

Effect of Virtual Reality Headset Wear on Tear Film Lipid Layer Grade and Non-Invasive Tear Break-Up Time in Young Emmetropic Adults

Binit Kumar Singh¹, Rahul Roy^{2*}, Kamal Thakur³, Sharath Narayan Sapaliya⁴

^{1,2*,3,4}Nethradhama School of Optometry, Bengaluru, Karnataka, India

Corresponding Author: Rahul Roy, Nethradhama School of Optometry, Kanakapura Main Road, Jayanagar 7th Block, Bengaluru – 560082, Karnataka, India, nsoviceprincipal@nethradhama.org

ABSTRACT

Background

Virtual reality (VR) headsets present near-eye digital displays for extended periods and have been proposed to influence tear film physiology through mechanisms distinct from conventional visual display terminals, including altered blink dynamics and a periocular thermal microenvironment. Existing studies on VR headset use and tear film have reported inconsistent and, at times, opposite findings. This study aimed to determine whether continuous VR headset use alters non-invasive tear film breakup time (NIBUT), tear meniscus height (TMH), and tear film lipid layer grade in healthy young emmetropic adults.

Methods

This prospective, single-group, repeated-measures observational study was conducted at the Nethradhama Superspeciality Eye Hospital, Bengaluru, India, between May and July 2021. Sixty emmetropic participants aged 18–30 years (spherical equivalent ± 0.25 to ± 0.50 D) were enrolled by convenience sampling. Each participant wore a smartphone-based VR headset continuously in a temperature-controlled room (22–24°C), between 9 AM and 12 PM. NIBUT, TMH, and tear film lipid layer grade (Guillon classification) were recorded using a Tearscope at baseline and after 15, 30, and 45 minutes of continuous wear. Normality was assessed using the Shapiro–Wilk test, and repeated-measures comparisons used the Friedman test with Bonferroni-corrected post hoc pairwise analysis (SPSS v25.0; $P < 0.05$ was considered significant).

Results

Sixty eyes of 60 participants (mean age 20.77 ± 0.71 years) completed the study. At baseline, median (interquartile range [IQR]) NIBUT was 10.25 (0.77) seconds, TMH was 0.17 (0.07) mm, and 51.7% of eyes showed an open-meshwork lipid layer pattern. The Friedman test showed a significant effect of headset-wear duration on NIBUT and TMH ($P < 0.001$). Progressive reductions were observed at 15 minutes (NIBUT 9.70 [0.90] s; TMH 0.15 [0.05] mm), 30 minutes (NIBUT 8.90 [0.97] s; TMH 0.14 [0.05] mm), and 45 minutes (NIBUT 7.40 [1.23] s; TMH 0.11 [0.05] mm), with all pairwise comparisons against baseline statistically significant ($P \leq 0.001$). The predominant lipid layer pattern shifted from open meshwork at baseline to closed meshwork by 15–30 minutes and to a wave (flow) pattern in 61.7% of eyes by 45 minutes.

Conclusions

In healthy young emmetropic adults, continuous VR headset wear was associated with a progressive, statistically significant decline in tear film stability and volume markers (NIBUT and TMH) and a shift toward less stable lipid-layer interference patterns with increasing wear duration. These findings contrast with reports of VR-associated tear film improvement in other cohorts and headset configurations, underscoring the need for controlled comparative studies to clarify the ocular surface safety of VR.

Keywords

Virtual Reality; Dry Eye Syndrome; Tears; Blinking; Computer Vision Syndrome

How to cite this article: Binit Kumar Singh¹, Rahul Roy², Effect of Virtual Reality Headset Wear on Tear Film Lipid Layer Grade and Non-Invasive Tear Break-Up Time in Young Emmetropic Adults. *Int J Drug Deliv Technol.* 2026;16(83s):910-915. DOI: 10.25258/ijddt.16.83s.101.

INTRODUCTION

Precorneal tear film is a multilayered structure comprising mucin, aqueous, and lipid components that together maintain corneal optical quality,

lubricate the ocular surface, and protect against microbial and environmental insults (Rentka et al., 2017). The outermost lipid layer, secreted

principally by the meibomian glands, retards the evaporation of the underlying aqueous layer and stabilises the tear film between blinks; its thickness and organisation can be graded non-invasively from characteristic interference patterns (Arita et al., 2017). Disruption of any component of this system, whether through reduced tear secretion, increased evaporation, or altered blink dynamics, can destabilise the tear film and contribute to dry eye disease (Yan et al., 2019).

Prolonged use of digital visual display terminals is a well-established risk factor for tear film instability and digital eye strain, largely attributed to a reduction in spontaneous blink rate and an increase in incomplete blinks during visually demanding near-fixation tasks (Uchino et al., 2018). Cross-sectional and occupational cohort studies have consistently linked the use of heavy visual display terminals to a higher prevalence of dry eye disease and reduced work productivity (Courtin et al., 2016). Virtual reality (VR) headsets introduce a further variant of this exposure: users view a near-eye display at a fixed vergence and accommodative demand inside an enclosed housing that isolates the ocular surface from ambient airflow while generating localised heat (Turnbull & Phillips, 2017).

The net effect of VR headset wear on tear film stability remains unresolved, with published studies reporting divergent outcomes. A randomised crossover study in computer operators found that VR headset wear improved lipid layer grade and prolonged NIBUT relative to conventional desktop display use, an effect attributed to a moisture-goggle-like thermal microenvironment inside the headset (Che Azemin, 2020). However, blink suppression has also been documented during VR and augmented-reality device use (J. Kim et al., 2022). A more recent time-course study using an in-headset interferometric camera similarly reported a significant increase in tear film lipid layer interference grade during 30 minutes of VR gameplay, again linked to periocular temperature elevation (Hong & Kang, 2024). In contrast, other investigators have reported no significant short-term change in tear film stability or ocular discomfort with VR use, while prolonged smartphone-based head-mounted display use has been associated with adverse changes in other

visual parameters. This inconsistency may reflect differences in headset design, ambient conditions, exposure duration, and study population, and highlights a gap in our understanding of how cumulative wear time interacts with tear film physiology. (Ortiz-Toquero et al., 2025)

The present study was undertaken to evaluate the effect of continuous, smartphone-based VR headset wear of increasing duration (15, 30, and 45 minutes) on three complementary, non-invasive tear film parameters, namely, NIBUT, tear meniscus height (TMH), and lipid layer interference grade, in a cohort of young, healthy emmetropic adults, in order to clarify the relationship between VR exposure time and tear film stability.

METHODS

Study design and setting

This prospective, single-group, repeated-measures (within-subject, before–after) observational study was conducted at Nethradhama Superspeciality Eye Hospital in association with Nethradhama School of Optometry, Jayanagar, Bengaluru, India, between May 2021 and July 2021.

Participants

Sixty healthy emmetropic individuals aged 18–30 years were recruited by convenience sampling. The inclusion criteria were: age 18–30 years; uncorrected distance visual acuity of 0.00 logMAR or better with N6 near visual acuity; emmetropia, defined as a spherical equivalent refractive error between ± 0.25 D and ± 0.50 D; and willingness to cooperate with the study procedures. Individuals with a history of ocular or systemic pathology, current alcohol or tobacco use, or an inability to cooperate with testing were excluded.

Procedure

Each participant wore a smartphone-based VR headset continuously in an air-conditioned examination room maintained at 22–24°C, with all testing performed between 9 AM and 12 PM to minimise diurnal variation in tear film parameters [12]. Tear film assessments were performed using a Tearscope at baseline, immediately prior to headset wear, and again after 15, 30, and 45 minutes of continuous VR exposure. At each time point, the following were recorded in one eye of

each participant: (i) non-invasive tear film break-up time (NIBUT), the interval between the last complete blink and the first appearance of disruption in the reflected grid pattern; (ii) tear meniscus height (TMH), measured at the central lower lid margin; and (iii) tear film lipid layer interference grade, classified according to the Guillon grading scheme (open meshwork, closed meshwork, wave/flow, amorphous, and colour-fringe patterns).

Statistical analysis

All statistical analyses were performed using SPSS version 25.0 (IBM Corp.). The normality of the distribution was assessed using the Shapiro–Wilk test, given a sample size exceeding 50. As the tear film parameters were not normally distributed, within-subject comparisons across the four time points (baseline, 15, 30, and 45 minutes) were performed using the repeated-measures Friedman test, with Bonferroni-corrected post hoc pairwise comparisons. A two-tailed P value <0.05 was considered statistically significant.

Results

Sixty eyes of 60 participants (both sexes) with a mean age of 20.77 ± 0.71 years completed all the study assessments. The Friedman test demonstrated a statistically significant effect of VR headset-wear duration on tear film NIBUT and tear meniscus height at the four time points ($P < 0.001$).

At baseline, the median (IQR) NIBUT was 10.25 (0.77) seconds, median TMH was 0.17 (0.07) mm, and the predominant lipid layer pattern was open meshwork, present in 51.7% of eyes. Following 15 minutes of continuous VR headset wear, the median NIBUT declined to 9.70 (0.90) seconds and TMH to 0.15 (0.05) mm, with the predominant lipid pattern shifting to closed meshwork (46.7% of eyes); this change was statistically significant relative to baseline (Bonferroni-corrected $P = 0.001$). After 30 minutes, NIBUT further declined to 8.90 (0.97) seconds and TMH to 0.14 (0.05) mm, with a closed-meshwork pattern persisting in 53.3% of eyes ($P < 0.001$ versus baseline). By 45 minutes of continuous wear, NIBUT had declined to 7.40 (1.23) seconds and TMH to 0.11 (0.05) mm, with 61.7% of eyes showing a wave (flow) interference pattern, consistent with progressive tear film lipid layer

thinning and destabilisation ($P < 0.001$ versus baseline). The time course of changes in these parameters is summarised in Table 1.

Table 1. Tear film parameters at baseline and after 15, 30, and 45 minutes of continuous VR headset wear (n = 60 eyes).

Parameter	Baseline	15 minutes	30 minutes	45 minutes
NIBUT, median (IQR), s	10.25 (0.77)	9.70 (0.90)	8.90 (0.97)	7.40 (1.23)
Tear meniscus height, median (IQR), mm	0.17 (0.07)	0.15 (0.05)	0.14 (0.05)	0.11 (0.05)
Predominant lipid layer grade (Guillon classification), %	Open meshwork, 51.7 %	Closed meshwork, 46.7 %	Closed meshwork, 53.3 %	Wave (flow) pattern, 61.7 %

NIBUT: non-invasive tear film break-up time; IQR: interquartile range. The lipid layer grade was classified according to the Guillon interference pattern scheme [13].

DISCUSSION

In this cohort of healthy, young, emmetropic adults, continuous VR headset wear was associated with a progressive and statistically significant decline in NIBUT and TMH, together with a shift in tear film lipid layer interference pattern from open meshwork toward closed meshwork and, ultimately, a wave (flow) pattern, over 45 minutes of continuous wear. These findings suggest that, under the conditions tested, sustained VR exposure was associated with cumulative tear film destabilisation rather than the

improvement in lipid layer grade reported elsewhere (H. Kim et al., 2024).

This result contrasts with two previously published reports. Turnbull et al. found that 40 minutes of VR headset use produced clinically significant improvements in lipid layer grade and NIBUT relative to conventional desktop display use, attributed to a moisture-goggle effect arising from modest increases in periocular temperature within the sealed headset environment (H. Kim et al., 2024). Similarly, Okazaki and Yokoi, using an in-headset interferometric camera, observed a significant increase in tear film lipid layer interference grade during a 30-minute VR gaming session, which they linked to temperature-driven changes in meibomian lipid fluidity and reorganisation (Okazaki & Yokoi, 2025). However, other investigators have reported no significant short-term change in tear film stability with VR use, and prolonged head-mounted display wear has been associated with adverse changes in other visual parameters, indicating that the ocular surface response to VR exposure is not uniform across studies (Lee et al., 2020).

Several factors may account for this divergence. First, headset design differed substantially between studies: a fully sealed, low-vented headset may trap heat and humidity and reduce evaporative tear loss, favouring the moisture-goggle effect described by Whereas a smartphone-based headset with greater ventilation, as used in the present study, may permit more evaporative loss while still suppressing blink rate through sustained near-fixation on a bright display (Kusumesh et al., 2025). Blink rate and completeness, not directly measured in the present study, are known to fall substantially during visually demanding near-target fixation and VR use and a recent controlled blinking study demonstrated that reducing blink frequency alone is sufficient to significantly worsen both TMH and NIBUT even without a change in the evaporative environment (Che Azemin, 2020). It is plausible that in the present study, blink suppression outweighed any thermal benefit as wear duration increased. Third, evaporation is known to make a major contribution to inter-blink tear film thinning and any airflow ingress around an incompletely sealed smartphone-based headset, combined with the ambient air-conditioned environment (22–

24°C) in which testing was performed, may have offset a potential thermal benefit. Ocular surface cooling has itself been linked directly to tear film thinning and breakup and the balance between headset-generated heat and ambient air conditioning may therefore be a key determinant of the direction of the observed effect (Li et al., 2024).

The findings of the present study are consistent with the broader literature linking prolonged near-fixation visual display use to reduced blink rate, evaporative stress, and tear film instability and support digital eye strain as a plausible mechanism specific to VR headset use, in addition to any thermal microenvironment effect. Given the increasing use of VR devices for entertainment, education, and clinical applications, particularly among children and young adults, the present findings raise the possibility that longer, continuous VR sessions may carry a distinct risk profile for the ocular surface that differs from that of shorter exposures or moisture-sealed headset designs (Yoon et al., 2021).

This study had several limitations. It was conducted at a single centre in a narrowly defined population of emmetropic individuals aged 18–30 years, which limits generalisability to older adults, ametropes, contact lens wearers, and individuals with pre-existing dry eye disease. Blink rate and completeness, periocular and corneal surface temperature, and ambient humidity inside the headset were not directly measured, precluding mechanistic confirmation of the pathway underlying the observed changes. The study also lacked a control arm (for example, a non-VR sham headset or conventional display comparator) and did not randomise the order of exposure, so a cumulative testing or fatigue effect over the single morning session cannot be entirely excluded, although testing was confined to a fixed morning window to minimise diurnal variation. Finally, only one eye per participant was assessed, and the specific smartphone-based headset model used may not be representative of other VR hardware configurations.

CONCLUSION

Continuous wear of a smartphone-based virtual reality headset was associated with a progressive, statistically significant reduction in non-invasive

tear film break-up time and tear meniscus height, and a shift toward less stable tear film lipid layer interference patterns, in healthy young emmetropic adults over 45 minutes of use. These findings differ from reports of VR-associated tear film improvement with other headset designs and exposure paradigms, suggesting that the ocular surface effect of VR headset wear may depend on headset ventilation, ambient conditions, and exposure duration. Clinicians advising VR users, particularly children and young adults engaging in extended sessions, should consider recommending regular breaks and conscious blinking. Controlled, comparative studies incorporating blink rate, periocular temperature and humidity monitoring, and a range of headset designs are warranted to clarify the mechanisms underlying these divergent findings and to inform evidence-based guidance on safe VR usage duration.

ETHICAL DECLARATION

This study adhered to the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrolment. Institutional ethical clearance was obtained from the Institutional Ethics Committee of the Nethradhama Superspeciality Eye Hospital.

FUNDING

This research did not receive any specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

ACKNOWLEDGMENTS

The authors thank all the study participants for their voluntary participation.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

References

Arita, R., Fukuoka, S., & Morishige, N. (2017). New Insights Into the Lipid Layer of the Tear Film and Meibomian Glands. *Eye & Contact Lens: Science & Clinical Practice*, 43(6), 335–339.
<https://doi.org/10.1097/icl.0000000000000369>

Che Azemin, M. Z. (2020). Short Term Effect of Virtual Reality on Tear Film Stability and Ocular

Discomfort. *Journal of Engineering and Science Research*, 4(1), 40–46.
<https://doi.org/10.26666/rmp.jesr.2020.1.7>

Courtin, R., Pereira, B., Naughton, G., Chamoux, A., Chiambaretta, F., Lanhers, C., & Dutheil, F. (2016). Prevalence of dry eye disease in visual display terminal workers: a systematic review and meta-analysis. *BMJ Open*, 6(1), e009675.
<https://doi.org/10.1136/bmjopen-2015-009675>

Hong, H., & Kang, H. (2024). Investigation of the effect of the alignment of the eye and the virtual image of virtual reality on fatigue in viewing VR device. *Journal of the Society for Information Display*, 32(11), 747–754.
<https://doi.org/10.1002/jsid.2007>

Kim, H., Gil, M., & Kang, H. (2024). Tear Film Break-Up Time before and after Watching a VR Video: Comparison between Naked Eyes and Contact Lens Wearers. *Electronics*, 13(13), 2448.
<https://doi.org/10.3390/electronics13132448>

Kim, J., Hwang, L., Kwon, S., & Lee, S. (2022). Change in Blink Rate in the Metaverse VR HMD and AR Glasses Environment. *International Journal of Environmental Research and Public Health*, 19(14), 8551.
<https://doi.org/10.3390/ijerph19148551>

Kusumesh, R., Ambasta, A., Venugopal, A., Kumari, R., & Singh, P. (2025). Visual impact of smartphones: A narrative review of ocular changes and management approaches. *Indian Journal of Ophthalmology*, 73(12), 1723–1728.
https://doi.org/10.4103/ijo.ijo_1389_25

Lee, S. H., Kim, M., Kim, H., & Park, C. Y. (2020). Relationship between Ocular Fatigue and Use of a Virtual Reality Device. *Journal of the Korean Ophthalmological Society*, 61(2), 125.
<https://doi.org/10.3341/jkos.2020.61.2.125>

Li, W., Graham, A. D., & Lin, M. C. (2024). A pilot study of the impact of repeated blink refrainment on ocular surface temperature and the interblink period. *Optometry and Vision Science: Official Publication of the American Academy of*

Optometry, 101(11), 652–659.

<https://doi.org/10.1097/opx.0000000000002195>

Okazaki, Y., & Yokoi, N. (2025). Time-course observation of tear film dynamics during VR headset use. *Scientific Reports*, 15(1), 33082. <https://doi.org/10.1038/s41598-025-16634-w>

Ortiz-Toquero, S., Sanchez, I., & Martin, R. (2025). Effects of artificial tears on ocular surface symptoms and visual task performance in digital device users. *Scientific Reports*, 16(1), 653. <https://doi.org/10.1038/s41598-025-22510-4>

Rentka, A., Koroskenyi, K., Harsfalvi, J., Szekanecz, Z., Szucs, G., Szodoray, P., & Kemeny-Beke, A. (2017). Evaluation of commonly used tear sampling methods and their relevance in subsequent biochemical analysis. *Annals of Clinical Biochemistry: International Journal of Laboratory Medicine*, 54(5), 521–529. <https://doi.org/10.1177/0004563217695843>

Turnbull, P. R. K., & Phillips, J. R. (2017). Ocular effects of virtual reality headset wear in young adults. *Scientific Reports*, 7(1), 16172. <https://doi.org/10.1038/s41598-017-16320-6>

Uchino, M., Uchino, Y., Kawashima, M., Ohta, M., & Yokoi, N. (2018). Association between tear film break up time and blink interval in visual display terminal users. *International Journal of Ophthalmology*, 11(10), 1691–1697. <https://doi.org/10.18240/ijo.2018.10.18>

Yan, D., Yan, C., & Fu, Y. (2019). Research advances in factors affecting homeostasis of the tear film. *Int Rev Ophthalmol*, 43(5), 337–340. <https://doi.org/10.3760/cma.j.issn.1673-5803.2019.05.010>

Yoon, H. J., Moon, H. S., Sung, M. S., Park, S. W., & Heo, H. (2021). Effects of prolonged use of virtual reality smartphone-based head-mounted display on visual parameters: a randomised controlled trial. *Scientific Reports*, 11(1), 15382. <https://doi.org/10.1038/s41598-021-94680-w>