

CONTROL OF MYOPIA

with **NEARPOINT PLUS**
as a
FUNCTION OF NEAR PHORIA

Literature Review & Additional Prospective Data



- David A. Goss, O.D., Ph.D.¹
- Bill B. Rainey, O.D., M.S.²

1. School of Optometry
Indiana University
Bloomington, IN 47405

2. Private Practice
Memphis, TN

Abstract

Studies which have examined the effect of bifocals or progressive addition lenses on the progression of myopia in children with different nearpoint phoria levels are reviewed. There is limited effect on myopia progression in children with exophoria or orthophoria. For children with esophoria, the number of subjects in various studies were often too small to achieve statistical significance. However, a reduction in the rate of progression with plus adds in esophoria can be recognized by comparing the results of multiple studies. A small previously unpublished prospective study, where rates of myopia progression is also presented. This study found that the difference in mean rates for esophoric plus add wearers who had their nearpoint phoria shifted out of esophoria with the add (-0.32D/yr) and single vision lens group subjects with esophoria at near (-0.49D/yr) was almost statistically significant ($p=0.052$). Implications of the literature reviewed and of the additional prospective data are discussed. Reduction in progression rates may be more likely in nearpoint esophoria when the phoria is shifted into exophoria with the add. Future studies to control myo-

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pia with plus adds should consider the use of individually prescribed add powers rather than providing all plus add group subjects with the same add power.

Key Words

accommodation, bifocals, convergence, myopia, progressive addition lenses

INTRODUCTION

For several decades clinicians have tried various regimens to slow childhood myopia progression.¹⁻³ A common method of myopia control has been the application of bifocal or progressive addition spectacle lenses. While there has been variability in the overall outcome of studies of plus adds to control myopia, an apparently uniform finding has been a lower rate of progression with plus adds than with single vision lenses in children with nearpoint esophoria. This paper reviews studies of the use of plus adds for slowing myopia progression where there are data on the effect of nearpoint phoria. It will also present some additional previously unpublished data from a small prospective study.

LITERATURE REVIEW

Bifocal Lenses

The first study to look at slowing myopia progression with nearpoint plus as a function of nearpoint findings is the study by Roberts and Banford.^{4,5} They investigated patient records from their practices in New York state. Included in the analysis were myopic patients who were examined at least twice before the age of 17 years. Dissociated near phorias (40 cm) were measured through the distance refractive correction with the von Graefe method. Bifocal add powers used varied from +0.75D to +2.00D, but most were +1.50D

or less. Rates of myopia progression for patients with ortho or exo at near were -0.41D/yr ($n=181$) with single vision lenses and -0.38D/yr ($n=17$) with bifocal lenses. When esophoria at near was present, the rates were -0.48D/yr ($n=167$) with single vision lenses and -0.28D/yr ($n=65$) with bifocal lenses. Roberts and Banford did not give the statistical significance level of the difference between single vision and bifocal wearing esophores, nor did they give the standard deviations. However, the 0.20D/yr difference for these esophores, given the numbers of subjects, would have been statistically significant at the 0.01 level with standard deviations of 0.5D/yr or less. This represents a very high standard deviation for rates of myopia progression. We can assume that the difference was statistically significant.

Goss and Grosvenor⁶ presented an analysis of the effect of phoria on myopia control with bifocals using data from the Houston myopia control study.⁷ In that study, children between the ages of 6 and 15 were randomized to single vision lenses, +1.00D add Executive bifocals, or +2.00D add Executive bifocals, and were followed for three years. Nearpoint phorias (40 cm) were determined with the von Graefe method. Patients were categorized by phoria using Morgan's norms: greater than 6Δ exo, the normal range of ortho to 6Δ exo, and any amount of eso.⁸ For subjects with higher exo, the mean rates of progression were -0.50D/yr ($n=5$, $SD=0.26$) with single vision lenses and -0.43D/yr ($n=6$, $SD=0.23$) with bifocals. Subjects with phorias in the normal range had average progression rates of -0.43D/yr ($n=20$, $SD=0.32$) in the single vision lens wearers and -0.42D/yr ($n=41$, $SD=0.27$) in the bifocal wearers. The mean rates

for the esophoric subjects were $-0.51\text{D}/\text{yr}$ ($n=7$, $\text{SD}=0.22$) with single vision lenses and $-0.31\text{D}/\text{yr}$ ($n=18$, $\text{SD}=0.31$) with bifocals. The difference in rates for esophores between the single vision group and the bifocal group was not quite statistically significant at the 0.05 level ($p<0.10$) due to the small number of subjects.

A study of Danish children was reported in 1991 by Jensen.⁹ At the start of the study subjects were in the 2nd through 5th grades and measured from -1.25 to -6.00D . A bifocal treatment group wore plastic lenses with $+2.00\text{D}$ adds in a 35 mm wide segment, with the top of the segment at the lower edge of the pupil when the eyes were in straightforward position. Nearpoint phorias (30 cm) were determined by prism neutralization with a cover test. Mean amounts of refractive change in two years for subjects with exophoria were -1.11D ($n=31$, $\text{SD}=0.79$) for the single vision lens wearers and -0.88D ($n=28$, $\text{SD}=0.64$) for the bifocal lens wearers. For subjects with ortho at 30 cm, the refractive changes in two years averaged -1.05D ($n=10$, $\text{SD}=0.64$) in the single vision lens group and -0.90D ($n=13$, $\text{SD}=0.44$) in the bifocal group. The subjects with eso at 30cm had mean two year refractive changes of -1.38D ($n=8$, $\text{SD}=0.45$) in the single vision lens wearers and -1.23D ($n=10$, $\text{SD}=0.40$) in the bifocal wearers. The amount of myopia progression appears to be a little less in the bifocal group than in the single vision lens group for each of the phoria categories, but the differences in the means were not statistically significant in any of the phoria categories. The numbers of esophores in the study were low and the phoria was measured with the cover test rather than the von Graefe method.

Goss and Uyesugi¹⁰ summarized data from six optometry practices for patients with at least 0.50D of myopia and at least four subjective refractions between the ages of 6 and 15 years. Bifocal add powers were usually in the range of $+0.75$ to $+1.25\text{D}$, but sometimes higher add powers, up to $+2.00\text{D}$, were used. The amount of add power was based on the individual practitioner's prescribing methods. Higher adds were more frequently used in cases with esophoria (von Graefe @ 40 cm) and higher plus on the binocular cross cylinder test.¹¹ Rates of myopia progression were calculated by linear regression. For near phorias of more than 6Δ exo, mean rates were $-0.43\text{D}/\text{yr}$ ($n=39$, $\text{SD}=0.23$) with single vision lenses and $-0.49\text{D}/\text{yr}$ ($n=21$, $\text{SD}=0.21$) with bifocals. In the patients

with phorias in the normal range (from ortho to 6Δ exo), rates averaged $-0.42\text{D}/\text{yr}$ ($n=64$, $\text{SD}=0.28$) for single vision lens wearers and $-0.41\text{D}/\text{yr}$ ($n=34$, $\text{SD}=0.23$) for bifocal wearers. For patients with esophoria at near, the mean rates were $-0.59\text{D}/\text{yr}$ in the single vision lens group and $-0.33\text{D}/\text{yr}$ in the bifocal lens group. The difference in rates between the esophoric single vision lens wearers and the esophoric bifocal wearers was statistically significant ($p<0.000002$). One of the variables that affects rate of myopia progression is the age of onset of myopia. The effect of lens type (bifocal vs. single vision) remained statistically significant when results were adjusted for an index of onset age based on initial examination age and initial amount of myopia in an analysis of variance.

Observing the trend in control of myopia progression with bifocals in children with esophoria at near, Fulk and Cyert¹² conducted a prospective study with subjects limited to children with esophoria at near (von Graefe). The age eligibility criteria at the start of the study were that girls were less than 13 years of age and boys were less than 14 years of age. Subjects were randomized to single vision lens or bifocal groups and followed for 18 months. There were 14 subjects in each group. The bifocal lenses used in the study were flat-tops with a 28 mm wide segment and an add power of $+1.25\text{D}$. The mean rates of progression were $-0.57\text{D}/\text{yr}$ for the single vision lens wearers and $-0.39\text{D}/\text{yr}$ for the bifocal wearers. The difference in rates was not statistically significant ($p=0.26$). However, Fulk and Cyert were sufficiently encouraged by the fact that the magnitude of difference was similar to the differences reported in previous studies that they conducted a follow-up study with a larger number of subjects.¹³

Eligibility criteria for this study¹³ included ages of 6 to 12.9 years for boys and 6 to 11.9 years for girls, at least 0.50D of myopia in both principal meridians of both eyes, and esophoria on the von Graefe test (40 cm). Subjects were randomized to wear either single vision lenses or bifocal lenses with a $+1.50\text{D}$ add in a 28 mm wide flat-top segment. The average spherical equivalent of the two eyes from autorefractometry after the instillation of two drops of 1% tropicamide was recorded. The average myopia progression in 30 months for the subjects who completed the study were -1.24D ($n=39$, $\text{SD}=0.65$) for the single vision lens group and -0.99D

($n=36$, $\text{SD}=0.68$) for the bifocal group. The difference was not statistically significant ($p=0.106$), but when the results were adjusted for age in an analysis of covariance, the effect of treatment group did become significant ($p=0.046$).

Progressive Addition Lenses

Since the Fulk et al paper on bifocals, attention on added plus for myopia control has shifted to progressive addition lenses. Brown et al¹⁴ reported a study done in Hong Kong with children who were 9 to 12 years old at the start of the study. Thirty-two subjects wore single vision lenses, 22 subjects wore progressive addition lenses with $+1.50\text{D}$ adds, and 14 wore progressives with $+2.00\text{D}$ adds. Myopia progression was determined based on the right eye spherical equivalent from non-cycloplegic refractions. Near phorias were determined using the Maddox wing test. Myopia progression in two years for the nonesophoric subjects averaged -1.17D ($n=18$, $\text{SD}=0.48$) for the single vision lens wearers and -0.84D ($n=20$, $\text{SD}=0.41$) for the subjects who used progressive addition lenses. For esophores, the two year progression averaged -1.29D ($n=14$, $\text{SD}=0.56$) for subjects with single vision lenses and -0.58D ($n=16$, $\text{SD}=0.42$) for subjects with progressives.

Another Hong Kong study was reported by Edwards et al.¹⁵ Subjects between the ages of 7 and 10.5 years at the start of the study had myopia ranging from -1.25 to -4.50D . The lenses used by the subjects were either single vision lenses or progressive addition lenses with a $+1.50\text{D}$ add. The measure used to determine myopia progression was spherical equivalents from autorefractometry. Phoria measurements were taken with the Howell card (33 cm). Mean myopia progression in two years for all subjects regardless of phoria were -1.26D ($n=133$, $\text{SD}=0.74$) for subjects with single vision lenses and -1.12D ($n=121$, $\text{SD}=0.67$) for subjects with progressive addition lenses. The myopia progression for two years in the subjects with esophoria was -1.26D ($n=21$, $\text{SD}=0.90$) in the single vision lens group and -0.89D ($n=21$, $\text{SD}=0.34$) in the progressive addition lens group. The difference in means for esophores did not reach statistical significance ($p=0.14$).

Gwiazda et al^{16,17} presented that results of a multi-center study performed at four locations in the United States. Subjects were 6 to 11 years of age at the beginning of the study and had spherical equivalent re-

fractive errors between -1.25 and -4.50D. The subjects were randomly assigned to a single vision lens group or a +2.00D add progressive addition lens group. Myopia progression was determined from spherical equivalent autorefractor measurements after the instillation of two drops of 1% tropicamide. Phorias were determined by cover test at 33 cm. Accommodative response was measured with an open view autorefractor at 33 cm. They divided the data into three phoria levels: 2Δ or more exo, 1Δ exo to 1Δ eso, 2Δ or more eso. For the latter eso group, the mean amounts of myopia progression in three years were -1.39D (n=89, SD=0.85) in single vision lens group and -1.18D (n=97, SD=0.79) in the progressive addition lens group. They also divided the data according to accommodative response to a 3D stimulus as higher or lower than 2.57D. For the subjects with lower accommodative response (higher lag of accommodation), myopia progression in three years averaged -1.60D (n=119, SD=0.87) for the single vision lens group and -1.27D (n=115, SD=0.86) for the progressive addition lens group. The difference in means for the high lag subjects was statistically significant (p<0.05). For the lower lag subjects, there was a minimal difference between treatment groups. When the esophores were divided into higher and lower lag of accommodation categories, the treatment effect was not statistically significant for lower lag esophores, but it was for higher lag esophores (p<0.05). Mean myopia progression in three years for higher lag esophores was -1.72D (n=34) for those wearing single vision lenses and -1.08D for those wearing progressives.

A Japanese study included 6 to 12 year olds with spherical equivalent refractive errors of -1.25 to -6.00D.¹⁸ Progressive addition lenses used in the study had +1.50D adds. A crossover study design was used with some subjects wearing single vision for 18 months and then progressives for 18 months. The other subjects used progressives for 18 months and then single vision for 18 months. Eighty-six children completed the full three years of both treatment periods. The amount of myopia progression was determined from cycloplegic autorefraction. Phoria was measured with prism neutralized cover test (33 cm). Lag of accommodation was evaluated with an open view autorefractor using 21 or 32.5 cm fixation distances. Phoria data were divided into two categories: more than 4Δ exo and a group includ-

ing less than 4Δ of exo, ortho, and eso. Lag of accommodation findings were divided into higher and lower categories (<1.8D accommodative response or ≥1.8 D accommodative response). There was a significant treatment effect for the first 18 months for those with esophorias ≥4Δ (p<0.05) and for those with higher lags (p<0.05). There were no significant treatment effects in the second 18 months.

The most recent progressive addition lens study at the time of this writing is a study from China by Yang et al.¹⁹ Seven to 13 year-old children with -0.50 to -3.00D of myopia were studied. The amount of the myopia progression was determined by cycloplegic autorefractor findings. Phorias (33 cm) were measured by prism neutralized cover test. For subjects with 2Δ or more exo, mean myopia progression in two years was -1.48D (n=29, SD=0.75) among the single vision lens wearers and -1.33D (n=31, SD=0.49) among the progressive lens wearers. In the subjects with phorias between 1Δ exo and 1Δ eso, myopia progression in two years averaged -1.48D (n=24, SD=0.51) for the single vision lens group and -1.23D (n=30, SD=0.64) for the progressive addition lens group. When the phoria was at least 2Δ of eso, the average myopia progression in two years was -1.65D (n=22, SD=0.76) with single vision and -0.88D (n=13, SD=0.51) with progressives. The treatment effect was statistically significant in the esophoric subjects (p<0.01) but not in the other two phoria categories.

Literature Review Summary and Comments

Table 1 summarizes the results of the studies discussed above. To put the results of the studies into a form to make them easier to compare, myopia progression was converted into a diopters per year (D/yr) if they were not already expressed that way in a particular paper. It may be noted that for esophoria, the mean reduction in rate with plus adds ranged from 0.07 to 0.39D/yr in different studies and was often in the range of 0.18 to 0.26D/yr. Despite the fact that the differences for esophores between single vision and plus add groups were not statistically significantly different in many of the studies, there is consistently less progression in the plus add groups. Differences in the amount of reduction of progression rates with plus adds from study to study might be at least partially explained by differences in subject populations, measurement methods,

categorization methods, add powers used, types of adds used.

Another way to try to grasp trends in the results of the various studies is to examine Figure 1. In this figure rates of increase of myopia with single vision lenses is on the x-axis and the corresponding rates of increase with plus adds is on the y-axis. (The minus signs used for rates of progression have been dropped for the purposes of the figure.) Results for esophores are shown with dots and results in ortho and exo cases are shown with "x" symbols. The lines from dots to "x" points connect the results from a given study. In the case of studies which had a phoria groupings which included both esos and exos, the results for that phoria grouping were not included in the points in the figure. The diagonal line across the figure from lower left to upper right is a 1:1 line on which points would fall if the rates of increase were the same with single vision and plus adds. The farther below the 1:1 line that a point falls, the greater the reduction in myopia increase with plus adds. It may be noted that the points for esophores fell farther below the line than the points for exophores for every study, thus illustrating myopia control with plus adds in esophoria, but little or no myopia control with plus adds in exophoria. Two studies^{12,13} included only subjects with esophoria, so there are two dots not connected to an "x." This graph illustrates another point. For every study the dot falls either to the right or straight below the "x." This indicates that increase in myopia with single vision lenses usually averaged greater, and always no less, for children with esophoria than for children with exophoria.

Next we could ask what the overall trend for reduction in progression rate was with plus adds in esophoria. Table 2 shows average rates for the different studies combined. For two retrospective studies of bifocals from private practice records^{4,5,10} the average reduction was 0.20D/yr. For four prospective studies of bifocals,^{6,8,12,13} the mean reduction was 0.13D/yr. For four prospective studies of progressive addition lenses,^{14-17,19} the average reduction of progression was 0.17D/yr. The overall mean reduction was 0.17D/yr. These averages are, of course, weighted by the studies with larger numbers of subjects.

On average, the reduction in rate was slightly greater in the retrospective studies than in the prospective studies. It is generally accepted that randomized prospective clinical trials are better than retro-

spective observational studies because the prospective study can control for many variables better than a retrospective study. The lack of control of such variables seems a likely explanation for the slightly better reduction of myopia progression in the retrospective studies. However, it is possible that there may be another explanation. Most research scientists and statisticians advocate that all subjects wear the same power add so that they all receive "the same treatment." This is the approach that was taken in the prospective randomized studies. However, the optimal treatment for a given individual under ordinary clinical circumstances should be individualized. For esophoria, one way that this might be achieved is by prescribing an add that shifts the near esophoria to a low exophoria. A previous study found that myopia progression rates were lowest when the habitual near phoria was in the ortho to 6 prism diopters exo range.²⁰ In retrospective studies based on private practice records, practitioners have derived the power of the add from appropriate clinical tests. Two extensive reviews of medical literature compared randomized clinical trials to observational studies. They concluded that the two types of study yielded similar results when similar criteria for subject selection were used. Observational studies do not systematically overestimate treatment effects.^{21,22} With bifocal treatment for myopia, it might be expected that the treatment effect in retrospective studies would be greater than that for prospective studies. This is because the use of one add power for all subjects is not the optimal treatment for many subjects, thus perhaps reducing the overall effect.

Two of the studies reviewed used lag of accommodation in an open view autorefractor.^{17,18} Based on those studies, it appears that lag of accommodation may be a factor in the effectiveness of plus adds for myopia control. Reduction of progression with plus adds may be more likely in cases with high lags of accommodation. In one of the prospective studies on progressive addition lenses there was a statistically significant reduction in progression in cases of esophoria and higher lag, but not in esophoria cases with lower lag.¹⁷ In one retrospective study, there was a reduction of progression rates with bifocals in esophoria regardless of whether the binocular cross cylinder finding was higher or lower than the average.¹⁰ It may be observed that patients with esophoria and higher lags of

Table 1. Rates of myopia progression in (D/yr) in different studies as a function of lens type and near test findings.

	Single vision lenses			Plus adds			Stat. sig. of difference
	n	Mean	SD	n	Mean	SD	
Roberts and Banford⁵							
ortho & exo	181	-0.41	--	17	-0.38	--	--
eso	167	-0.48	--	65	-0.28	--	--
Goss and Grosvenor⁶							
>6 exo	5	-0.50	0.26	6	-0.43	0.23	n.s.
0-6 exo	20	-0.43	0.32	41	-0.42	0.27	n.s.
eso	7	-0.51	0.22	18	-0.31	0.31	<0.10
Jensen⁹							
exo	31	-0.56	0.40	28	-0.44	0.32	n.s.
Ortho	10	-0.53	0.32	13	-0.45	0.22	n.s.
eso	8	-0.69	0.23	10	-0.62	0.20	n.s.
Goss and Uyesugi¹⁰							
>6 exo	39	-0.43	0.23	21	-0.49	0.21	0.3060
0-6 exo	64	-0.42	0.28	34	-0.41	0.23	0.7595
Eso	52	-0.59	0.32	66	-0.33	0.20	<0.0001
Fulk and Cyert¹²							
Eso	14	-0.57	0.41	14	-0.39	0.45	0.26
Fulk et al¹³							
Eso	39	-0.50	0.26	36	-0.40	0.27	0.106
Brown et al¹⁴							
ortho & exo	18	-0.59	0.24	20	-0.42	0.21	--
Eso	14	-0.65	0.28	16	-0.29	0.21	--
Edwards et al¹⁵							
ortho & exo	112	-0.63	--	100	-0.59	--	--
Eso	21	-0.63	0.45	21	-0.45	0.34	0.14
Gwiazda et al^{16,17}							
phoria \leq -2	37	-0.46	0.26	45	-0.48	0.25	n.s.
phoria=-1to1	108	-0.52	0.28	93	-0.42	0.29	n.s.
phoria \geq +2	89	-0.46	0.28	97	-0.39	0.26	n.s.
lower lag	115	-0.45	0.29	120	-0.43	0.29	n.s.
higher lag	119	-0.53	0.29	115	-0.42	0.29	<0.05
high lag, eso	34	-0.57	--	42	-0.36	--	<0.05
Hasebe et al¹⁸							
phoria<-4	36	-0.65	--	36	-0.63	--	--
phoria \geq -4	44	-0.79	--	44	-0.56	--	--
lower lag	44	-0.66	--	44	-0.55	--	--
higher lag	36	-0.81	--	36	-0.65	--	--
Yang et al¹⁹							
phoria \leq -2	29	-0.74	0.38	31	-0.67	0.25	0.41
phoria=-1to1	24	-0.74	0.26	30	-0.62	0.32	0.17
phoria \geq +2	22	-0.83	0.38	13	-0.44	0.26	<0.01

Units: phorias = prism diopters.

Signs for phoria: (-) = exo; (+) = eso; (SD) = standard deviation; (n.s.) = not significant

accommodation would be more likely to have greater comfort and efficiency with plus adds, suggesting that prescribing for

comfort and efficiency is also more likely to reduce myopia progression.

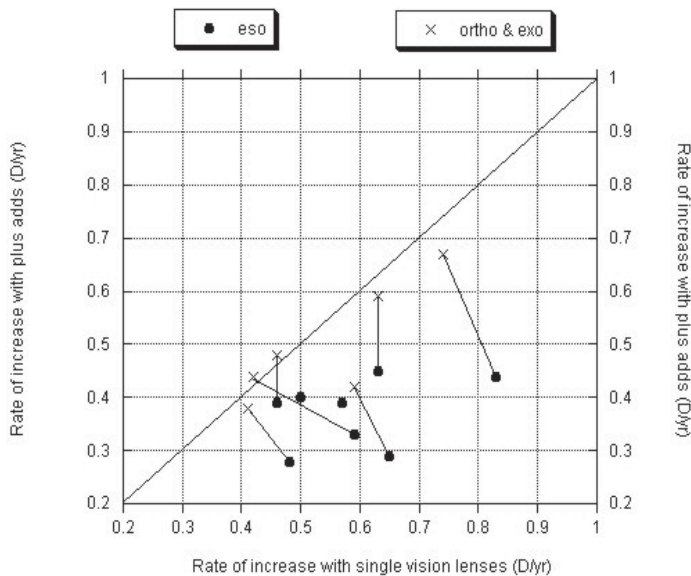


Figure 1. Comparison of mean rates of myopia increase (D/yr) with single vision lenses (x-axis) to rates of increase with plus adds (y-axis) for children with esophoria (dots) and children with ortho and exophoria (x symbols). Each point represents the mean rates from one study. A dot and an x connected by a line represent the means from the same study. The farther below the diagonal 1:1 line a point falls, the greater the reduction in rate of increase with plus adds. See text for further explanation and discussion.

ADDITIONAL PROSPECTIVE DATA

Methods

This study was conducted at Indiana University School of Optometry. Study protocols were approved by the Indiana University Human Subjects Committee. Subjects were recruited from August, 1993 to May, 1995 at the School of Optometry's Bloomington clinics and by newspaper announcements. Subjects were also recruited with an informational segment during half time of a television broadcast of an Indiana University basketball game. Eligibility criteria were as follows: (1) at least 0.50D of myopia in both principal meridians of both eyes as measured by the manifest subjective refraction, (2) 5 to 13 years of age, (3) corrected visual acuity of at least 20/25 in each eye, (4) no strabismus, (5) no ocular disease, (6) no history of systemic disease or systemic drug use with potential ocular effects, and (7) no previous contact lens wear. These eligibility criteria were confirmed by the authors at the baseline examination for entrance into the study.

Subjects were randomly assigned to one of four groups: (1) the control group where subjects wore single vision spectacle lenses equal in power to the manifest binocular maximum plus subjective refraction to best visual acuity; (2) the flat-top bifocal lens group where subjects wore spectacle

lenses with the distance portion having a power equal to the manifest subjective refraction and the reading portion having a +1.25D add. The lenses were positioned 2 mm higher in the frame than standard progressive lens fitting; and (4) the vision training group where subjects wore single vision lenses with the power equal to the manifest subjective refraction. This group did regular out-of-office training procedures to improve accommodation and convergence function. The results for the vision training group are presented in a separate paper beginning on page 123 of this *Journal*. Based on the recommendations of biostatisticians and research scientists, the same add power was used for all subjects in the bifocal and progressive addition groups to reduce the number of variables. The reasoning behind that recommendation was that different add powers theoretically may be considered different treatments for the purpose of statistical analysis, even though the optimal effect is most likely to be achieved by add powers that are variable from one patient to another.

Spectacles and all study examinations were provided at no cost to the subjects. All subjects were advised to wear their

Table 2. Mean rates of myopia progression (D/yr) averaged across studies for subjects with esophoria at near.

	Single vision lenses		Plus adds	
	n	Mean	n	Mean
Retrospective bifocal studies	219	-0.51	131	-0.31
Prospective bifocal studies	68	-0.54	78	-0.41
Progressive addition studies	146	-0.56	147	-0.39
All studies	433	-0.53	356	-0.36

lenses with the distance portion having a power equal to the manifest subjective refraction and a 28 mm wide reading segment with a +1.25D add and the top of the segment placed at the lower margin of the pupil

spectacles full-time and to read through the bottom portion of the lenses. The subjects assigned to the single vision lens control group and the progressive addition lens group along with their parents were not informed of the group assignment. The flat-top bifocal group could easily observe the bifocal line so they knew their group assignment. If the spherical equivalent of a subject's subjective refraction increased in minus in either eye by 0.50D or more, a new pair of spectacles was provided. Subjective refractions were always performed by the same investigator (BBR).

Group assignment randomization was performed separately for subjects with esophoria at near and subjects with orthophoria or exophoria at near (40 cm). The phoria was determined by the von Graefe method by one of the authors (DAG). Randomization was based on the von Graefe near phoria finding at the baseline examination.

The subjects were randomized for esophores, orthophores and exophores. There was an exception to the randomization procedure: the sibling of a child in the vision training group was also assigned to the training group. The reason for this exception was that non-training group subjects might try the training procedures done by their siblings.

Full participation by a subject in the study was three years. Subjects in groups 1, 2, and 3 who completed three years in the study had a minimum of eight study visits: a baseline examination, a spectacle dispensing visit, three six-month progress checks, and three yearly examinations. Subjects who had changes in spectacle lenses had additional dispensing visits. Subjects in the training group had all of those visits plus additional two-month progress checks to monitor their training activities.

The baseline examination and the yearly examinations were comprehensive eye and vision examinations. These included dilated fundus examination and cyclople-

gic autorefraction. Fourth year optometry student interns did entrance tests and ocular health tests. One of the authors (BBR) did the subjective refractions, and one of the authors (DAG) did accommodation and vergence tests, including near von Graefe phorias with the subjective refraction and with a +1.00 D add. The six month progress checks consisted of a case history with reminders about full-time wear of the glasses and reading through the bottom of the glasses. Visual acuity, cover test with spectacles and subjective refraction (by BBR) were performed. The outcome variable used for analysis was autorefraction after instillation of 2 drops of 1% tropicamide, 5 minutes apart. This variable was chosen because of the good reliability of cycloplegic autorefraction (Nikon NRS5100).^{a,23} Autorefraction is unlikely to be affected by inadvertent examiner bias as a subjective refraction could potentially be. Investigators and study personnel were not masked to subject group assignment. The refractive error used for analysis was the mean of the spherical equivalents of the two eyes from the autorefraction. Rates of myopia progression in diopters per year (D/yr) were calculated by dividing the difference between the end and the beginning refractive errors by the years in the study. The number of years in the study was determined to two decimal places from the years, months, and days from the date of the baseline examination. Attempts were made to have annual visits as close as possible to one year apart. However, they were sometimes as little as nine months or as much as 15 months apart. To compare the results of this study with the rates of progression found in other studies, rates were used for analysis of progression rather than the dioptric changes between visits. For some analyses of the effects of plus adds, the data for the bifocal and progressive addition lens groups were combined into one plus add group due to the small number of subjects.

Subjects

A total of 95 subjects were enrolled in the study's four groups during the 21-month recruitment period. This fell significantly short of the original goal for the minimum number of subjects in each study group. Parents of many prospective subjects declined participation due to the one in four chance of their child wearing bifocals. Considering the esophoric subjects needed for a two-tailed statistical significance

Table 3. Characteristics of subjects completing the full three years in the study. (*mean of the spherical equivalents of the subjective refractions of the two eyes)

Group	n	No. males	No. females	Mean initial age in yrs. (SD)	Mean initial myopia in diopters* (SD)
Single vision	21	15	6	10.39 (1.60)	-2.64 (1.71)
Bifocals	18	9	9	9.02 (2.65)	-2.42 (1.38)
Progressive addition	18	11	7	10.76 (1.82)	-2.18 (1.28)

level of 0.05; a power of 80%, a difference between control and plus add groups of 0.2D/yr (an expected difference based on previous studies), and a standard deviation of 0.25, a minimum of 25 esophoric subjects in each of the single vision and plus add groups would be required.

The number of subjects enrolled in the single vision group or in the plus add groups was 73. Of those 73 subjects, 57 completed the full three years of the study. Typical reasons for drop-out were moving from the area or wanting to wear contact lenses. Although parents of potential subjects expressed reticence about their children wearing bifocals, the drop-out rate in the bifocal group did not appear to be greater than in the other groups. However, it is conceivable that children wearing bifocals may not have complied with their use as completely as subjects in other groups despite instructions on their proper use.

Data analysis considered only the subjects completing the full three years in the study. Despite randomization, the characteristics of the subjects at the baseline examination differed between groups. Baseline characteristics are given in Table 3. The bifocal wearers were on average 1.37 yrs. younger than the single vision lens group. Younger age and higher myopia are associated with greater subsequent myopia progression rates.^{7,20,24-26} The gender distribution also differed somewhat from one group to another. The vast majority of subjects were of European ancestry. Three subjects were African Americans, and three subjects were of Asian ancestry.

Results

The mean rate of myopia progression for the 36 subjects with plus adds (bifocal and progressives) was -0.44D/yr (SD=0.28). The mean rate for the 21 single vision lens wearers was -0.50D/yr (SD=0.34). These means were not significantly different by t-test ($p=0.4891$).

There were differences in age and gender distributions in the different study groups (Table 3). The Pearson coefficient of correlation of initial age with rate of myopia

progression was -0.38 ($p<0.001$). Thus initially younger subjects tended toward greater rates of progression. The correlation coefficient of initial amount of myopia with progression rate was +0.25 ($p<0.05$). Higher initial amounts of myopia were associated with higher rates of progression. An analysis of variance using subjects in the single vision and plus add groups found significant effects of initial age ($p=0.001$), initial myopia ($p=0.003$), but not of gender ($p=0.916$) or single vision vs. plus add correction ($p=0.362$).

The mean rate for the 12 single vision lens wearers with esophoria at near was -0.49D/yr (SD=0.19). The mean rate for the 19 plus add wearers with nearpoint esophoria was -0.38 D/yr (SD=0.28). The difference was not statistically significant ($p=0.2546$). Rates by phoria and treatment group are given in Table 4.

Several subjects wearing plus adds had high amounts of esophoria at near, and according to their gradient AC/A ratios, did not have their near phorias shifted out of esophoria with their +1.25D adds. For the 13 esophores whose plus adds did shift them out of esophoria, the mean rate of progression was -0.32D/yr (SD=0.22). When this rate was compared to the mean rate for single vision lens wearing esophores (-0.49D/yr), the difference was almost statistically significant ($p=0.052$). Examining the cumulative frequency distributions of these rates in Figure 2, it appears that the curve for the patients wearing adds who were still esophoric with their plus adds is very close to the curve for the single vision lens wearing subjects with esophoria. The curve for the plus add wearers who were shifted to ortho or exo with their adds is displaced to lower rates compared to the other two. The findings of this supplementary analysis are only suggestive because the number of subjects is low.

DISCUSSION

In the present study, the mean rates for nearpoint esophores were -0.49D/yr ($n=12$; SD=0.19) for single vision lens wearers and -0.38D/yr ($n=19$; SD=0.28)

Table 4. Mean myopia progression rates (D/yr) by treatment groups and near phoria.				
	n	Mean	SD	Median
Esophoria				
Single vision	12	-0.49	0.19	-0.45
Bifocals	9	-0.47	0.31	-0.42
Progressive addition	10	-0.30	0.22	-0.31
Orthophoria and exophoria				
Single vision	9	-0.52	0.48	-0.44
Bifocals	9	-0.51	0.25	-0.46
Progressive addition	8	-0.52	0.32	-0.45

Table 5. Rates of progression (D/yr) for subjects with esophoria at near.			
	n	Mean	SD
Single vision lenses	12	-0.49	0.19
Still eso with plus add	6	-0.52	0.35
Shifted out of eso with plus add	13	-0.32	0.22

for the plus add wearers. As with several of the previous studies, the sample size was small and the difference was not statistically significant. The magnitude of the difference (0.11D/yr) was in the low end of the range of differences from previous studies (0.07 to 0.39D/yr) when esophoric subjects are considered.

A factor that might have affected study outcome for esophores is the fact that there were more high esophores in the treatment groups than in the control group. In the single vision lens group, there was one subject with more than 10 prism diopters of esophoria. There were five subjects with more than 10 prism diopters of esophoria in the bifocal group and two in the progressive addition lens group.

Using the gradient AC/A ratio based on the von Graefe phorias taken at the baseline examination, six of the nine bifocal wearing esophores still were esophoric with the +1.25D nearpoint add. Although the numbers of subjects was quite low, we can speculate that the plus adds may not have been effective if the nearpoint phoria was not shifted out of esophoria. For the six who were still esophoric with their near adds, the mean rate of progression was -0.52D/yr. For the 13 bifocal and progressive lens wearers with esophoria at near through the subjective refraction and orthophoria or exophoria at near through their adds, the mean rate of progression was -0.32D/yr (Table 5). When the mean rate of progression for the 12 esophoric subjects in the single vision group

(-0.49 D/yr; SD=0.19) is compared to the mean rate for the 13 whose plus adds shifted them out of esophoria (-0.32 D/yr; SD=0.22), the difference is almost statistically significant (p=0.052). The difference in these rates (0.17 D/yr) is similar to the reduction in myopia progression rates reported for esophores in a number of other studies.^{5,6,10,12,15}

Though the sample size is small in the present study, there is a trend toward lower rates in subjects whose esophoria was shifted to ortho or low exo with their plus adds. This trend would be consistent with findings from previous studies of an association of esophoria with higher rates of myopia progression and with risk for the onset of myopia.^{5,20,27-30}

COMMENTS

There is sufficient evidence to conclude that childhood myopia progression rates are reduced with plus adds in children with esophoria at near. Reduction in progression rate might be most likely with an add power that shifts the near phoria into a low amount of exophoria. It can also be stated that prescribing adds for comfort and efficiency may have the additional benefit of slowing myopia progression. A number of investigators are developing models to predict the best lens corrections to slow myopia progression based on accommodation and vergence parameters.³¹⁻³³ Jiang et al,³³ for example, considered a model of add powers that would yield either 3Δ exophoria at near or zero accommodative

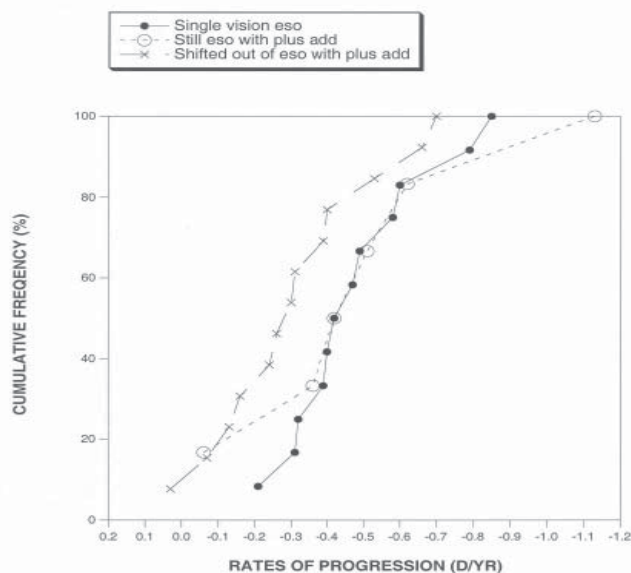


Figure 2. Cumulative frequency distribution of rates of myopia progression for esophoric single vision group subjects, for plus add subjects whose near phoria was still eso with the plus add, and for plus add subjects whose plus add shifted their near phoria out of esophoria. The numbers of subjects are as follows: single vision lens wearers with esophoria at near (N=12), subjects still esophoric with their plus adds (N=6), subjects shifted out of esophoria with plus adds (N=13).

error at near. They suggested that: “Using progressive addition lenses to delay the progression of myopia may have promising results if each subject’s prescription is customized.”³³ Future studies of bifocals and progressive addition lenses for myopia control should consider use of individualized add powers rather than the same arbitrary add power for all subjects.

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Source

- a. Nikon Corp.
Fuji Bldg
2-3 Marunouchi 3-chome,
Chiyoda-ku Tokyo, Japan 100-8331

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Corresponding author:
David A. Goss, O.D., Ph.D., FAAO, FCOVD-A
School of Optometry, Indiana University
Bloomington, IN 47405
dgoss@indiana.edu
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