29], omega-3 supplementation and use of a warm compress [32–34].

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as a potential competing interest: The MyDryEye app was created by James Wolffsohn, Alec Kingsnorth and Mark Nattriss and is freely available to patients.

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