A Comparison of Dissociated Phoria Test Findings with von Graefe Phorometry & Modified Thorington Testing

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Abstract

The von Graefe test has been the standard dissociated phoria test for many years. The tangent scale dissociated phoria test commonly known as the modified Thorington test is gaining in popularity. This study compared distance and near phorias obtained with the von Graefe and modified Thorington procedures in 68 young adult subjects (mean age = 24.5 years). This study also compared the +/-1.00 gradient and calculated AC/A ratios obtained using von Graefe phorometry vs. modified Thorington testing. Distance phorias averaged very close to zero on both tests (0.1 Δ eso on the modified Thorington and 0.2 Δ exo on the von Graefe). Near phorias averaged 2.1Δ exo on the modified Thorington test and 3.7Δ exo on the von Graefe test. The von Graefe test showed more variability on both distance and near phorias and on AC/A ratios. The von Graefe test showed more relatively high phorias and more relatively high and low AC/A ratios than the modified Thorington test.

Key Words

AC/A ratio, binocular vision testing, dissociated phoria, modified Thorington test, von Graefe test

INTRODUCTION

The von Graefe testing procedure has been the standard method of subjective dissociated phoria testing for many years. A tangent scale dissociated phoria testing technique, commonly known as the modified Thorington test, has been shown to yield more repeatable results than the von Graefe method.[1-4] The modified Thorington procedure is also quick and simple to perform and easy for patients to understand. For those reasons, the modified Thorington test is becoming more commonly used. The purpose of this study is to compare test findings obtained with the modified Thorington test to those from the longer established von Graefe test.

METHODS

Data were collected using von Graefe and modified Thorington tests with 68 students and staff of the Indiana University School of Optometry serving as subjects. Protocols and procedures of this study were approved by the Indiana University Human Subjects Committee. Subjects ranged in age from 21 to 27 years (mean age 24.5), with 29% (20 of 68) being male and 71% (48 of 68) being female. All subjects had a best-corrected visual acuity at distance of 20/20 or better in each eye and no strabismus as determined by cover test.

Prior to phoria testing, interpupillary distance (PD) was measured for each subject at distance and near. For subjects who did not wear spectacles habitually or who were wearing contact lenses at the time of testing, a power of zero was set in the phoropter. For odd-numbered subjects, the von Graefe test was performed prior to the modified Thorington test. For even-numbered subjects, the modified Thorington test was performed prior to the von Graefe test. von Graefe phorometry was performed at distance (6m) and near (40 cm) with the distance correction in place. von Graefe near phorias were also performed with a +1.00 D add and a -1.00 D add over the distance correction lenses. The order of the near testing was: +1.00 D, distance correction and then -1.00 D Modified Thorington testing was performed using the phoropter at the same distances and with the same lenses used for von Graefe testing. The von Graefe tests were performed with standard procedure.[5] The modified Thorington tests were performed using the cards available from Bernell (items BC 1209F and BC 1209N in the 2005 catalog).[a.] For all testing, subjects were instructed to keep the numbers or letters clear in an effort to control accommodation.

Gradient AC/A ratios were determined by finding the difference between the phoria through the distance correction and the phoria through the add. Two gradient AC/A ratios were found, one with the +1.00 D add and one with the -1.00 D add. Calculated AC/A ratios were determined by the following formula:

AC/A=(convergence stimulus for near target-distance phoria+near phoria)/2.50 D

where convergence stimulus in prism diopters was equal to PD in cm divided by 0.427 m, and where exophorias were negative values and esophorias were positive values. The derivation of that formula is described in the literature.[6]

The statistical analyses performed were:

(1) calculation of the mean difference and standard deviation of the differences between test methods,

(2) correlation of test methods by Pearson correlation coefficient, and

(3) Pearson correlation coefficient of the differences between test results from the two methods with the means of the test results from the two test methods.

In the first of the analyses listed above, the standard deviation of the differences can be used to determine a 95% limits of agreement, indicating the range of differences expected between two methods 95% of the time. The 95% limits of agreement value is found by multiplying the standard deviation of the differences by 1.96. The second analysis listed above is a simple correlation of results on the two tests. This will indicate the strength of the relation of the results from the two tests. However, it should be noted that it is not useful for assessing how closely results on the two tests agree with each other.[7] The third analysis listed above is the procedure of finding a Pearson correlation coefficient of the differences between findings from the two methods with the means of findings from the two test methods. This procedure was recommended by Altman and Bland,[8] and serves to indicate whether the difference between methods may vary depending on the magnitude of the test findings.

RESULTS

Distance Phorias

Distance phorias averaged 0.2Δ exo with the von Graefe test and 0.1Δ eso with the modified Thorington test (Table 1). The mean difference was a 0.3Δ more convergent phoria with the modified Thorington test, and the standard deviation of the differences was 1.8Δ (Table 2). Based on that mean difference and multiplying the standard deviation of the difference by 1.96, we can suggest that 95% of the time, the modified Thorington distance phoria can be expected to be within the range of 3.8Δ more convergent to 3.2Δ more divergent than the von Graefe distance phoria.

The difference between von Graefe and modified Thorington distance phorias showed a significant correlation with the mean of the two (r=0.38), indicating the difference is dependent on the magnitude of the phoria. This can be observed in the scatterplot in Figure 1. For low phorias, the two methods were very close to each other, and the agreement of the methods is better than the calculated limits of agreement. For example, there were 55 subjects with von Graefe phorias between 3Δ exo and 3Δeso. The modified Thorington distance phoria was within 2Δ of the von Graefe for 54 (98%) of those

Table 1.
Means and standard deviations (parentheses) for each of the test findings with the two phoria procedures. Units are prism diopters for phorias and prism diopters per diopter for AC/A ratios.

	von Graefe	modified Thorington
Distance phoria	0.2 exo (2.6)	0.1 eso (2.0)
Near phoria	3.7 exo (5.6)	2.1 exo (4.6)
Calculated AC/A ratio	4.3 (1.8)	4.8 (1.3)
+1 D Gradient AC/A	3.1 (2.0)	2.2 (1.1)
-1 D Gradient AC/A	2.9 (1.8)	2.5 (1.3)

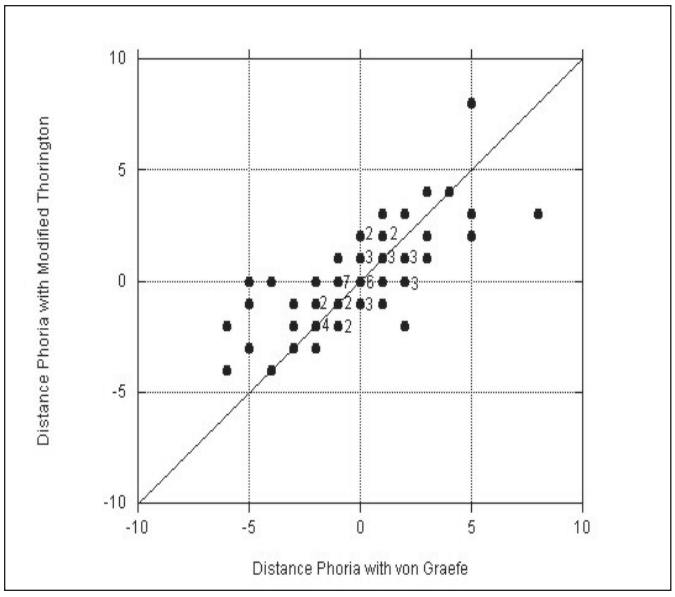

Figure 1. Scatterplot of distance phorias with von Graefe method and modified Thorington test. Numerals are placed just to the right of points to indicate multiple subjects at those points. The diagonal line marks points where the von Graefe and modified Thorington findings were the same. Points above the line were more eso or less exo with the modified Thorington test than with the von Graefe.

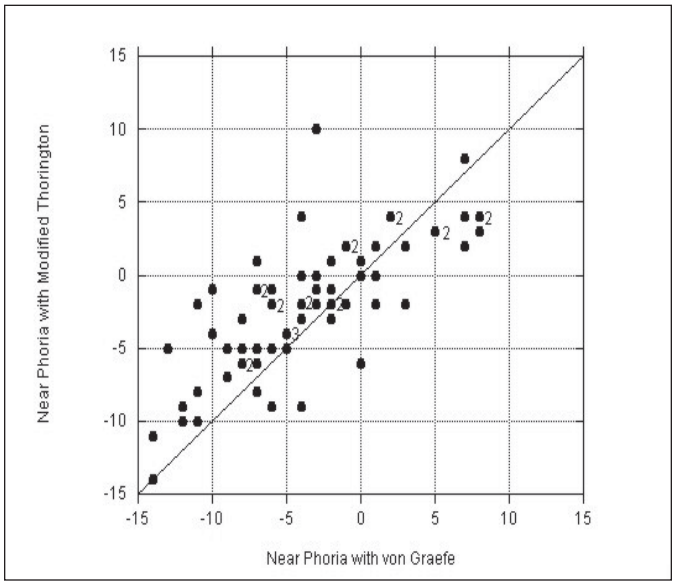

Figure 2. Scatterplot of near phorias with von Graefe method and modified Thorington test. Numerals are placed just to the right of points to indicate multiple subjects at those points. The diagonal line marks points where the von Graefe and modified Thorington findings were the same. Points above the line were more eso or less exo with the modified Thorington test than with the von Graefe.

Table 2.

Statistics describing the relation between findings with the von Graefe and modified Thorington procedures. The first column contains the mean difference in prism diopters (phorias) or in prism diopters per diopter (AC/A ratios) between the two methods and the standard deviations of the differences in parentheses. The next column is the Pearson correlation coefficient of the von Graefe result with the modified Thorington finding. The last column is the Pearson correlation coefficient of the differences between methods with the mean of the two methods for each subject.

	Mean difference (SD)	Correlation (r) between methods	Correlation (r) of differences with means
Distance phoria	0.3 (1.8)	0.74**	0.38*
Near phoria	1.4 (3.7)	0.75**	0.31*
Calculated AC/A ratio	0.5 (1.4)	0.65**	0.40**
+1 D Gradient AC/A	0.9 (1.9)	0.40**	0.57**
-1 D Gradient AC/A	0.4 (2.0)	0.18	0.32*

* p<0.01; ** p<0.001

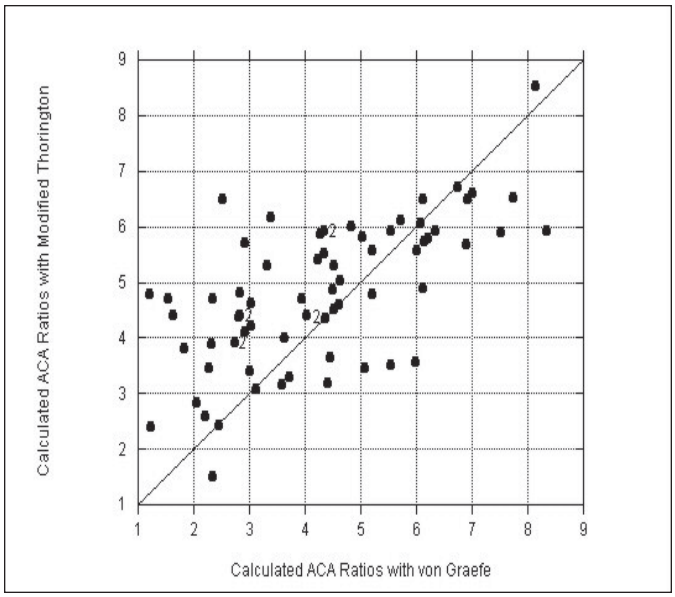

Figure 3. Scatterplot of calculated AC/A ratios with von Graefe method and modified Thorington test. Numerals are placed just to the right of points to indicate multiple subjects at those points. The diagonal line marks points where the von Graefe and modified Thorington findings were the same. AC/A ratios were higher with the modified Thorington test than with the von Graefe above the diagonal line.

55 subjects. For higher exophorias, the modified Thorington tended to show less exo, and for higher esophorias, the modified Thorington tended to show less eso. That is supported by the lower standard deviation for modified Thorington. For high phorias, the two tests are often not as close as suggested by the calculated limits of agreement.

Near Phorias

The means for the near phorias were 3.7Δ exo for the von Graefe test and 2.1Δ exo for the modified Thorington test. The mean difference was a 1.6Δ more divergent phoria with the modified von Graefe than with the Thorington, and the standard deviation of the differences was 3.7Δ (Table 2).

The difference between von Graefe and modified Thorington distance phorias showed a significant correlation with the mean of the two (r=0.31), indicating the difference is dependent on the magnitude of the phoria. This can be observed in the scatterplot in Figure 2. For low phorias, results for the two methods were in close agreement. For example, for the 22 subjects with von Graefe phorias between 3Δ exo and 3Δ eso, the modified Thorington distance phoria was within 3Δ of the von Graefe for 18 (82%) of those subjects. For higher exophorias, the modified Thorington was less exo than the von Graefe in 33 (87%) of 38 subjects. For von Graefe esophorias greater than 3Δ, the modified Thorington showed less eso in 7 (88%) of 8 subjects. The lesser exo in the average for modified Thorington can thus be explained by the greater number of exophoric subjects and the lesser exo found for them. The lower standard deviation on the modified Thorington can be explained by the lower phoria magnitudes in both higher exo and higher eso.

Calculated AC/A Ratio

The mean calculated AC/A ratio on the von Graefe test was 4.2 Δ/D (SD = 1.8). The mean calculated AC/A ratio on the modified Thorington test was 4.8 Δ/D (SD = 1.3). The standard deviation of the differences multiplied by 1.96 is 2.7Δ/D. The positive correlation of the difference in AC/A ratios (von Graefe minus modified Thorington) with the means of the two AC/A ratios and a perusal of the scatterplot in Figure 3 shows that with higher AC/A ratios the von Graefe AC/A ratio tends to be higher than the modified Thorington and that with lower AC/A ratios, the modified Thorington tends to be higher than the von Graefe.

Gradient AC/A Ratio with a +1.00 D Add

The mean +1.00 D gradient AC/A ratio on the von Graefe test was 3.1 Δ/D (SD = 2.0). The mean +1.00 gradient AC/A ratio on the modified Thorington test was 2.2 Δ/D (SD = 1.1). The difference in AC/A ratios between methods for each subject showed a significant correlation with the means of the findings with the two methods for each subject. That result along with observation of the scatterplot in Figure 4 indicates that there is more variability in the von Graefe AC/A ratios than the modified Thorington AC/A ratios, with the former tending to be lower for low AC/A ratios and higher for high AC/A ratios.

Gradient AC/A Ratio with a -1.00 D Add

The mean -1.00 D gradient AC/A ratio on the von Graefe test was 2.9 Δ/D (SD = 1.8). The mean -1.00 D gradient AC/A ratio on the modified Thorington test was 2.5 Δ/D (SD = 1.3). A scatterplot of the gradient (-1.00) AC/A ratios with the two methods is shown in Figure 5. The significant correlation of the difference in AC/A ratios between methods for each subject with the means of the findings with the two methods for each subject and plot in Figure 5 suggests more variability in the von Graefe AC/A ratios than the modified

Thorington AC/A ratios, with the former tending to be lower for low AC/A ratios and higher for high AC/A ratios as with the +1 gradient AC/A ratios.

DISCUSSION

Table 3 summarizes results of studies with comparison data for von Graefe and modified Thorington near phorias.[2,3,9,10] Most of the studies found the average near modified Thorington finding to be 1 to 2 Δ less exo than the average von Graefe finding. The standard deviations for von Graefe findings were higher than the standard deviations for modified Thorington findings.

The average gradient AC/A ratio given by Morgan was 4 ± 2 Δ/D.[11] The present study found a means for the gradient AC/A using von Graefe testing of 3.1 Δ/D (SD=2.0) for the +1.00 D gradient and of 2.9 Δ/D (SD=1.8) for the -1.00 D gradient. Means for modified Thorington testing in the present study were 2.2 Δ/D (SD=1.1) for +1.00 D gradient and 2.5 Δ/D (SD=1.3) for the -1.00 D gradient.

Mean AC/A ratios in the present study and in the study by Escalante and Rosenfield[4] are summarized in Table 4. The mean difference between modified Thorington and von Graefe results for the +1.00 D gradient for the present study was 0.9 Δ/D, which is similar to the 0.8 Δ/D difference found by Escalante and Rosenfield.[4] Escalante and Rosenfield also found a 1.2 Δ/D mean difference for the -1.00 D gradient, and the present study found a difference of 0.4 Δ/D.

The average calculated AC/A ratio (±SD) derived from Morgan's average phorias is 5.2 ± 1.6 Δ/D.[11] The mean calculated AC/A ratio from the present study for von Graefe testing was 4.2 Δ/D (SD=1.8), and for modified Thorington it was 4.8 Δ/D (SD=1.3). Modified Thorington testing produced a slightly higher calculated AC/A ratio than von Graefe testing, but less variability than von Graefe testing. The lower variability in AC/A ratios with modified Thorington reflects its lower variability on phoria testing. To our knowledge, this was the first study to compare calculated AC/A ratios using von Graefe and modified Thorington testing. This study also appears to be the first to compare distance phorias using von Graefe and modified Thorington methods.

AC/A ratios determined out of phoropter have been found to be more repeatable than those done with the phoropter.[4] In this study, both testing procedures were done in the phoropter so that proximal factors would be constant. The modified Thorington test is typically performed outside the phoropter.

Seeing that the modified Thorington test is more repeatable than the von Graefe test, it seems reasonable to use modified Thorington test to determine ACA ratios. However, because of the slight differences in modified Thorington and von Graefe ACA ratios found in this study, it may be prudent to adjust normal ranges accordingly.

Several studies[1-4] have shown that of the subjective heterophoria tests, modified Thorington testing is more repeatable than von Graefe testing. Because of its greater repeatability and because of the ease of performing it, the modified Thorington test is gaining in popularity. With any relatively less commonly used test, it is helpful to characterize its results by compar-

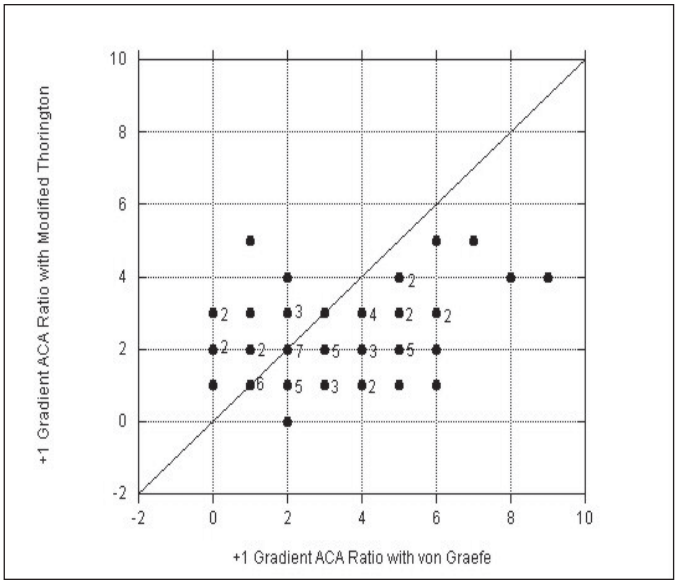

Figure 4. Scatterplot of +1 D gradient AC/A ratios with von Graefe method and modified Thorington test. Numerals are placed just to the right of points to indicate multiple subjects at those points. The diagonal line marks points where the von Graefe and modified Thorington findings were the same. AC/A ratios were higher with the modified Thorington test than with the von Graefe above the diagonal line.

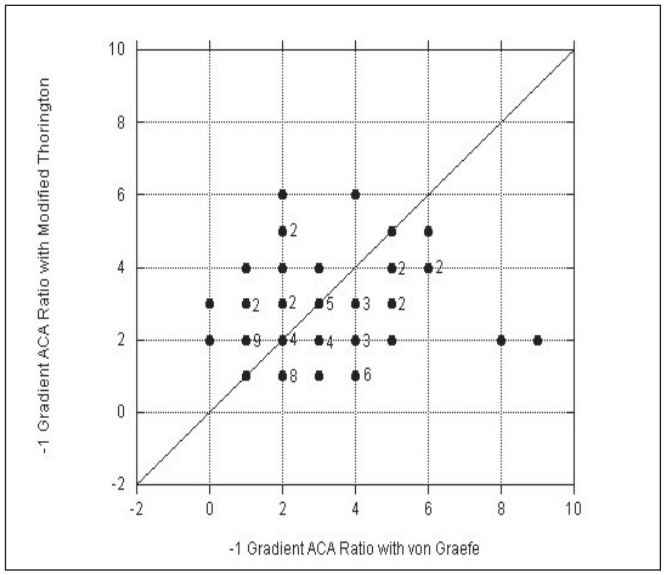

Figure 5. Scatterplot of -1 D gradient AC/A ratios with von Graefe method and modified Thorington test. Numerals are placed just to the right of points to indicate multiple subjects at those points. The diagonal line marks points where the von Graefe and modified Thorington findings were the same. AC/A ratios were higher with the modified Thorington test than with the von Graefe above the diagonal line.

Table 3.
Means and standard deviations (parentheses) for near von Graefe and modified Thorington phorias from different studies. Units are prism diopters. (In studies with variations in testing procedures, the data in this table are those from small letters for the testing target and from continuous presentation of the test target)

	von Graefe	modified Thorington
Hirsch and Bing[9]	4.6 exo (5.4)	3.4 exo (4.2)
Hirsch,[10] students	4.0 exo (6.4)	3.2 exo (6.2)
Hirsch,[10] instructors	4.3 exo (6.1)	3.1 exo (5.9)
Rainey et al,[2] examiner 1	4.3 exo (4.7)	2.2 exo (3.0)
Rainey et al,[2] examiner 2	5.0 exo (6.3)	2.1 exo 3.2)
Wong et al[3]	2.2 exo (4.2)	2.8 exo (3.7)
Present study	3.7 exo (5.6)	2.1 exo (4.6)

Table 4.
Means and standard deviations (parentheses) for AC/A ratios from different studies. Units are prism diopters per diopter.

	von Graefe	modified Thorington
Escalante and Rosenfield,[4] +1.00 D gradient	3.4	2.6
Escalante and Rosenfield,[4] -1.00 D gradient	3.6	2.4
Present study, +1.00 D gradient	3.1 (2.0)	2.2 (1.1)
Present study, -1.00 D gradient	2.9 (1.8)	2.5 (1.3)
Present study, calculated	4.3 (1.8)	4.8 (1.3)

ing it to an established standard test. This study suggests that the modified Thorington and von Graefe procedures give similar findings on midrange phorias and AC/A ratios. There was more variability in AC/A ratios on the von Graefe so that AC/A ratios were often higher on the von Graefe in high AC/A cases and lower on the von Graefe in low AC/A cases. Because these trends were more pronounced for lower calculated AC/A ratios (Figure 3) and for higher gradient AC/A ratios (Figure 4), the calculated AC/A ratio averaged higher for the modified Thorington test and the gradient AC/A ratios averaged higher for the von Graefe test. For higher exo or higher eso, the von Graefe method tends to yield higher values than the modified Thorington test.

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Source

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