Article ▸ # Variation In AC/A Ratio While Using the Gradient Method With Plus or Minus Lenses

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ABSTRACT

Purpose: To compare the measurement of AC/A ratios while using the gradient method with plus or minus lenses at a fixed near point

Method: A convenience sampling method of 30 Malaysians aged 13 to 30 years was used in this study. Relevant demographic and clinical data were obtained. The measurement of the near phoria was performed with a Maddox wing using both plus and minus lenses. The AC/A ratios with ±3.00 diopter (D) lenses were compared. The data were analyzed using the Wilcoxon Signed Rank test to investigate the changes in AC/A ratio while using plus and minus lenses.

Result: The mean age of the subjects was 23.46±5.09 years. The mean AC/A ratios with plus lenses and minus lenses were 2.14±0.85 and 1.53±0.71, respectively. The AC/A ratio measured via the gradient method was significantly different (p=0.002). However, the association of AC/A ratio and phoria among gender and age groups was not significant (p>0.05).

Conclusion: This study shows that the gradient AC/A ratio with a +3D lens is significantly different from a -3D lens. Clinically, we should use both plus and minus lenses while measuring the AC/A ratio with the gradient method rather than a single lens type.

Keywords: AC/A, accommodation, convergence, gradient method, heterophoria

Introduction

The AC/A ratio is a measurement of the convergence induced per diopter of accommodation. It is measured to determine the change in accommodative convergence that occurs when the patient stimulates or relaxes accommodation. The AC/A finding is important in diagnosing and treating binocular vision anomalies.[1] Two types of AC/A ratios are described in the literature: the stimulus and the response AC/A. The stimulus AC/A ratio reflects the alteration of convergence capacity as the eyes are stimulated with lenses of different fraction power or with different object distances, resulting in different accommodation.[2] The response AC/A ratio reflects the ratio of accommodative response, which usually is not measured in the clinic, to the alteration of convergence capacity.[2] The response AC/A ratio should be 1.08-fold greater than the stimulus AC/A ratio due to the lag of accommodation.[2] The accommodative response will be about 10% less than the stimulus.[3] Thus, when we measure accommodative response directly, we find that for a +2.50D (40 cm) stimulus, there will be a lag of accommodation of about +0.25 to +0.75D.[3]

Ludwig et al. classified high AC/A ratios into three grades according to the amount of disparity. The grades described were grade 1 (10-19$^{\Delta}$), grade 2 (20-29$^{\Delta}$), and grade 3 (30$^{\Delta}$ or greater). A disparity of 0 to 9$^{\Delta}$ is considered a normal AC/A ratio.[4] The AC/A ratio is inversely related to the adaptability of tonic accommodation (lens adaptation) and directly related to adaptability of tonic vergence (prism adaptation).[5] Therefore, the distance phoria depends on the tonic vergence of the eyes, and the near phoria depends on the AC/A ratio.

Clinically, there are three methods used to determine the AC/A ratio: the gradient, fixation disparity, and calculated heterophoria methods.[6] Though all of the methods are simple, practical, and often used interchangeably, they are really quite different. The heterophoria method involves phoria measurement and simple mathematical calculation using the subject's inter-pupillary distance. The gradient AC/A measures the amount of convergence generated by a diopter of accommodative effort. The AC/A ratio computed using the heterophoria method is usually greater due to the effect of proximal convergence. Therefore, the gradient method gives a true estimate of the AC/A ratio because of the consistency of proximal, fusional, and tonic convergence.[7]

The measurement of the AC/A ratio is influenced by the use of plus or minus lenses along with different fixation distances. Jackson et al. showed that the mean gradient AC/A measured with plus lenses was statistically identical to the AC/A with the minus lens method.[8] A comparison study of AC/A ratios was performed among 50 healthy primary school children by Amaechi et al. They found that there was a clinically significant difference between plus and minus lenses. This study has recommended that borderline patients should

Table 1. Comparison of AC/A Ratio by Using Plus and Minus Lenses

AC/A	Mean±SD	P-value
+3.00D	2.14±0.85	0.002
-3.00D	1.53±0.71	

Wilcoxon signed rank test

have gradient AC/A assessment through both lenses for more precise diagnosis and management.[9]

Havertape et al. found variability in the AC/A ratio with plus versus minus lenses. The study was performed on subjects having accommodative esotropia.[10] They concluded that further studies using the gradient method in patients without significant distance disparity are required.[10] In our study, the gradient method was performed on orthophoric patients and only at a fixed near distance. The use of a low-powered lens for the gradient method is not as effective as using a higher-powered lens.[11] Therefore, ±3.00D lenses were adopted in order to determine the variation in the AC/A ratio by using the gradient method for a fixed fixation distance.

Methodology

A cross-sectional study was conducted with 30 Malaysian subjects, aged 13 to 30 years, regardless of gender and race from both east and west Malaysia. Subjects were seen within a period of six months at the Twintech Vision Care Center. Written informed consent was obtained from all subjects. Subjects with a best-corrected visual acuity of 6/6 and N6 were included study, and those having any ocular pathology, eye movement disorder, binocular vision anomaly, systemic illness, or who were currently using contact lenses were excluded. A detailed history was obtained from each subject, followed by measurement of:

- visual acuity
- objective and subjective refraction
- pupillary evaluation
- near point of accommodation
- near point of convergence
- negative and positive relative accommodation
- negative and positive fusional vergence for both distance and near
- accommodative and vergence facility
- monocular estimation method retinoscopy
- cover test
- version and duction eye movements
- slit lamp and fundus examination

After successful completion of initial assessments, those who passed the inclusion criteria were included in the study. Near phoria for each subject was measured by using a Maddox wing at a distance of 33cm. The Maddox wing is a suitable dissociation test. The horizontal deviation is typcially measured first. The instrument uses a septum so that one eye sees a scale, and the other eye sees an arrow. The number on the scale to which the arrow points indicates the horizontal deviation. This instrument is also suitable for measuring the AC/A ratio. The Maddox wing test also has a scale for measuring vertical heterophoria and cyclophoria. These aspects of the test are particularly useful because cyclovertical deviations are difficult to detect with a cover test.[12] The AC/A ratio was calculated by using the gradient method for both +3.00D and -3.00D lenses on top of the best distance correction. The use of the Maddox wing allowed the interpupillary distance and vertex distance to be kept constant during the measurements. Data analysis was carried out by using SPSS 16.0 software. The normality of the data was checked by using the Shapiro-Wilk test. The Wilcoxon signed rank test was used to assess the significance of the AC/A ratio changes while using the plus and minus lenses. The Kruskal-Wallis Test was performed to find the correlation for near phoria and AC/A ratio using a plus or minus lens among three age groups. The Mann-Whitney test was also performed to determine the correlation between near phoria and gender with plus and minus lenses.

Table 2. Comparison of Near Phoria between Plus and Minus Lenses

Near Phoria	Mean±SD	P-value
+3.00D	-6.90±3.15	0.01
-3.00D	3.96±2.41	

Wilcoxon signed rank test

Table 3. Comparison of Near Phoria between Genders

Gender	Mean±SD	P-value
Male	0.5681±1.131	0.374
Female	0.2857±0.699	

Mann-Whitney test

Results

This study had a total of 30 subjects; 22 subjects were male (73%), and 8 subjects were female (27%). Subjects were categorized into three subgroups based on age: 13-18, 19-24, and 25-30 years. A clinically significant difference was observed for both AC/A ratio ($p=0.002$) and near phoria ($p=0.01$) while using minus and plus lenses, as shown in Tables 1 and 2, respectively. No clinically significant association was established for gender and age group with near phoria ($p>0.05$) and AC/A ratio ($p>0.05$), as shown in Tables 3-6.

Discussion

The prime focus of this study was to compare the effect of plus and minus lenses on the AC/A ratio by using the gradient method. Our desire was to determine whether the use of plus or minus lenses has a similar impact or whether using both lenses is necessary in clinical practice.

This study shows that a significant difference exists between the AC/A ratio when using two different lens powers. In contrast, a study done by Jackson et al. found that the mean

Table 4. Comparison of AC/A Ratio between Genders

AC/A	Gender	Mean±SD	P-value
+3.00D	Male	1.955±0.655	0.100
	Female	2.617±1.095	
-3.00D	Male	1.440±0.692	0.226
	Female	1.782±0.679	

Mann-Whitney test

Table 5. Association between Near Phoria and Age Group

Age Group	Phoria (Mean±SD)	P-value
13-18	-0.4±1.33	0.707
19-24	-1.25±2.43	
25-30	-0.625±0.932	

Kruskal-Wallis test

gradient AC/As while using plus (+3.00D) and minus (-2.00D and -1.00D) lenses were statistically identical.[8] The study was performed using 69 patients who were divided into disparity (near measurement less than 10^{Δ} of distance measurement) and distance-near disparity groups. The mean AC/A ratios while using plus lenses and minus lenses for the non-disparity group were 2.3/1±0.2 and 2.1/1±0.3, whereas for the disparity group, they were 5.1/1±0.5 and 5.3/1±1.1. The student t-test revealed no statistically significant difference in the gradient AC/A ratio for either the non-disparity ($p=0.70$) or the disparity group ($p>0.8$).[8] The results of this study contradict our study results because of different sample size, age groups, and methodologies of phoria measurements. We believed that using higher-strength lenses such as ±3.00 would yield clinically more significant results, as recommended by Von Noorden.[7] Martens and Ogle found that with normal binocular vision within non-diplopic and non-blur domains, the accommodative convergence induced by optic lenses exhibited 90% linear correlation in a sample of 250.[11] Havertape et al. showed similar results to our study, where the AC/A ratio was calculated for 45 subjects with accommodative esotropia by using plus or minus lenses in the gradient method.[10] The gradient method appears to give variable results if performed on subjects with a disparity and abnormal AC/A ratio. This finding contradicts Jackson's study, which found no variability in the AC/A ratio measurement between disparity and non-disparity groups.[8] Another study by Amaechi et al. showed a significant difference ($p<0.05$) in the gradient AC/A ratio through ±1.00D lenses. The mean AC/A ratio through +1.00D was 3.4±1.4 and through -1.00D was 4.2±2.0. This study supports our study findings, where we also found a significant difference ($p=0.002$) between gradient AC/A through ±3.00D lenses, although both studies use two different techniques for phoria measurement. In our study, we used the Maddox wing technique for measuring near phoria, whereas Amaechi et al. used the Von Graefe technique.[9]

In our study, we also found a statistically significant difference for near phoria measurements while using plus or minus lenses. Our findings are supported by Scattergood et al., who demonstrated that plus lenses decrease and minus lenses increase the measured strabismic deviation.[13] Our study is also supported by Vidhyapriya et al., where the effect of +2.00D on accommodation and phoria was measured binocularly and monocularly. This study found that near phoria showed a significant increase towards exophoria by 6^{Δ}±0.56 upon the introduction of +2.00D lenses.[14]

When phoria was compared amongst the age groups, no significant difference in near phoria was found ($p=0.707$). Our results contradict the findings from AlAnazi et al., where near phoria differed significantly ($p<0.0001$) across age groups (20-67 years) and correlated positively with age ($r^2=0.27$, $p<0.0001$).[15] It is theorized that this contradicts our result because of smaller sample size and a narrow age range (13-30 years). Also, in our study, we used the Maddox wing to measure the near phoria, whereas in AlAnazi's study, they used the Saladin card placed at 40 cm with an illumination level of 300 lux. Differences can be attributed because of unequal methodology, especially the method of determining and measuring heterophoria. In another study, Chung et al. showed no significant difference between near phoria and age ($p=0.99$), which is similar to our study.[15] The near phoria data were collected with the Maddox wing technique, which is believed to have good validity and repeatability.[16,17]

Yekta et al. divided the age group into pre-presbyopic (10-39 years) and presbyopic (40-69 years), where the associated heterophoria and fixation disparity increased towards more exo-direction with increasing age.[18] Fixation disparity and associated heterophoria are related to binocular problems for near vision in all age groups.[18] Ciuffreda investigated 42 subjects using a subjective haploscope-optometer to show that the stimulus AC/A significantly decreased with age (approximately 0.04 delta/D/year), whereas the response AC/A exhibited a significant increase with age (approximately 0.08 delta/D/year).[19] For subjects above 45 years of age, the AC/A could not be reliably assessed due to minimum accommodative response.[19] In our study, age ranges were between 13 and 30 years, whereas Ciuffreda's study included an age range of 22-65 years. Different techniques to measure AC/A ratio could also account for the differences between study results. Mutti et al. examined how the response AC/A varied as a function of age in an age group of 6 to 14 years.[20] The response AC/A ratio was found not to change as a function of age.[20] Although all of the above-mentioned studies adopted different techniques for measurement compared to our study, they each demonstrated

Table 6. Association between AC/A Ratio and Age Group

Age Group	AC/A ratio			
	+3.00	P-value	-3.00	P-value
13-18	1.8675±0.641	0.707	1.6625±0.784	0.707
19-24	2.2488±0.911		1.8066±0.749	
25-30	2.2384±0.893		1.2615±0.494	

Kruskal-Wallis test

no statistically significant difference in stimulus or response AC/A in relation to age.

The current study did not show a significant association of near phoria with gender (p=0.374). Our study contradicts the findings of Makgaba, who demonstrated a statistically significant variation between near phoria and gender (p<0.05).[21] No significant gender variation for distance phoria was observed, but there was a statistically significant gender variation in the near horizontal phoria.[21] Near horizontal heterophoria in females ranged from 17^{Δ} esophoria to 15^{Δ} exophoria, with a mean of 3.56^{Δ} exophoria ±4.99. For males, near phoria ranged from 11^{Δ} esophoria to 15^{Δ} exophoria, with a mean of 4.28^{Δ} exophoria ±4.46. Analysis of variance indicated that there was no statistically significant gender variation in vertical heterophoria values (p>0.05), but there was a statistically significant gender variation in near horizontal heterophoria values (p<0.05).[21] In our study, vertical phoria was not measured, and the finding of an association between heterophoria and gender does not support the study result by Makgaba et al. due to the huge difference in number of subjects. The age group in this study covers only the middle age range from 13 to 30 years, which hampers greater comparison.

Conclusion

To measure the AC/A ratio, it is necessary to change the subject's accommodation and to measure the associated changes in convergence. This study shows that gradient AC/A ratio with a +3D lens is significantly different from a -3D lens. Age and gender showed no special relationship with the measurement of gradient AC/A ratio. Clinically, we should use both plus and minus lenses while measuring AC/A ratios with the gradient method rather than a single lens type.

References

1. Wright KW, Edelman PM, Walonker F. Reliability of fixation preference testing in diagnosing amblyopia. Arch Ophthalmol 1986;104:549-53.
2. Alpern M. Vergence and accommodation. III. Am J Ophthalmol 1959;48:141-8.
3. Scheiman M, Wick B. Clinical Management of Binocular Vision, 3rd ed. Philadelphia: Lippincott Williams Wilkins, 2008.
4. Ludwig IH, Parks MM, Getson PR, Kammerman LA. Rate of deterioration in accommodative esotropia correlated to the AC/A relationship. J Pediatr Ophthalmol Strabismus 1988;25:8-12.
5. Schor C, Horner D. Adaptive disorders of accommodation and vergence in binocular dysfunction. Ophthalmic Physiol Opt 1989;9:264-8.
6. Pickwell LD. Binocular Vision Anomalies. Investigation and Treatment, 3rd ed. Oxford: Butterworth-Heinemann, 1997.
7. Von Noorden GK. Binocular Vision and Ocular Motility: Theory and Management. St. Louis: Mosby, 1996.
8. Jackson JH, Arnoldi K. The gradient AC/A ratio: What's really normal? Am Orthopt J 2004;54:125-32.
9. Amaechi OU, Obiora I. A comparative study of the gradient accommodative convergence/accommodation ratios obtained through +1.00DS and -1.00DS in primary school children. J Nigerian Optom Assoc 2004;11:8-11.
10. Havertape SA, Cruz OA, Miyazaki EA. Comparison of methods for determining the AC/A ratio in accommodative esotropia. J Pediatr Ophthalmol Strabismus 1999;36:178-83.
11. Ogle KN, Martens TG, Dyer JA. Oculomotor Imbalance in Binocular Vision and Fixation Disparity. Philadelphia: Lea & Febiger, 1967.
12. Rosenfield M, Logan N, Edwards KH. Optometry: Science, Techniques and Clinical Management, 2nd Ed. New York: Elsevier Butterworth-Heinemann, 2009.
13. Scattergood KD, Brown M, Guyton D. Artifacts introduced by spectacle lens in the measurement of strabismic deviations. Am J Ophthalmol 1983;96:439-48.
14. Sreenivasan V, Suryakumar R, Irving EL, Bobier WR. Adaptation to near addition lens. Invest Ophthalmol Vis Sci 2006;47:1183.
15. AlAnazi SA, AlAnazi MA, Osuagwu UL. Influence of age on measured anatomical and physiological interpupillary distance (far and near), and near heterophoria, in Arab males. Clin Ophthalmol 2013;7:711-24.
16. Chung KM, Chong E. Near esophoria is associated with high myopia. Clin Exp Optom 2000;83:71-5.
17. Parks MM. Abnormal accommodative convergence in squint. Arch Ophthalmol 1958;59:364-80.
18. Yekta AA, Pickwell LD, Jenkins TC. Binocular vision, age and symptoms. Ophthalmic Physiol Opt 1989;9:115-20.
19. Ciuffreda KJ. The AC/A ratio, age and presbyopia. Ophthalmic Physiol Opt 1997;17:307-15.
20. Mutti DO. AC/A ratio, age, and refractive error in children. Invest Ophthalmol Vis Sci 2000;41:2469-78.
21. Makgaba NT. A retrospective analysis of the heterophoria values in a clinical population aged 18 to 30 years. S Afr Optom 2006;65:150-6.

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