Original Article

Inverting peripheral hyperopic defocus into myopic defocus among myopic schoolchildren using addition power of multifocal contact lens

Kareem Allinjawi[1,2], Sharanjeet Kaur[1], Saadah M. Akhir[1], Haliza A. Mutalib[1]

Access this article online

Quick Response Code:

Website:
www.saudijophthalmol.org

DOI:
10.4103/1319-4534.305035

Abstract:

PURPOSE: The purpose was to determine the minimum near-addition power needed using Proclear® multifocal D-Design contact lens (adds: +1.50 D, +2.50 D, +3.00 D, and +3.50 D) to invert the pattern of relative hyperopic defocus in the peripheral retina into relative myopic defocus among the eyes of myopic schoolchildren.

METHODS: Twenty-seven right eyes (24 females and 3 males) of 27 myopic schoolchildren aged between 13 and 15 years were included in this study. The measurements of central refraction, peripheral refraction (between 35° temporal and 35° nasal visual field in 5° steps), and lag of accommodation were conducted using the Grand-Seiko WR-5100K open-field autorefractometer initially without correction (WC), followed by with correction using four different addition powers of Proclear® multifocal D-Design contact lens in random sequence. Axial length was measured using a handheld probe ultrasound A-scan (Tomey AL-2000).

RESULTS: The relative peripheral refractive error showed high hyperopic defocus of +1.08 ± 1.24 D at 35° nasal and +1.06 ± 1.06 D at 35° temporal visual field WC. All Proclear multifocal contact lenses (MFCLs) decreased the peripheral hyperopic defocus with increasing addition powers (F [2.938, 47.001] = 13.317, $P < 0.001$). However, only +3.00 D addition and +3.50 D addition ($P = 0.001$) could invert the peripheral hyperopic defocus into peripheral myopic defocus. Apart from that, the +3.00 D addition lens showed the lowest lag of accommodation (+1.10 ± 0.83 D) among the other MFCL adds ($P = 0.002$).

CONCLUSION: A +3.00 D addition Proclear MFCL is the optimal addition power that can invert the pattern of peripheral hyperopic defocus into myopic defocus.

Keywords:

Multifocal contact lenses, myopia, peripheral hyperopic defocus, peripheral myopic defocus, schoolchildren

[1]Optometry and Vision Science Programme, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Jalan Raja Muda Abdul Aziz, Kuala Lumpur, Malaysia, [2]Department of Optometry, University of Jeddah, Hamzah Ibn Al Qasim Street, Al Sharafeyah, Jeddah, Saudi Arabia

Address for correspondence:
Prof. Sharanjeet Kaur,
Optometry and Vision Science Programme, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Jalan Raja Muda Abdul Aziz, 50300 Kuala Lumpur, Malaysia.
E-mail: sharanjeet@ukm.edu.my

Submitted: 10-Jul-2019
Revised: 13-Sep-2020
Accepted: 13-Sep-2020
Published: 28-Dec-2020

INTRODUCTION

Myopia, the most common type of refractive error, has become a global health problem. Myopes with high degree of myopia are at risk of potentially irreversible blinding myopia pathologies.[1] The etiology of myopia has been extensively studied. Indeed, the effects of environmental factors could manipulate myopia prevalence among children. It is believed that accommodative response (AR) and binocular vergence has an important impact on the progression of myopia.[2] Myopes have been shown to have larger lag of accommodation than the emmetropes.[3] Because there is a well-established association between myopia progression and near work, it is believed that the larger lag of accommodation could be an accelerating factor in myopia progression. However, many clinical trials conducted using reading addition to reduce the accommodative lag have shown small clinically insignificant treatment effects.[4-6]

Insufficient accommodation during near work leads to hyperopic defocus on the peripheral retina, which eventually stimulates the eye to grow axially backward.[2,7] Researchers have

How to cite this article: Allinjawi K, Kaur S, Akhir SM, Mutalib HA. Inverting peripheral hyperopic defocus into myopic defocus among myopic schoolchildren using addition power of multifocal contact lens. Saudi J Ophthalmol 2020;34:94-100.

shown that hyperopic and emmetropic eyes have peripheral refractive errors that are myopic relative to the fovea.[8,9] In contrast, myopic eyes have less myopia in the peripheral retina compared to that of the central retina, especially in the horizontal visual field. This means that the myopic peripheral retina has increasingly greater amount of hyperopic blur. Mutti *et al*. suggested that relative hyperopic peripheral refractive error may be a risk factor at the onset and progression of myopia in children and adults and the traditional spectacle lens design shows no effect to reduce or eliminate peripheral hyperopia defocus.[10] Researchers found that both children and adults who exhibited myopia at the fovea typically demonstrated more hyperopia shift at the periphery.[10,11]

Curcio *et al*. explained that the human fovea, where spatial vision is most accurate, is only about 1°, which is <1% of the visual field diameter.[12] Therefore, the fovea, which is usually assessed during refraction, only accounts for a small area of the overall visual field. Wallman and Winawer pointed out that with this huge imbalance, the peripheral retinal refractive errors could probably drive the development of the refractive error of the eye.[13]

Contact lenses are commonly used by optometrists to correct refractive error. Few studies have attempted to control the progression of myopia by reducing the demand of accommodation using bifocal[14] or multifocal contact lens (MFCL).[15] The hypothesis to control myopia progression among children is to afford clear vision over a wide range of viewing conditions with minimum need of accommodation. With a +3.00 D addition Proclear multifocal dominant design contact lens (Cooper Vision), it has been shown that there are changes in the pattern of relative peripheral hyperopic defocus in young adults.[16] However, the progression of myopia is greater and faster in children, which might have different clinical characteristics than that in young adults. Because there is evidence that a reduction in the peripheral retinal hyperopic defocus could slow myopia progression,[10] this study aimed to experimentally determine the minimum near-addition power required to invert the pattern of relative hyperopic defocus in the peripheral retina into myopic defocus and maintain a near-normal lag of accommodation among myopic schoolchildren.

METHODS

The purpose, benefits, risks, and procedures involved were explained to all parents and children. A written consent form in accordance with Universiti Kebangsaan Malaysia (UKM) guidelines was signed by each parent. This research was approved by the Ethics Committee of UKM, UKM (1.5.3.5/244/NN-144-2013), and the tenets of the Declaration of Helsinki in using human subjects were followed. The study was conducted at the UKM Optometry Clinic and Vision Science Lab.

Schoolchildren aged between 13 and 15 years were recruited in this study. Twenty-seven right eyes (24 females and 3 males) of 27 myopic schoolchildren were examined. The inclusion criteria were visual acuity of 6/9 or better with best correction in both eyes, spherical component refractive error between −3.00 D and −6.00 D, normal ocular and systemic health condition, astigmatism <−1.00 D, and have been myopic for >6 months. The exclusion criteria were having any manifest strabismus or amblyopia, a history of bifocal or progressive spectacles wear, orthokeratology contact lens wear, or current soft contact lens wearer.

Noncycloplegic objective and subjective refractions were obtained to determine the refractive error for each child. Contact lens fitting was initially conducted. Only if the fitting was optimal, the child was recruited into the study. Central and peripheral refraction were measured using the open-view autorefractometer Grand-Seiko WR-5100K (Grand Seiko Co., Ltd., Hiroshima, Japan). The mean illumination of the examination room was 9.91 ± 1.73 lux (mean of three measurements, measured using Topcon Illuminance Meter IM-5, Topcon Corp, Japan). This allowed a sufficiently large pupil size to measure peripheral refraction without using dilation drops.

The measurements obtained were initially without correction (WC), then re-measured again with each one of the four addition powers (+1.50 D, +2.50 D, +3.00 D, and +3.50 D) of Proclear® MFCL D-design (Cooper Vision) in random sequence.

These lenses are made from 38% omafilcon A and 62% water content. It has a diameter of 14.4 mm and a base curve of 8.7 mm. The lens design has 2.3-mm inner distance central spherical area which compensates for the patient's distant refractive error, surrounded by an annular aspheric zone where the addition power increases gradually to reach its maximum at 5-mm chord area, followed by a second spherical zone from 5- to 8.5-mm chord which has the maximum addition power. The modality of this lens is monthly disposable.

The schoolchildren were instructed to fixate targets at 4 m arranged horizontally in the positions corresponding to eccentricities from 35° temporal to 35° nasal, in 5° steps. This study used straight ahead viewing technique where the children rotated their eyes to view a series of fixation targets. Five refraction measurements were taken at each eccentricity target for the right eye, whereas the left eye was occluded. For statistical analysis, the spherocylindrical refractive error measurements were converted into vector components of refraction M, J_0, and J_{45} using the following equations recommended by Thibos *et al*.:[17]

$$M = \text{sph} + (\text{cyl}/2),$$

$$J_0 = (-\text{cyl}/2)\cos(2\alpha),$$

$$J_{45} = (-\text{cyl}/2)\sin(2\alpha),$$

Where shp, cyl, and (α) are the values of sphere, cylinder, and axis, respectively. Relative peripheral refractive error (RPRE) was calculated as the difference between eccentric peripheral point and central value (eccentric point − central refraction).

Axial length was measured using a handheld probe ultrasound A-scan (Tomey AL-2000). The outcome was calculated as the mean of five measurements taken. AR was measured monocularly (right eye only) at 40 cm using an open-field autorefractometer WR-5100K (Grand Seiko Co., Ltd., Hiroshima, Japan). The lag of accommodation was calculated by using the following equation:

$$\text{Lag} = 2.50\ \text{D} - \text{AR}.$$

Analysis was performed using SPSS statistical software version 20 (SPSS Inc., Chicago, IL, USA). For all the 27 participants in this study, only data from the right eyes were analyzed. A Shapiro–Wilk test was used to evaluate the normality of the data distribution. A paired *t*-test was used for paired comparisons at the different eccentricities within each addition power lens. When normality could not be assumed, the Wilcoxon signed-rank test was used. The differences were considered statistically significant when $P < 0.05$. Repeated-measures analysis of variance (ANOVA) was performed to compare eccentricity and accommodation lag between WC and each addition lens power.

RESULTS

The mean central spherical equivalent refractive error for the study population was found to be − 4.39 ± 0.95 D (range: −3.12 D to − 5.93 D) WC; the axial length ranged from 23.51 mm to 26.39 mm (mean: 24.72 ± 0.92 mm); and the mean age of the study population was 14.18 ± 0.88 years.

Relative peripheral refractive error

Table 1 illustrates the values of mean spherical equivalent

Table 1: Mean value of spherical equivalent refractive error (M±standard deviation), horizontal astigmatism component (J_0±standard deviation), and oblique astigmatism component (J_{45}±standard deviation) for 70° different horizontal eccentricity visual for without correction (WC), with Proclear +1.50 D add, Proclear +2.50 D add, Proclear +3.00 D add, and Proclear +3.50 D add

Eccentricity	M±SD														
	M					J_0					J_{45}				
	WC	+1.50 D	+2.50 D	+3.00 D	+3.50 D	WC	+1.50 D	+2.50 D	+3.00 D	+3.50 D	WC	+1.50 D	+2.50 D	+3.00 D	+3.50 D
N35	−3.32±1.59	0.02±1.35	−1.05±1.38	−1.66±1.34	−2.15±1.15	0.11±0.84	−0.04±1.15	0.05±1.31	−0.04±1.1	0.04±1.36	0.18±0.91	0.17±0.83	−0.02±0.94	−0.12±1.36	−0.43±1.23
N30	−3.6±1.49	−0.41±1.19	−1.31±1.13	−1.76±1.07	−2.45±1.1	0.02±0.93	−0.08±0.78	0.14±0.94	0.15±0.88	−0.25±1.25	−0.15±0.58	−0.1±0.7	0.07±0.97	−0.16±1.08	−0.02±1.01
N25	−4.09±1.36	−0.78±0.97	−1.64±0.94	−2.08±0.91	−2.79±0.98	0.06±0.7	0.23±0.55	0.09±0.66	0±0.85	−0.06±1.12	−0.18±0.58	−0.18±0.73	0.07±0.85	0.08±0.92	−0.14±0.92
N20	−4.31±1.09	−1.14±0.76	−1.82±0.73	−2.29±0.84	−2.88±0.85	0±0.36	0±0.42	−0.18±0.58	−0.23±0.67	0.06±0.77	0.07±0.51	0.21±0.45	0.24±0.60	−0.23±0.74	0.26±0.77
N15	−4.41±1.11	−1.16±0.62	−1.51±0.7	−2.08±0.72	−2.45±0.94	0.01±0.28	−0.02±0.43	0.04±0.37	−0.08±0.55	−0.04±0.63	0.05±0.37	−0.09±0.38	−0.15±0.47	0.03±0.53	0.09±0.66
N10	−4.43±0.93	−1.22±0.55	−1.36±0.8	−1.86±0.65	−2.21±0.68	−0.03±0.23	0.11±0.28	−0.08±0.38	−0.12±0.33	0.15±0.62	−0.04±0.25	−0.04±0.41	0±0.40	−0.02±0.49	−0.06±0.43
N5	−4.37±0.89	−1.13±0.4	−1.19±0.7	−1.56±0.64	−1.81±0.75	0±0.27	0.04±0.26	−0.14±0.34	0±0.37	−0.07±0.44	−0.01±0.23	0.06±0.27	0.03±0.33	0.02±0.31	−0.04±0.46
C	−4.39±0.95	−1.11±0.36	−1.2±0.64	−1.49±0.62	−1.77±0.77	−0.04±0.25	0±0.24	−0.11±0.32	−0.01±0.32	0.09±0.50	−0.03±0.23	−0.01±0.27	0.02±0.38	0.04±0.40	−0.02±0.33
T5	−4.2±0.98	−1.19±0.5	−1.28±0.64	−1.51±0.71	−1.65±0.90	0.02±0.26	0.07±0.22	0.01±0.39	0±0.37	−0.02±0.34	−0.06±0.28	−0.01±0.4	0.06±0.43	−0.02±0.47	−0.01±0.51
T10	−4.52±1.04	−1.21±0.7	−1.2±0.84	−1.47±0.92	−1.74±1.01	0.07±0.31	0.01±0.35	0.02±0.36	−0.04±0.29	−0.14±0.38	0.02±0.32	−0.05±0.25	−0.07±0.37	0.1±0.43	0.17±0.44
T15	−4.33±1.34	−1.13±0.86	−1.15±0.94	−1.34±0.99	−1.68±1.14	0.03±0.34	0.11±0.31	−0.02±0.35	−0.07±0.37	−0.13±0.49	−0.07±0.27	0.06±0.38	0.09±0.41	−0.01±0.39	0.07±0.45
T20	−4.19±1.2	−0.77±0.98	−1.13±1.21	−1.2±1.17	−1.53±1.34	−0.07±0.38	−0.04±0.45	−0.05±0.39	−0.08±0.32	−0.19±0.50	−0.04±0.36	−0.2±0.35	0.02±0.51	0.02±0.53	0.12±0.47
T25	−3.86±1.31	−0.69±1.02	−1.14±1.23	−1.52±1.26	−1.54±1.49	−0.05±0.34	0.01±0.36	0.1±0.49	−0.02±0.43	0.05±0.39	−0.01±0.36	−0.02±0.27	0.07±0.47	−0.05±0.53	−0.02±0.55
T30	−3.63±1.35	−0.5±1.13	−1.11±1.08	−1.46±1.25	−1.8±1.2	−0.07±0.54	0.07±0.45	−0.01±0.52	−0.04±0.72	0.06±0.67	0.11±0.41	0.02±0.45	−0.07±0.58	−0.12±0.61	−0.19±0.62
T35	−3.34±1.32	−0.3±1.11	−0.99±1.17	−1.55±1.09	−1.89±1.47	0.13±0.5	−0.25±0.58	0±0.59	−0.16±0.57	−0.13±0.58	−0.01±0.59	0.04±0.6	−0.2±0.63	−0.28±0.74	−0.19±0.89

Eccentricity points represented as: *C* is center, *N* is nasal visual field, and *T* is temporal visual field. WC=Without correction; SD=Standard deviation

Table 2: Relative peripheral refractive error in mean spherical equivalent values (M±standard deviation), horizontal astigmatism component (J_0±standard deviation), and oblique astigmatism component (J_{45}±standard deviation) for without correction (WC), with Proclear +1.50 D add, Proclear +2.50 D add, Proclear +3.00 D add, and Proclear +3.50 D add

Eccentricity	WC		+1.50 D		+2.50 D		+3.00 D		+3.50 D	
	M±SD	Significant	M±SD	Significant	M±SD	Significant	M±SD	Significant	M±SD	Significant
					M					
N35	1.08±1.24	<0.001^p	1.13±1.31	<0.001^p	0.15±1.37	0.579^p	−0.17±1.41	0.526^p	−0.38±1.44	0.283^p
N30	0.8±1.1	0.001^p	0.69±1.16	0.004^p	−0.1±1.16	0.786^p	−0.26±1.15	0.243^p	−0.68±1.22	0.031^p
N25	0.31±0.86	0.074^p	0.32±0.91	0.075^p	−0.44±0.88	0.015^p	−0.59±0.94	0.003^p	−1.02±1.02	0.001^p
N20	0.09±0.57	0.429^p	−0.03±0.66	0.808^p	−0.62±0.71	<0.001^p	−0.8±0.87	<0.001^p	−1.11±0.83	<0.001^p
N15	−0.03±0.43	0.717^p	−0.06±0.5	0.568^p	−0.31±0.51	0.004^p	−0.6±0.70	0.001^p	−0.67±0.86	0.004^p
N10	−0.02±0.35	0.716^p	−0.1±0.41	0.209^p	−0.1±0.57	0.175^p	−0.36±0.64	0.007^p	−0.44±0.66	0.011^p
N5	0.02±0.19	0.578^p	−0.02±0.22	0.643z	0.01±0.40	0.850z	−0.07±0.52	0.324^p	−0.04±0.47	0.736^p
T5	−0.02±0.31	0.708^p	−0.08±0.43	0.694^p	−0.08±0.55	0.432^p	−0.01±0.64	0.906z	0.12±0.49	0.316^p
T10	−0.13±0.5	0.196^p	−0.1±0.59	0.364^p	0±0.68	0.982^p	0.02±0.79	0.900^p	0.03±0.73	0.881^p
T15	0.06±0.92	0.733^p	−0.02±0.79	0.882^p	0.05±0.85	0.736^p	0.15±0.9	0.384z	0.09±0.75	0.627^p
T20	0.2±0.77	0.178^p	0.34±0.94	0.072^p	0.1±1.21	0.685^p	0.29±1.15	0.200z	0.34±1.15	0.240^p
T25	0.54±0.9	0.018^p	0.42±0.95	0.031^p	0.06±1.24	0.796^p	−0.03±1.29	0.903^p	0.23±1.41	0.505^p
T30	0.76±1.09	0.001^p	0.64±1.05	0.004^p	0.09±1.01	0.640^p	0.03±1.29	0.893^p	−0.03±1.12	0.901^p
T35	1.06±1.06	<0.001^p	0.81±1.1	0.001^p	0.21±1.03	0.301^p	−0.06±1.11	0.780^p	−0.12±1.4	0.718^p
					J_0					
N35	−0.02±0.97	0.090^p	0.16±0.86	0.858^p	0.12±1.32	0.642^p	−0.03±1.08	0.889^p	−0.06±1.28	0.855^p
N30	−0.05±0.99	0.855^p	0.20±0.67	0.226^p	0.25±1.02	0.202^p	0.52±0.86	0.004^p	−0.34±1.21	0.248^p
N25	0.22±0.69	0.495^p	0.02±0.68	0.920^p	0.20±0.67	0.129^p	0.02±0.92	0.916^p	−0.15±1.18	0.585^p
N20	0.05±0.47	0.629^p	−0.03±0.45	0.410^p	−0.07±0.70	0.614^p	−0.19±0.73	0.197^p	−0.03±0.96	0.908^p
N15	0.07±0.30	0.683^p	0.01±0.40	0.505^p	0.15±0.47	0.102^p	−0.06±0.66	0.616^p	−0.13±0.81	0.500^p
N10	0.06±0.29	0.630^p	0.05±0.41	0.568^p	0.04±0.58	0.749^p	−0.11±0.52	0.284^p	0.06±0.82	0.750^p
N5	0.03±0.41	0.865^p	0.07±0.37	0.487^p	−0.02±0.50	0.791^p	0.01±0.46	0.901^p	−0.16±0.73	0.361^p
T5	0.14±0.31	0.125^p	−0.03±0.41	0.497^p	0.12±0.56	0.271^p	0.02±0.51	0.873^p	−0.11±0.45	0.327^p
T10	0.12±0.36	0.421^p	0.01±0.48	0.741^p	0.11±0.43	0.186^p	0.01±0.44	0.935^p	−0.24±0.65	0.138^p
T15	0.17±0.40	0.398^p	−0.01±0.47	0.187^p	0.09±0.50	0.337^p	−0.06±0.49	0.535^p	−0.22±0.82	0.266^p
T20	0.05±0.52	0.852^p	0.11±0.56	0.414^p	0.07±0.53	0.465^p	−0.06±0.44	0.500^p	−0.25±0.78	0.182^p
T25	0.05±0.40	0.894^p	0.01±0.51	0.948^p	0.21±0.58	0.066^p	0±0.56	0.997^p	−0.04±0.83	0.777z
T30	0±0.52	0.310z	0.05±0.60	0.918^p	0.09±0.71	0.472^p	−0.03±0.85	0.863^p	−0.03±0.84	0.871^p
T35	0.16±0.56	0.967z	0.2±0.43	0.301z	0.11±0.59	0.324^p	−0.15±0.58	0.200z	−0.22±0.80	0.247^p
					J_{45}					
N35	0.21±1.01	0.440^p	0.21±1	0.149^p	−0.04±1.15	0.853^p	−0.16±1.31	0.528^p	−0.41±1.26	0.185^p
N30	−0.12±0.67	0.139^p	0.22±0.87	0.355^p	0.04±0.91	0.793^p	−0.2±1.09	0.344^p	0±1.04	0.995^p
N25	−0.15±0.68	0.190^p	−0.04±0.62	0.722^p	0.04±1	0.812^p	0.04±1.04	0.835^p	−0.12±0.93	0.573^p
N20	0.09±0.51	0.953^p	−0.09±0.51	0.084^p	0.22±0.73	0.135^p	−0.27±0.81	0.090^p	0.28±0.86	0.185^p
N15	0.07±0.42	0.674^p	−0.03±0.41	0.746^p	−0.17±0.62	0.175^p	0±0.72	0.973^p	0.12±0.73	0.501^p
N10	−0.02±0.26	0.386^p	−0.02±0.38	0.692^p	−0.01±0.56	0.894^p	−0.06±0.71	0.665^p	−0.04±0.47	0.711^p
N5	0.02±0.28	0.911^p	0.04±0.39	0.965^p	0±0.51	0.946^p	−0.01±0.53	0.879^p	−0.02±0.58	0.885^p
T5	−0.03±0.37	0.428^p	0.11±0.40	0.436^p	0.04±0.62	0.755^p	−0.06±0.61	0.631^p	0.01±0.63	0.921^p
T10	0.06±0.40	0.972^p	0±0.39	0.729^p	−0.13±0.54	0.224z	0.03±0.64	0.818^p	0.23±0.45	0.047^p
T15	−0.04±0.31	0.144^p	−0.05±0.41	0.570^p	0.07±0.58	0.514^p	−0.05±0.57	0.659^p	0.09±0.42	0.355^p
T20	−0.01±0.44	0.408^p	0.11±0.43	0.054^p	0±0.72	0.977^p	−0.02±0.75	0.871^p	0.14±0.46	0.200^p
T25	0.02±0.45	0.805^p	0±0.41	0.447^p	0.05±0.59	0.671^p	−0.09±0.58	0.418^p	0±0.68	0.997^p
T30	0.14±0.44	0.250^p	0.08±0.62	0.650^p	−0.09±0.74	0.530^p	−0.16±0.73	0.254^p	−0.17±0.82	0.381^p
T35	0.02±0.59	0.793^p	0.06±0.48	0.627^p	−0.24±0.79	0.123^p	−0.32±0.75	0.037^p	−0.16±0.95	0.463^p

*The value of statistical significant test represented as: (*p*) is paired sample *t*-test, or (*z*) is Wilcoxon signed-rank test. The red color indicates statistically significant difference when compared with central value (95% confidence). SD=Standard deviation

refraction (M), horizontal astigmatism component (J_0), and oblique astigmatism component (J_{45}) with the standard deviation (SD) along the central and peripheral horizontal visual field (35° temporal to 35° nasal) for WC and with Proclear® MFCL D-design (Coopervision) (addition powers: +1.50 D, +2.50 D, +3.00 D, and +3.50 D).

Table 2 shows the different values of refractive components between center refraction and each peripheral eccentricity (RPRE) for M, J_0, and J_{45}, with the SD for WC and with Proclear® MFCL D-design (Cooper

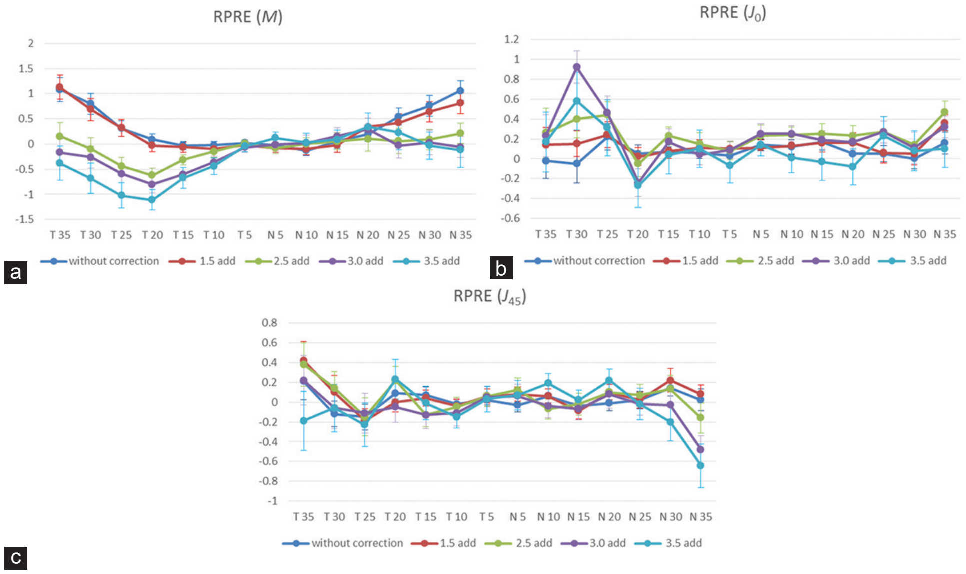

Figure 1: Relative peripheral refractive error in (a) mean spherical equivalent values (*m*), (b) horizontal astigmatism component (J_0), and (c) oblique astigmatism component (J_{45}) for without correction, +1.50 D add, +2.50 D add, +3.00 D add, and +3.50 D add multifocal contact lenses. Error bars represent standard error, *T* is temporal visual field, and *N* is nasal visual field. RPRE = Relative peripheral refractive error

Table 3: Accommodative response and lag of accommodation for without correction and Proclear multifocal contact lenses

Contact lens	Accommodative response	Lag of accommodation
WC	0.23 D±0.28	2.27 D±0.28
Proclear + 1.5 D add	1.30 D±0.65	1.20 D±0.65
Proclear + 2.5 D add	1.26 D±0.89	1.24 D±0.89
Proclear + 3.0 D add	1.40 D±0.83	1.10 D±0.83
Proclear + 3.5 D add	1.38 D±1.16	1.12 D±1.16

WC=Without correction

Vision) (addition powers: +1.50 D, +2.50 D, +3.00 D, and +3.50 D). WC, there was hyperopic defocus beyond 25° in the nasal and temporal field. The same was observed with a +1.50 D addition power. However, with a +2.50 D addition power, there was a shift toward myopic defocus only in the nasal field (from N10: −0.15 ± 0.57 to N30: −0.10 ± 1.16) but was statistically significant only at N25 and N15 ($P < 0.05$). The myopic shift was observed in the entire nasal field and at the extremities of the temporal field with a +3.00 D and +3.50 D addition power. The myopic shift was however statistically significant only in the nasal field between N10 and N25 with a +3.00 D addition lens and between N10 and N30 with a +3.50 D addition lens. The J_0 and J_{45} showed no statistically significant difference for all the addition powers used in the study along all eccentricity visual field.

By using repeated-measures ANOVA to compare between WC and each addition power of MFCLs, the results for RPRE indicated significant differences based on Greenhouse–Geisser correction (F [2.710, 43.362] = 12.513, $P < 0.001$). Bonferroni *post hoc* test showed a statistically significant difference between WC and +2.50 D addition, +3.00 D addition, and +3.50 D addition ($P = 0.009$, $P = 0.006$, and $P < 0.001$, respectively). However, +1.50 D addition showed no statistically significant difference when compared with that of WC ($P = 1.000$).

Figure 1a-c illustrates the profile of RPRE for mean spherical equivalent (M), horizontal astigmatism component (J_0), and oblique astigmatism component (J_{45}) for WC and all additions of MFCLs used in the study. The vertical bars represent standard error for each lens. MFCLs with +1.50 D addition maintained hyperopic defocus at the peripheral retina similar to that of WC. Although MFCLs with +2.50 D addition still did not present a myopic shift at the periphery, it flattened the curve pattern. However, MFCLs with +3.00 D and +3.50 D addition showed similar myopic defocus shifts at the nasal and temporal visual field. Therefore, a +3.00 D addition is the minimum addition power of MFCLs needed to invert the pattern of peripheral refraction.

Accommodative response measurements

Table 3 demonstrates the values of mean and SD for AR and lag of accommodation. MFCLs of +3.00 D addition show near-normal lag of accommodation compared to other addition powers. One-way repeated-measures ANOVA results indicated a statistically significant difference in mean accommodative lag between groups with a Greenhouse–Geisser correction (F [15.444, 26.442] = 8.117, $P < 0.001$). *Post hoc* tests using the Bonferroni correction revealed that there was a statistically significant difference in the lag of accommodation between WC and every addition power of contact lenses used in this study (+1.50 D, $P = 0.017$; +2.50 D, $P = 0.009$; +3.00 D, $P = 0.002$; and +3.50 D, $P = 0.009$). However, there was no statistically significant difference in lag of accommodation between the different addition powers of MFCLs ($P > 0.05$). Nevertheless, +3.00 D addition showed a minimum lag of accommodation among the different addition powers.

DISCUSSION

Animal studies have demonstrated that ocular growth is controlled by local retinal mechanisms.[18] The axial eye growth occurs over a restricted area to minimize the image degradation at the corresponding retinal location.[19] Studies on infant monkeys optically imposed with hyperopic defocus in the periphery demonstrated central axial myopia.[8,20-22] They suggest that visual signals from the periphery can influence the overall growth of the eye during the emmetropization period.

In order to determine the optimal power of near-addition MFCL, two fundamental factors should be considered, that is, the peripheral retinal defocus and the AR. The present study measured the effect of different addition powers of MFCLs on peripheral refraction and accommodation status on myopic schoolchildren. Research suggests that hyperopic defocus is associated with progression of myopia in humans.[22,23] Recently, there was evidence showing that progression of myopia was related to the quality of the image at both the central and peripheral retina, whereby poor quality of image stimulated the progression of refractive error.[24] Mutti *et al*. reported that peripheral relative hyperopic defocus was greater in myopic children compared to emmetropic and hyperopic children.[23] The results of the current study showed gradual increase of hyperopic defocus toward peripheral visual field. The hyperopic shift peaked to 1.08 ± 1.24 D and 1.06 ± 1.06 D at 35º nasal and temporal visual field, respectively, in the uncorrected eye (WC).

It has been hypothesized that imposing a myopic defocus at the peripheral retina will inhibit eyeball elongation, which will control or slow down the myopia progression.[25] Furthermore, in 2011, Lopes-Ferreira *et al*. measured the peripheral refraction along the horizontal visual field on 28 emmetropic adults using different additions of Coopervision MFCLs. They reported that only +3.00 D and +4.00 D add powers demonstrated a true peripheral myopization effect and generated a significant change in peripheral refractive pattern compared to baseline.[26] The need to measure the effects of different add MFCL on myopic children is essential because it is the critical age of myopia progression. In the present study, the results of repeated-measures ANOVA showed that only +3.00 D and +3.50 D add lenses could invert the peripheral refractive pattern into myopic defocus. However, there is no statistically significant difference between +3.00 D add and +3.50 D add ($P = 1.000$), and the +3.50 D add would not seem to have a significant advantage.

Accommodation is a fundamental factor in mediating the amount of retinal defocus when viewing near objects. Lam *et al*. noticed that most myopes demonstrate low AR and high accommodation lag.[27] A large lag of accommodation will locate the best image behind the retina, which will cause a retinal hyperopic defocus. Previous studies have mentioned that a +2.00 D add lens is not the most appropriate means to create zero accommodative error.[28,29] The authors proposed to optimize the addition lens based on accommodative error as well as near phoria. A study on 12-year-old Australian schoolchildren in 2008 reported that children who read continuously for >½ h were more likely to develop myopia than those who read for <½ h. It is well believed that working distance correlates with myopia progression in children. The farther the working distance performance, the less likely to develop myopia in children.[30] Autorefractometer Grand-Seiko WR-5100K has been validated to measure AR for adults and children.[31] Table 3 illustrates the accommodation status for WC and all Proclear MFCL additions. A +3.00 D addition power shows higher AR and least lag of accommodation (1.10 ± 0.83 D) in comparison with other addition powers, but the difference was not statistically significant. The lag of accommodation is higher with MFCLs because of the surrounding progressive zone which interferes with autorefractometer readings.

CONCLUSION

Commercially available dominant design multifocal soft contact lenses are capable of inverting the relative peripheral hyperopic defocus into relative myopic defocus with addition powers. Proclear MFCLs with +3.00 D addition power seems to be the optimal addition to induce significant effect on peripheral retinal profile of myopic children, with near-normal lag of accommodation.

Financial support and sponsorship

This study was supported by a grant from Universiti Kebangsaan Malaysia (DPK-2014-002).

Conflicts of interest

There are no conflicts of interest.

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