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

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Abstract
Accommodation involves changes in lens shape and optical power facilitated by the ciliary muscle, while vergence adjusts binocular gaze for different distances. Prism, used in treating binocular vision issues, induces convergence and thereby affects accommodation indirectly, especially during near tasks. Spectacle wearers may inadvertently experience prism effects due to optical centre misalignment, potentially impacting accommodation. Previous research combining prism-induced effects on vergence and accommodation among individuals with normal binocular vision found no significant effects, although the specific impact on accommodation remains underexplored. This study aims to provide focused insights into the specific effects of prism-induced accommodation, addressing gaps left by previous research. The purpose of this research was to compare the accommodation parameters before and after 20 minutes of 3-prism base-out wear. Thirty (30) subjects were recruited in this clinical cross-sectional study and all subjects wore the 3-prism base-out for 20 minutes while watching a movie at 6 m distance. All accommodation parameters were measured before and after watching the movie at 6 m with 3-prism base-out inducement. The results showed that there was no significant difference in accommodation parameters before and after the intervention except for the monocular accommodation facility, which were on the right eye (p=0.001) and left eye (p=0.007). In conclusion, it was suggested that wearing 3-prism base-out during distance fixation for 20 minutes had increased monocular accommodation facility in healthy individuals. This indicates that this approach may potentially benefit patients with accommodative infacility, suggesting further exploration for alternative treatments.

Keywords:
Prism Base-out, Amplitude of Accommodation, Lag of Accommodation, Accommodative Facility, Relative Accommodation

Introduction

Accommodation occurs when the eye focuses on a close target which involves changing the optical power and crystalline lens shape of the eye (Glasser, 2006). The process of accommodation system involves the contraction of ciliary muscle and relaxation of zonules fibres that connect the ciliary body to the crystalline lens, causing the thickening and steepening of crystalline lens, which results in an increase in the refractive power of the eye (Plainis et al., 2014). As a result of these physiological changes, the eye can adjust its optical system to maintain clear vision at varying distances (Artal, 2014).

The accommodation and vergence systems are linked to provide a coordinated near response (Sweeney et al., 2014). The accommodation and vergence systems work together to provide clear bifoveal retinal images which are then unified in the visual cortex to form a single binocular image during normal binocular vision (Sweeney et al., 2014). The binocular gaze point is redirected to the physical distance of the visual target by vergence eye movement (Maiello et al., 2018). Vergence is primarily elicited by a combination of retinal disparity and accommodative demand, whereas accommodation is primarily elicited by retinal defocus blur and vergence demand (Maiello et al., 2018). As a result, in normal vision, vergence and accommodation are inextricably linked. Furthermore, convergence may result in indirect accommodation. When convergence takes place, the accommodation system will be stimulated where ciliary muscle contraction will occur which leads to lens shape changes followed by pupil constriction (Motlagh & Geetha, 2022). In addition, coordination of these three responses called near triad alters the eye's power, allowing the focus point of the eye to shift from a distant object to a near object or vice versa.
Prism is a transparent and triangular shape device that functions to create a response whereby when a light enters, it will shift to the base while the image will shift to the apex and the eye examined will deviate towards the apex (Antony, 2017). Prism is mostly used in binocular vision problems, and it is one of the important treatment options for such patients. The decision in prescribing a prism, as well as the value of the prism, is determined subjectively depending on different clinical opinions and practices (Gray, 2008). In relation with accommodation, prism can also create an accommodation demand by using prism base-out. The application of a prism base-out is known to stimulate convergence, thereby indirectly prompting the eyes to accommodate. This phenomenon occurs because the prism alters the visual input, compelling the visual system to adjust both convergence and accommodation in response to the prism-induced changes in binocular vision. Accommodative efforts are increased when prism base-out is placed before the eye, especially during near tasks like reading or using digital devices.

Subsequently, an unintentional prism induction frequently may occur among spectacle wearers. This phenomenon often due to the spectacle decentration, where the optical centre of the lenses does not align perfectly with the individual's pupillary distance. When the optical centre and pupillary distance are not aligned with each other, it will induce an unnecessary prism called prismatic effect causing stereopsis distortion (Arshad et al., 2019). When there is prism base-out inducement, it usually will result in eso-deviation shift, thus indirectly stimulating the accommodation system. There is a similar study that has been conducted with inducement of 6-prism base-out for 15 minutes on vergence and accommodation systems where it concluded that there was no significant effect on both systems among subjects with normal binocular vision (Abu Bakar & Ithnin, 2020). However, the research paper was combined both vergence and accommodation together, hence the result could not be straightforwardly interpreted as they were presented. Since previous investigations inadequately addressed the short-term impact of prism induction solely on the accommodation system, this study was proposed to comprehensively evaluate the effect of 3-prism base-out wear on accommodation parameters before and after 20 minutes watching video at 6-metres.

Materials and Methods

This study was conducted in International Islamic University Malaysia (IIUM) Optometry Clinic, IIUM Kuantan campus, Kuantan, Pahang. The protocol of study adhered to the tenets of Helsinki Declaration and approval of conducting the study was approved by IIUM Research Ethics Committee (IREC 2023-KAHS/DOVS4). A cross-sectional clinical study was conducted between March 2023 and July 2024. The calculation of sample size was obtained from the G*Power software version 3.1.9.4 for Windows. The effect size selected was 0.5, while alpha error and power value was set at 0.05 and 0.80, respectively.
The inclusion criteria of the subject for this study were healthy (free from ocular and systemic diseases), aged between 19-24 years, low spherical equivalent refraction (SER) myopic range between -0.50 D to -3.00D (Syeda et al., 2023), astigmatism less than 1.00 D and normal binocular vision. Subjects were excluded from the study if they presented with strabismus or had undergone strabismic surgery, amblyopia, were currently taking medications known to have ocular side effects or exhibited any other abnormalities that could potentially impact visual function and the development of refractive conditions.

All subjects were explained about the procedure of the study and were asked to sign a consent form if he or she agreed to participate in the study. Next, the screening was conducted including history taking, refraction, stereopsis, Worth-4-Dot (W4D) test and ocular motility test to exclude those who did not meet the inclusion criteria. The refractive status was measured initially using Oculus PARK 1® autorefractor followed by subjective refraction. Subject's stereopsis was measured using TNO stereoacuity test with normal level 60 seconds or better (Zhang et al., 2021). Furthermore, the W4D test was done for both distance and near, followed by ocular motility test using Broad H test.

The subjects who passed the screening underwent further comprehensive binocular vision assessment mainly focused on accommodation parameters which included amplitude of accommodation (AA), lag of accommodation (LA), accommodative facility (FA), negative relative accommodation (NRA) and positive relative accommodation (PRA).

The AA was measured monocularly with Royal Air Force (RAF) rule using push-up and push down methods while focused on the N5 letter target. The subject was asked to wear his or her habitual correction prior to this test. The target was pushed slowly towards the subject until the letter became and remained blurry. Then, it will be pulled away until the letters became clear. The test was repeated for 3 times to obtain the average value. The average expected amplitude of accommodation was calculated using Hofstetter's formula which is 18.5-0.3(age) (Carlson & Kurtz, 2016).

Next, LA was determined by the monocular estimation method (MEM) using dynamic retinoscopy. The test was also conducted where the subject was wearing habitual correction. They were instructed to read the words on the card that was attached to the retinoscope while the LA was neutralised simultaneously for both right and left eyes. The trial lens power used to neutralise indicates whether subjects' accommodation was lead or lag. The value for LA between +0.25 D and +0.75 D was considered normal in all age group (Thakur et al., 2019)

Moreover, the FA test was also conducted monocularly and binocularly using ±2.00 D flipper lens and rock card N10 letter target at a 40 cm distance. The flipper lens was interchangeably started with +2.00 D followed by -2.00 D as rapidly as one can after the subject saw the target became clear. The test was set for one minute and the result was recorded in cycles per minute (cpm). The test's expected findings for adults 13 to 30 years old is 10 cpm binocularly and 11 cpm monocularly (Carlson & Kurtz, 2016).

In addition, the NRA and PRA were also measured binocularly whereby NRA was performed by adding plus lenses in 0.25 D step at a time until the subject experienced first sustained blur. Meanwhile PRA was performed by adding minus lenses 0.25 D step at a time until the subjects reported first sustained blur. The expected findings for NRA were +2.00 D (±0.50 D), while PRA was -2.37 D (±1.00 D) in the non-presbyopic subject (Carlson & Kurtz, 2016).

Subsequently, a 3-prism base-out lens was placed in front of the right eye over their habitual correction, and they were instructed to watch a video for a duration of 20 minutes at 6 m distance. Following this viewing period, post-accommodation parameters were measured for each subject to assess any changes of accommodation parameters induced by the prism.

The data was analysed using IBM SPSS Software version 20.0 for Windows (IBM SPSS, Armonk, NY, USA). The normality test was performed for all data using central limit theorem since 30 subjects were recruited prior to analysation of data. As the normality assumption was met, a parametric paired *t*-test was used to compare the accommodation parameters measured before and after wearing the 3-prism base-out for 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. Table 1 shows the comparison between pre- and post-intervention of 3-prism base-out on the accommodation parameters after 20 minutes watching a movie at 6 m distance. A parametric paired *t*-test analysis showed that there was no significant difference in accommodation parameters before and after the intervention ($p>0.05$), except for the monocular accommodation facility, which on the right eye ($p=0.001$) and left eye ($p=0.007$). Also, for the mean difference, all accommodation parameters show reduction in the range of 0 D to 0.17 D, except for the monocular accommodation facility which showed an increment of -0.84 D in the right eye and -0.57 D in the left eye.

Table 1: Comparison table between pre- and post-intervention of 3-prism base-out on the accommodation parameters

Accommodative Parameters	Pre-Intervention (Mean±SD)	Post-Intervention (Mean±SD)	*t*-value (*p-value*)
AA right eye (D)	10.53±1.69	10.53±1.53	0.00 (1.000)
AA left eye (D)	10.64±1.62	10.56±1.44	-0.073 (0.942)
LA right eye (D)	0.65±0.20	0.61±0.25	1.409 (0.169)
LA left eye (D)	0.65±0.21	0.64±0.25	0.273 (0.787)
FA right eye (cpm)	10.23±2.13	11.07±2.16	-3.878 (0.001)
FA left eye (cpm)	10.83±2.45	11.40±2.47	-2.895 (0.007)
FA both eyes (cpm)	10.10±1.88	10.10±2.01	0.00 (1.000)
NRA (D)	3.07±0.52	2.98±0.69	1.044 (0.305)
PRA (D)	-4.03±1.00	-4.20±0.88	1.238 (0.226)

Discussion

In this study, we compared the accommodation parameters before and after wearing the 3-prism base-out for 20 minutes while looking at 6 m distance on subjects with normal binocular vision. The findings revealed that accommodation parameters of normal subjects did not show any significant changes except for monocular accommodation facility. The accommodation facility is also closely related to dynamic accommodation. The accommodation facility measures the speed and flexibility of the eye's focusing system (Maxwell et al., 2012), while dynamic accommodation assesses its real-time ability to adjust focus in response to changing target distances such as from distance to near target or vice versa, and rates of distance accommodation facility seem to correlate with accommodative dynamic in term of overall performance of the accommodative system (Allen et al., 2010). While looking at near target accommodation will be stimulated, whereas it will be relaxed when someone looks at a distance viewing (Plainis et al., 2014). It was related to this research whereby the subject was wearing 3-prism base-out which will induce convergence and stimulate accommodation indirectly as per the eye is actually looking at a near target. Moreover, in this research, the subjects were instructed to watch a movie at 6 m distance, which represents that the accommodation was relaxed. Both stimulation and relaxation of eye muscles occur at the same time within 20 minutes and surprisingly, it results in an improvement in accommodation facility monocularly.

This result has provided an insight for individuals with accommodative anomalies, especially accommodative infacility. The accommodative infacility was defined as slow adjustment in focusing between near and far distances (Balke et al., 2022). Usually in optometric practices, this accommodative infacility will be treated by prescribing visual therapy to patient. As for the office-based therapy, the ±2.00 D flipper lens will be used while focus on a rock card at 40 cm (Calo-Santiago et al., 2019), whereas for home-based therapy, patients are prescribed with a hart chart therapy which consists of distance and near charts (Balke et al., 2022). Both therapies have the same concept which trains the eye muscle to stimulate and relax the accommodation with the aim of restoring normal value of accommodation facility.

In this study, it has suggested the idea for an alternative treatment that by incorporating a specified amount of prism base-out over the refractive correction for a certain duration could potentially help in improving accommodative infacility issues in affected individuals. This method might also serve as a passive therapeutic option for patients who struggle with adhering to active visual therapies, particularly children with limited attention spans. By adopting this approach, patients experiencing such challenges would simply need to incorporate some amount prism base-out over their spectacle correction and follow instruction to watch movies or videos at a specified distance for a designated period of time.

Although there was a significant increment of monocular accommodation facility, the changes in other accommodation parameters were not statistically significant. This outcome could potentially be attributed to the relatively small magnitude of the 3-prism base-out used in this study, especially when compared to similar research that utilised a 6-prism base-out for 15 minutes, which also found no significant effects on vergence and accommodation systems (Abu Bakar & Ithnin, 2020). Thus, it is recommended to consider a higher magnitude of prism dioptres in future studies, as this may lead to more pronounced improvements in various accommodation parameters.

In addition, given that the intervention period of 20 minutes was relatively short, it is suggested to extend the duration of the intervention to approximately 30 minutes in future research. Conducting the intervention continuously without interruption could potentially enhance the effectiveness of the intervention and provide more robust insights into its effects on desired outcomes related to accommodation system.

Furthermore, the research was mostly conducted during evening sessions, which may have contributed to visual fatigue and potentially influenced visual performance, particularly affecting the accommodation system (Sigamani et al., 2022). To improve future research methodologies, it is recommended to carefully select appropriate and coordinated timing, such as conducting experiments in the morning, to minimise the risk of visual fatigue throughout the day. Additionally, it could be beneficial to conduct separate measurements of accommodation parameters, especially after prism intervention. This approach would help mitigate the impact of visual fatigue and provide more reliable data on the effects of prism base-out interventions on accommodation system.

Apart from that, only subjects with normal binocular vision were selected for participation in this study. For future research, it is suggested to broaden the scope by including subjects with abnormal binocular vision conditions, such as accommodation anomalies. This expanded approach would enable a comprehensive assessment of whether wearing a prism base-out induces alterations in accommodation parameters among individuals experiencing accommodation anomalies. Such investigations could potentially deepen our understanding and contribute valuable insights into the therapeutic applications of prism use in clinical settings.

Conclusion

The findings of this research imply that wearing 3-prism base-out at distance fixation for only 20 minutes lead to increment of monocular accommodation facility in a healthy individual. This study provides insight into the potential benefits of using prism base-out as a passive therapy, combined with distance fixation for improving accommodative infacility issues in patients. With the presence of this study, it becomes evident that applying a specific amount of prism base-out while engaging in distance fixation for a prescribed duration could offer an alternative treatment approach for patients experiencing accommodative infacility problems. This approach holds promise for enhancing therapeutic strategies, potentially leading to more effective management and improvement of visual accommodation difficulties. Therefore, expanding this research to include accommodative infacility patient groups could further validate its efficacy and broaden its application as a viable treatment option. Ultimately, the aim is to offer new avenues for addressing visual accommodation challenges and improving quality of life for affected individuals.

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