Effect of 20 Minutes 3-Prism Base-Out Wear on Vergence Parameters

Nik Amira Athirah Muhamad Hakimi[1], Shah Farez Othman[1,2], Mohd Hafidz Ithnin[1], Nizam Tamchek[2]
[1]Kulliyyah of Allied Health Sciences, International Islamic University Malaysia
[2]Faculty of Science, Universiti Putra Malaysia

Corresponding author:
mohdhafidz_ithnin@iium.edu.my

Abstract
Prism is utilised in visual treatment and binocular vision evaluation. Previous studies did not provide a satisfactory explanation for the impact of a 20-minute prism base-out wear on the vergence system when viewing at a distance. This study aimed to assess the effect of 3 prism base-out wear on the vergence system when viewing at distance position. Thirty (30) subjects were recruited in this cross-sectional clinical study. Subjects wore 3-prism base-out for 20 minutes while watching a movie at 6 m. Phorias were tested at distance and near, near point of convergence (NPC), negative fusional vergence (NFV) at distance and near, and positive fusional vergence (PFV) at distance and near. All vergence parameters were measured before and after watching the movie at 6 m with a 3-prism base-out inducement. A parametric paired *t*-test results analysis showed that there were significant differences in the mean phoria at 6 m ($t(29) = 2.37$, $p<0.05$) and the mean phoria at 6 m ($t(29) = 2.21$, $p<0.05$) before and after the intervention. However, there were no significant differences in the other mean vergence parameters studied ($p>0.05$). In conclusion, after a 20-minute period of 3 prism base-out wear, the vergence parameters observed in this investigation were almost identical for all normal subjects when viewing a distance fixation.

Keywords:
Prism Base-out, Near Point of Convergence (NPC), Negative Fusional Vergence (NFV), Positive Fusional Vergence (PFV), Phoria

Introduction

Vergence can be defined as the simultaneous movement of the pupils of the eyes inward or outward, in order to get a clear image at any distances. Vergence can be defined as both eyes moving in opposite directions which occur together at the same time in order to gain binocular single vision (Solé Puig et al.,2021). Vergence systems play an important role in the fixation of eye movements and depth perception. Vergence includes convergence and divergence in which the fovea of each eye is aligned with the objects in observer's looked at any distance. When looking at a closer object, the eyes rotate towards each other which convergence is involved, while divergence is involved when the eyes rotate apart from each other when looking at a farther object (Solé Puig et al.,2021). If a patient has vergence problems, they may encounter symptoms such as asthenopia, headaches, pulling sensation, blurred vision, intermittent diplopia, inability to sustain concentration, pulling of the eyes and burning or tearing of the eyes. In order to prevent diplopia and facilitate a fused perception, these movements must be extremely correct.

Prism is a transparent, solid, triangular, base-and-apex refracting medium. The power of the prism is determined by its apical angle. The light rays from an object will be deflected outward which is to the base and fall on the retina outer to fovea if a prism is placed in front of one eye with its base pointed outward (Antony, 2017). Since the light rays are deflected outer fovea but still fall on the macula of the other eye, it may result in double vision or diplopia. As a result, the eye with the prism base pointed outward will turn inward, shifting the light that was previously deflected onto the macula providing binocular vision (Antony, 2017). The light deviates towards the prism's base, whereas the eye shifts towards the apex of the prism. Antony (2017) also stated that an adducting prism is a base-out prism, while an abducting prism is a base-in prism. Santos et al. (2018) mentioned that the eyes will rotate inward which is in convergent movement when prisms are positioned base-out.

The inducement of prismatic effects due to off-centred spectacle may give problems to a person's vergence system. Madrolu et al. (2023) reported that the quantity of prismatic effects created relies on the power of the ophthalmic lenses and the displacement of the optical centre of the lens to the pupillary centre of the eye. Reduced stereo acuity and fusional convergence are the results of the induced prismatic effects, which also has an impact on the state of single vision (Madrolu et al., 2023). One of the causes of the common symptoms of aesthenopic symptoms, which include nausea, mild headaches, blurred vision, eye strain, and visual stress that most people encounter nowadays, is the unintentional prismatic effect that is produced in the wearers' glasses. Madrolu et al. (2023) stated that aesthenopic sensations and visual discomfort were present in 40% of the patients with misaligned optical centers that induced prismatic effects. Madrolu et al. (2023) also discovered that the prismatic effect is the main source of intolerance resulting in visual discomfort in those with single-vision lenses and earlier studies indicated that the prolonged usage of decentred spectacle lens can lead to strabismus.

This study aimed to compare the effect of 3 prisms base-out wear on vergence parameters before and after watching a movie for 20 minutes with 6 metres. In this study, the wearing of 3 prisms base-out resembled the off centre of spectacle as the 3 prisms base out will deviate the eye inducing eso-deviation shift causing misalignment of the eye with the optical centre and induces prismatic effects. According to Valiyaveettil et al. (2018), unwanted prisms in eyewear can cause vision issues and discomfort for the wearers including nausea, blur vision, headaches, and double vision. However, the effect of prism wear on vergence is under explored in previous literature.

Materials and Methods

Data collection was conducted at Optometry clinic, Kulliyyah of Allied Health Sciences, International Islamic University Malaysia (IIUM) Kuantan, Pahang. This study was approved by IIUM Research Ethics Committee (IREC) (2023-KAHS/DOVS6) and adhered to the Declaration of Helsinki. Normal and healthy subjects aged 19 to 24 years who had low spherical equivalent refractive error (SER) myopia, range -0.50 D to -3.00 D (Syeda et al.,2023), astigmatism less than -2.00 D (Syeda et al., 2023), TNO stereoacuity test of 60 seconds of arc or better, normal Worth-4-Dot findings and normal extraocular muscle (EOM) findings were recruited for this study. Subjects were excluded if they had microtropia or heterophoria with outside normal range, strabismus or undergone strabismic surgery, complaint of diplopia, amblyopia, taking medication or eye drops with ocular side effects, ocular or systemic diseases, and history of abnormalities that may affect visual function and refractive development.

This clinical cross-sectional study was conducted between March 2023 and July 2024. The sample size calculation was measured using the G*Power version 3.1.9.4 software (Universität Düsseldorf). The effect size chosen was 0.50, while alpha error and power of study value was set at 0.05 and 0.80 respectively. The minimum of sample size recruited for this study was 26 subjects. An informed consent form explaining the screening process and the procedure of the study was explained briefly to the subjects.

In order to fulfil the study's inclusion and exclusion criteria, a preliminary examination or a screening-tests were performed to the subjects. The screening tests which include history taking, refraction, and TNO stereoacuity test, Worth-4-Dot, and EOM test were performed before conducting the study. Refraction was measured initially using the Oculus PARK 1 autorefractor to determine the refractive status followed by subjective refraction.

Subjects' stereopsis was measured using TNO stereoacuity test with the normal value of 60 seconds of arc or better followed by ocular motility test using Broad H test. Subjects that had passed the screening tests following the inclusion criteria will be selected to proceed to the next stage which are pre-measurement of vergence parameters.

The pre-measurement of vergence parameters was categorised as measurement of vergence before intervention. The NPC test, phoria test, PFV and NFV were measured. The amount of NPC was measured using Royal Air Force (RAF) rule. The subject was asked to focus on the black dot on the line which is the standard target for NPC. When using the RAF near point rule (RNPR) to measure the near point of convergence (NPC), a dot on the line is the typical target (Sharma, 2018). The ruler that was held by the examiner will slowly move towards the subject's eyes until the subject reports diplopia or the slide was stopped by the cheek rest. It was known as the subjective breakpoint. When the slide was slowly moved back, the subject may report that one target was seen, and it was noted as recovery. A clinical cut off value of 5 and 7 cm, respectively, have been proposed by several authors for the NPC break and NPC recovery between people with normal binocular vision and convergence insufficiency (Sharma, 2018). Phoria test measurement was purposely to know the magnitude of phoria at distance and near using Howell phoria card. At least 6 prism BD will be placed in front of the subject's right eye and will cause a double image of the numbered line resulting in downward pointing arrow may be seen. If it is pointing towards the blue line, it indicates exophoria while yellow line esophoria. Results on the blue side show even numbers while on the yellow side show odd numbers. Normal results for distance phoria range between 1 esophoria to 3 exophoria while for near between 0 to 6 exophoria. NFV and PFV were also measured at near and distance. It was aimed to measure the fusional reserves of the subjects which can enable the oculomotor system to sustain binocular single vision (BSV) under rising vergence demand. Base in prism was used to measure NFV while base out prism was used to measure PFV. During the test, break and recovery was noted for distance and near. These tests must be done with the subject wearing his or her best corrected VA. For distance, prisms were introduced in one eye while the subject needed to focus on the target that was above than his or her best corrected VA. Prisms were slowly increased, increasing the vergence demand until the subject reported double image was seen which is known as "breakpoint" as the fusion has been disrupted at that point. When the prisms were slowly decreased reducing the vergence demand, the point that the subject reported a single image was seen is the "recovery point". The prisms power at break point and recovery point were noted. For near, the subject needed to focus on the target that was 40 cm from him or her and was done with the same procedure as how the distance NFV and PFV were measured.

Following that, the participants were required to watch a video for 20 minutes at a distance of 6 meters, and they were prescribed 3 prisms base-out with the habitual correction within the 20 minutes of watching the movie. After the participants had watched the movie with 3 prisms base-out for 20 minutes, the participants' vergence parameters were measured again as post-vergence parameters.

The data was analysed by using IBM SPSS software version 20 for Windows (IBM SPSS, Armonk, NY, USA). Normal distribution of the data was analysed using the Shapiro-Wilk test of normality. As all the data were normally distributed, a parametric paired sample t-test was used in order to compare the vergence parameters measured before and after wearing the 3-prism base-out after 20 minutes.

Results

Thirty (30) subjects consisted of 24 females and 6 males with the mean age 22.10±0.76 years were recruited in this study. The mean±SD of vergence parameters and comparison results between pre- and post-intervention of 3-prism base-out on the vergence parameters are shown in Table 1.

Table 1: Mean±SD of vergence parameters and comparison results between pre- and post-intervention of 3-prism base-out on the vergence parameters

Vergence Parameters ($^{\Delta}$)	Pre-Intervention (Mean±SD)	Post-Intervention (Mean±SD)	*t*-value *(p-value)*
Phoria at 6 m	-0.53±1.01	-1.33±1.65	2.37 (0.02)
Phoria at 40cm	-1.90±2.37	-2.80±2.75	2.21 (0.04)
NFV at 6 m	11.07±4.57	11.53±4.19	-1.84 (0.08)
NFV at 40 cm	15.10±5.53	14.83±4.84	1.19 (0.24)
PFV at 6 m	18.17±6.24	20.80±7.13	-0.74 (0.47)
PFV at 40 cm	19.70±7.98	18.40±7.15	0.27 (0.79)
AVG NPC	5.23±3.06	5.20±3.94	0.09 (0.93)

A parametric paired *t*-test results analysis showed that there were significant differences in the mean phoria at 6 m (t (29) =2.37, $p<0.05$) and the mean phoria at 6 m (t (29) =2.21, $p<0.05$) before and after the intervention. However, there were no significant differences in the other mean vergence parameters studied ($p>0.05$).

Discussion

The unintentional shift of optical centres in spherical or spherocylindrical spectacle lenses can induce prism, which can result in heterophoria and patient complaints of diplopia, which typically varies with gaze direction (Serdiuchenko, 2022). Serdiuchenko (2022), also stated that prisms are useful for compensating for latent strabismus and developing fusional reserves in heterophoria, particularly when asthenopic complaints are present. According to Santos et al. (2018), when prisms are positioned base-out, the eyes will rotate inward, in a convergent motion. Wearing 3 prisms base-out is similar to wearing an off-centre spectacle because it causes an eso-deviation shift, which misaligns the eye with the optical centre and produces prismatic effects. Both binocular vision and the vergence-accommodation response can be negatively impacted by spectacles with a decentred optical centre (Logan et al., 2021). Logan et al. (2021) also reported that the vergence-accommodation relationship may be inconsistent due to a decentred optical centre, which could impact how well eye movements and focusing coordinate. Binocular vision also may be affected by this disturbance, which may put stress on the visual system. In this study, the 3 prisms base-out worn for 20 minutes when watching a movie at 6 metres had significant changes on the phoria parameters, both at distance and near

The results of this study revealed that although no significant changes, NFV values at distance and near were increased after wearing 3 prism base-out for 20 minutes when looking at distance. Due to poor motor control brought on by fatigue following convergence inducement, the eye could shift slightly outward in the NFV near findings, which also show significant changes. It also proved that PFV values at distance were improved while at near slightly decrease. Since the 3 prisms' base-out wear might cause the eyes to converge at a distance, the data also show some significant differences in PFV at distance. In addition, NPC values also showed a slight increase but not significant and the results still in normal limit. Despite that, it was found that the phoria at distance and near values have significant changes that showed some increment to the exodeviation values in which the participants' eyes tended to deviate out more after 20 minutes of 3 prisms base-out worn.

Wearing 3 prisms base-out induced convergence as light is bent inward by the base-out prism, making objects appear as if they are coming from a position more towards the centre than they actually are. To preserve single vision in this situation, the eyes must shift inward. Maintaining the necessary eye position requires more effort from the extraocular muscles, especially the medial rectus muscles, which are in charge of converging the eyes. Based on the results of this investigation it is proved that prolonged eye convergence induced outward deviation, or divergence which can increase NFV at distance and near. Following a period of sustained symmetric convergence, the participants displayed divergence eye movements. The rate of divergence varied according to how long the convergence period lasted (Ying & Zee, 2006). Ying and Zee (2006) also discovered that this outward deviation can be exacerbated by sustained convergence efforts, as prolonged convergence can induce muscle potentiation aftereffects in the extraocular muscles, particularly the medial recti, which are responsible for convergence. When the convergence attempt stops, the eyes may deviate outward due to a phenomenon known as muscle potentiation, in which the muscles tense even after the stimulus is eliminated.

Based on Moodley et al. (2011), convergence-inducing prisms can in fact cause eye tiredness. Prism effects due to decentration of ophthalmic lenses can change features of binocular vision, including fusion, and may cause headaches or eye fatigue (Moodley et al., 2011). According to Moodley et al. (2011), prismatic effects can cause diplopia, asthenopia, and blurred vision, among other symptoms. Prisms induce convergence also can lead to eye fatigue over time (Zichun et al., 2022). Numerous investigations have demonstrated that eye fatigue can in fact cause exophoria deviation. This is due to a transient lack of control over eye alignment caused by strained ocular muscles. Exophoria deviation brought on by distance convergence eye fatigue can result in occasional distance exotropia (Sharma et al., 2017). Thus, it proved that wearing prisms induced convergence which resembled the decentred optical centre of glasses can affect motor control and induce outward deviation. Prolonged durations of overconvergence or eye strain can induce exophoria, or the propensity for the eyes to deviate outward (Horn, 2011). The results of this study were also supported by Horn (2011) in which he stated that consequently, eye fatigue brought on by excessive convergence may aggravate or initiate exophoria, affecting visual comfort and perhaps resulting in other visual problems. Thus, this proved that after wearing 3 prisms base out for 20 minutes when looking at distance can increase NFV at distance, induce divergence eye movement, and eyes tend to deviate outward.

The results in this study may improve if it is conducted with higher magnitude of prism power, i.e., 6 prisms base-out and it is better for the subjects to wear the prisms for a longer period which is 30 minutes continuously without losing interest or not focus. This study only includes subjects who were in normal binocular vision status, including the normal range of close and distance phoria. Regarding this, it is also advised to expand the number of subjects participating and incorporate exophoria, or phoria that falls outside of the normal range. This is to assess whether the PFV of exophoric people changes as a result of wearing the prism base-out. Two distinct outcomes might be expected: either the PFV value increases, perhaps helping the state of decompensated exophoria to become compensated exophoria, or the phoria value decreases until it falls within the normal range of phoria. Moreover, as in this study the vergence tests were performed mostly in the evening, it might affect the accuracy of the results. Therefore, it is recommended to perform the vergence tests in the morning to prevent eye fatigue that can affect the results. The visual system is probably more rested in the morning, which lessens the possibility of pre-existing tiredness exacerbating vergence dysfunctions. Vergence-accommodation conflicts impair visual performance and create visual tiredness, hence testing vergence early in the morning is essential to preventing eye fatigue (Vienne et al., 2023)

Conclusion

In conclusion, a 20 minutes 3 prisms base-out inducement when looking at distance provides some significant changes to phoria at distance and near which is more exophoric after the investigation. Some significant changes in PFV at distance also can be seen in the results as the 3 prisms' base-out wear can induce the eyes to converge at distance. The results for NFV near also have significant changes as the eye may drift a slight outward due to poor motor control caused by fatigue after convergence inducement. NPC results, PFV near and NFV distance did not give any significant impact after 3 prisms base out wear inducement at distance fixation. Therefore, the glasses that have a decentred optical centre which can create prismatic effects may give significant changes to phoria distance and near, PFV distance and NFV near to non-binocular vision anomaly participants. To sustain appropriate vergence-accommodation responses and promote healthy binocular vision, it is imperative to ensure adequate centration of optical lenses (Logan et al.,2021). It is envisaged that this study can be carried out further in the future to add and expand more knowledge on the impact of the binocular vision system during prism inducement wear as recommended and suggested in this study. Also, further research could be conducted to add to and broaden our understanding on the effects of the binocular vision system during prism induction wear, as suggested in this study.

Acknowledgement

Special thanks and gratitude to the collaborators, Ms Raihanah Athirah Abdul Halim and Mr Farhi Mohd Hashim for the kind assistance during data collection process.

References

Antony, J. (2017). Prisms in clinical practice. *Kerala Journal of Ophthalmology*, *29*(2), 79. https://doi.org/10.4103/kjo.kjo_84_17

Horn, N. F. (2011, January 1). Esophoria and exophoria in relation to personality [Video recording]. https://typeset.io/papers/esophoria-and-exophoria-in-relation-to-personality-3qft3qd21g

Kumari, P., Azam, S., Abbas, S., Waheed, N., Talpur, A. H., & Bukhari, S. (2022). Effect of vision therapy on fusional vergences in intermittent exotropia. *Advances in Ophthalmology & Visual System, 12*(1), 3–8. https://doi.org/10.15406/aovs.2022.12.00408

Lança, C. C., & Rowe, F. J. (2019). Measurement of fusional vergence: A systematic review. *Strabismus, 27*(2), 88–113. https://doi.org/10.1080/09273972.2019.1583675

Le, Z., Antonov, E., & Mao, Q. (n.d.). Anti-Fatigue Glasses Based on Microprisms for Preventing Eyestrain. *Sensors, 22*(5). https://www.mdpi.com/1424-8220/22/5/1933

Logan, N. S., Radhakrishnan, H., & Cruickshank, F. E. (2021). IMI accommodation and binocular vision in myopia development and progression. *Investigative Ophthalmology & Visual Science, 62*(5), 4–4. https://doi.org/10.1167/IOVS.62.5.4

Madrolu, V. S. K., Male, S. R., Bhardwaj, R., & Theagarayan, B. (2023). Influence of prismatic effect due to decentration of optical center in ophthalmic lens. *Health Science Reports, 6*(8), e1472. https://doi.org/10.1002/hsr2.1472

Moodley, V. R., Kadwa, F., Nxumalo, B., Penciliah, S., Ramkalam, B., & Zama, A. (2011). Induced prismatic effects due to poorly fitting spectacle frames. *African Vision and Eye Health, 70*(4), Article 4. https://doi.org/10.4102/aveh.v70i4.115

Rovira-Gay, C., Mestre, C., Argiles, M., Vinuela-Navarro, V., & Pujol, J. (2023). Feasibility of measuring fusional vergence amplitudes objectively. *PLOS ONE, 18*(5), e0284552. https://doi.org/10.1371/journal.pone.0284552

Santos, E. M., Yaramothu, C., & Alvarez, T. L. (2018). Comparison of symmetrical prism adaptation to asymmetrical prism adaptation in those with normal binocular vision. *Vision Research, 149*, 59–65. https://doi.org/10.1016/j.visres.2018.06.004

Schroth, V., Joos, R., & Jaschinski, W. (2015). Effects of prism eyeglasses on objective and subjective fixation disparity. *PLOS ONE, 10*(10), e0138871. https://doi.org/10.1371/journal.pone.0138871

Serdiuchenko, V. I. (2022). Use of prisms in ophthalmology: A review. Part 2. Use of prisms in heterophoria, nystagmus, and visual nervous system disorders. *Oftalmologicheskii Zhurnal, 97*(2), 48–53. https://doi.org/10.31288/oftalmolzh202224853

Sharma, I. P. (2018). RAF near point rule for near point of convergence-A short review. *Annals of Eye Science, 2*, 16–16. https://doi.org/10.21037/aes.2017.02.05

Sharma, K., Panwar, P., & Chaudary, P. (2017). Intermittent divergent squint in prematurity and its neurophysiological aspects. *Journal of Pediatric Neurosciences, 12*(2), 124–129. https://doi.org/10.4103/JPN.JPN_11_17

Solé Puig, M., Romeo, A., & Supèr, H. (2021). Vergence eye movements during figure-ground perception. *Consciousness and Cognition, 92*, 103138. https://doi.org/10.1016/j.concog.2021.103138

Sreenivasan, V., & Bobier, W. R. (2015). Increased onset of vergence adaptation reduces excessive accommodation during the orthoptic treatment of convergence insufficiency. *Vision Research, 111*, 105–113. https://doi.org/10.1016/j.visres.2015.04.001

Valiyaveettil, B. (2018). Predictors of unwanted prismatic effect among bespectacled symptomatic ametropes (refractive error less than 4 D) with displaced optical centre. *Delhi Journal of Ophthalmology, 28*(3). https://doi.org/10.7869/djo.330

Vienne, C., Blonde, L., & Doyen, D. (2011). Eye movements during vergence effort in stereoscopic ocular pursuit task and their relations to visual fatigue and stereopsis. *F1000Research, 11*(11), 325–325. https://doi.org/10.7490/F1000RESEARCH.1492.1

Ying, S. H., & Zee, D. S. (2006). Phoria adaptation after sustained symmetrical convergence: Influence of saccades. *Experimental Brain Research, 171*(3), 297–305. https://doi.org/10.1007/s00221-005-0267-8