

Comparison of Von Graefe and Maddox Rod Techniques in Measurement of Lateral Phoria

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ABSTRACT

Phoria is a phenomenon in binocular vision and commonly assessed during eye examinations. This study observed the outcomes of lateral phoria testing performed using the two common phoria testing methods (Von Graefe and Maddox rod) and compared to each other in order to determine the influences of the different techniques on the lateral phoria status results with respect to the phoria type detected, phoria magnitude and the testing distance. A sample size of 100 participants aged 16 to 30 years old (21.90 ± 2.60), were randomly selected and their lateral phoria assessed using both the Von Graefe method and the Maddox rod method. The results showed that the two phoria assessment methods, Von Graefe and Maddox rod, are both reliable in the assessment of lateral phoria at far and at near distances, there was no significant difference in the phoria results obtained from the two methods in terms of the type of phoria detected and the test distance. However, in magnitude of lateral phoria detected, Von Graefe results were slightly higher than the results derived from the Maddox rod method. After scatter plot of regression analysis, a positive correlational relationship ($p < 0.05$) was established between the Von Graefe method and the Maddox rod method of phoria assessment at far and at near as well. The authors conclude that there is a significant difference between Maddox rod method and the Von Graefe method only in magnitude of lateral phoria results, with the Von Graefe phoria results slightly higher than Maddox rod results.

Keywords: phoria assessment, lateral phoria, von Graefe, Maddox rod, test distance, Heterophoria

INTRODUCTION

Heterophoria (phoria) is a misalignment of the visual axes which occurs when the fusion of the two ocular images is interrupted; it is usually compensated for during binocular viewing by fusional vergence¹. Phoria is the ability to maintain visual focus of an object with both eyes, thereby creating a single visual image and this is achieved by the coordinated efforts of the two eyes to focus clearly at an object of

focus. Misalignment of the visual axes in heterophoria may be found in the horizontal, vertical or cyclo directions and may be correctable by fusional reserves or disparity vergence.² Phoria measurements are a routine part of the examination of the binocular vision status.³

A divergent misalignment is termed exophoria and a convergent misalignment is termed esophoria.⁴ Orthophoria is said to occur when the visual axes of both eyes

intersect at the target of focus.² Dissociated heterophoria is the latent deviation of the visual axes in the absence of visual input to one eye while the other eye maintains fixation on a target. When one eye is occluded during binocular fixation, the occluded eye may remain at its position (orthophoria), deviate toward nasal direction (esophoria), deviate temporally (exophoria), deviate upward (hyperphoria) or downward (hypophoria).⁵ The magnitude of heterophoria is expressed in prism dioptres (Δ).

Phoria measurement is an important clinical test as it indicates the demand on the fusional vergence system.⁴ The assessment of the patient's heterophoria status, both at far and at near, is an important part of any ocular examination for the diagnosis of binocular disorder and the management of accommodative and vergence disorder.⁶ Several tests and procedures are available to clinicians for the subjective assessment of phoria, such as the estimated alternate cover test, the cover test with prisms (subjective and objective), the Von Graefe technique (continuous and flash presentation), the Maddox rod test, the Thorington and the modified Thorington (continuous and flash presentation) method.³ All the assessment methods aim to determine the direction and or magnitude of any displacement of the visual axes when binocular fusion is interrupted. Although these tests have some common features and are all used in clinical practice, they may differ in their measurement outcomes.²

The Von Graefe technique is an in-phoropter measurement method that is favoured by many clinicians, the Von Graefe technique can be performed immediately after subjective refraction after the tentative spectacle prescription has been determined.⁷ The Von Graefe's technique reveals the presence of the phoria using the dissociation method as well as estimates the phoria magnitude and the phoria type. This technique (Von Graefe's) involves the placement of dissociating prism in front of one eye and the measuring prism in front of

the other eye.⁸ The Von Graefe technique is very popular and is probably the most common method for measuring heterophoria, with dissociation achieved by using horizontal and vertical prisms.⁶

The Maddox rod technique utilises a Maddox rod, a type of lens that consists of a series of glass or plastic rods mounted in a trial lens ring in a refractor, or in a wooden or plastic handle, to achieve dissociation. It is available in white or red lenses. Each individual rod within the series acts as a strong convex cylindrical lens, and incident light is spread in form of a streak in a direction 90 degrees to the orientation of the rods.

Purpose of study

This study observed the outcomes of the two common phoria testing methods and compared them with respect to type of phoria, magnitude of phoria and the test distance, in order to determine the influences of the different techniques on accuracy of the phoria status results. The assessments for phoria are considered relevant in the diagnosis of binocular vision anomalies; due to several assessment methods available, the choice of measurement technique may result in different sensitivities and specificities when diagnosing or monitoring binocular vision anomalies.

Aim and objectives of the study

The aim of the study was to compare Von Graefe and Maddox rod phoria testing techniques in the measurement of lateral phoria. The Objectives included:

- i. To compare Von Graefe and Maddox rod techniques in the measurement of lateral phorias based on phoria type.
- ii. To compare Von Graefe and Maddox rod techniques in the measurement of lateral phorias based on phoria size.
- iii. To compare Von Graefe and Maddox rod techniques in the measurement of lateral phorias based on test distance.

Significance of study

Patients with decompensated heterophoria may experience symptoms such as headache, eye strain, blurred vision and diplopia that may affect visual efficiency, which is important for near vision activities such as reading and working on digital devices.² The current reality of more frequent near work demands and the increased incidence of binocular vision-related symptoms among young adults today calls for improved application of the various binocular vision assessment techniques such as phoria assessments during eye examinations to facilitate proper diagnosis and intervention.

Some authors have compared the Von Graefe Technique with other methods, such as the modified Thorington test or the alternate cover test;⁶ more studies on the comparison of the effects of the methodology for phoria assessment have been recommended. The information gathered from the outcomes of this study is beneficial to clinicians in making an informed choice between Von Graefe techniques or the Maddox rod method for phoria assessment, depending on the magnitude of phoria, the type of phoria and the testing distances used in each method. This study also contributes to existing information on details of Von Graefe technique and Maddox rod phoria assessment.

MATERIAL AND METHODS

This study was carried out in Owerri, the host city for the Imo State University, and the capital city of Imo State, Nigeria. The University community is an adequate setting to find young adults who are actively engaged with reading and near visual tasks.⁹ A comparative quantitative study design was adopted for this study; lateral phorias were assessed using the Von Graefe method and the Maddox rod method at different distances. The study was carried out among participants aged 16 to 30 (21.90 ± 2.60) years of age. The age limits (16 – 30 years) chosen for this study served to eliminate any

undue age-related influence on binocular vision and consequently the phoria results. Purposive sampling was employed for this study, using a sample of 100, of both males and females, made up by randomly drawing from eligible study participants.

Direct ocular examination and heterophoria measurements were used to generate data in this study. The phoria tests using both Von Graefe technique and Maddox rod technique were administered to all the eligible participants for the study irrespective of ametropic status, using Snellen letters N5 at near as the near letter target and 20/20 at far (6m) as the distant target. This procedure was done to assess any differences between the results obtained by the two different methods of lateral phoria testing (Von Graefe and Maddox rod technique). The phoria tests were carried out using the phoropter, rotary prisms, and red Maddox rod. All results were duly recorded, categorised and collated accordingly. Phoria results can be influenced by the technique used for dissociation, ability to control accommodation adequately, the length of time that fusion is suspended.² In order to generate reliable results, due diligence was taken to avoid procedural errors and increase test sensitivity by repeating each test 3 times with each method and deriving the mean values.

For this study, ethical approval and permission to utilise the Optometry clinic was obtained and the willing participants were duly informed of the various test procedures to be performed on them. Only candidates who voluntarily gave written informed consent to participate in this study were assessed for this study. Furthermore, the anonymity and confidentiality of all the research respondents was maintained throughout the data collection, categorization and analytical processes.

All intending participants were pre-screened to determine/confirm their eligibility to participate in this study. A data collection tool and short questionnaire to determine demographic characteristics, was applied to all the candidates to reveal information

regarding age, sex, eye/health records/history, current eye/health status. Preliminary eye exams were also conducted – binocularity assessment (cover/uncover test), refractive status assessment (retinoscopy and subjective refraction), and assessment of the accommodative system (near point of accommodation and amplitude of accommodation). Participants with any form of binocular dysfunction such as strabismus, amblyopia, convergence insufficiency, corrected visual acuity worse than 20/40 in either eye, history of ocular surgery or trauma, ocular or systemic pathologies affecting accommodation and binocular vision, and in use of ocular or systemic drugs affecting accommodation and binocular vision, were excluded from this study.¹⁰ Traditional normative values to determine whether a subject has an accommodative or non-strabismic binocular vision disorder was applied.¹¹ All the participants who met the inclusion criteria underwent phoria assessment using both the Von Graefe method and the Maddox rod method.

For Von Graefe assessment, a dissociating prism of 6 Δ base-up was placed in front of the left eye and a measuring prism (12 Δ base-in) before the right eye, using the phoropter. For both distance and near vision, subjects were instructed to fixate at the line above their best visual acuity letters (at 6m for distant assessment, and 40cm for near assessment) and were told to keep the letters clear all the time.² The subjects were instructed to focus on the lower target and inform the examiner when the upper target became aligned just above the lower target. For that, the magnitude of the horizontal prism (12 Δ) was changed in one-dioptre steps until subjects saw both images aligned. The procedure was repeated three times to obtain three measurements and the mean value obtained.⁶ The residual prism value at point of target alignment was recorded as the phoria status of the participant at the specified test distance (for far and for near) - with prism dioptre base in

for exophoria, base out for esophoria, 0 for orthophoria.

For the Maddox rod assessment, a small bright source of light was used as a fixation object and the rods were oriented horizontally for lateral phoria (esophoria) measurement. The spot of light (the test target) was held at 40 cm (for near assessment) and 6m (for distant assessment). This caused the subject to see a vertically oriented red line and a spot of light. A measuring prism of 12 Δ was then placed in front of the left eye in base-out form leaving the Maddox rod in front of the right eye. The examiner then instructed that the participant report when the line and spot of light were superimposed. The measuring prism was then altered in one prism dioptre steps until superimposition was reported to have occurred. The amount of prism present when this alignment was reported was recorded as the measure of the patient's lateral phoria measurement.⁸ This test was done at far with target distance at 6m and at near with target distance at 40cm.

The results recorded were categorized according to testing method (Maddox rod or Von Graefe), according to test distance (far or near), according to type of phoria detected and magnitude, data was also classified based on gender, age and refractive error. Data analysis was performed using the IBM SPSS statistics version 25.0. Descriptive statistic such as frequencies, percentages mean and standard deviation were used for initial data description. Data was categorised according to age, gender, refractive error, phoria type.

STATISTICAL ANALYSIS

Data analysis was performed using IBM SPSS statistics version 25.0 (IBM Corp, Armonk, NY, USA). Scatter plots of regression analysis were constructed to explore relationships between data variables and, paired z-test was used to test for difference in mean. All tests were performed at 5% level of significance. The probability value (p) and 95% confidence interval (95% conf. Int.) were used to

interpret the result. Therefore $p < 0.05$ and 95% conf. int. not containing zero within the interval were considered significant.

RESULTS

There was a total of 100 samples taken, the basic descriptive characteristics of the study group is represented in Table 1. The table shows that the average age of the subjects with corresponding standard deviations from the mean was 21.9 ± 2.60 . The sample comprised of 42 males (42.0%) and 58

females (58.0%). The youngest person was 16 years old male while the oldest person among them was 28 years (a female). The average age was slightly lower in males 20.98 ± 2.52 than in females 22.55 ± 2.47 .

In terms of refractive errors, a total of 32 (32%) with average the age of 21.9 ± 2.82 did not have any refractive errors (Plano), 8 (8%) had astigmatism (mean age: 22.63 ± 3.33), 24 (24%) had hyperopia (mean age: 21.96 ± 1.94), and 36 (36%) had myopia (mean age: 21.7 ± 2.67).

Table 1: Characteristics of study population

Characteristics	Number (%)	Mean (st. dev)	Min (Max)
Age (years)	N=100	21.90 (2.60)	16 (28)
Sex			
Male	42	20.98 (2.52)	16 (27)
Female	58	22.55 (2.47)	17(28)
Total	100		
Refractive errors			
Astigmatism	8	22.63 (3.33)	17 (28)
Hyperopia	24	21.96 (1.94)	18 (25)
Myopia	36	21.67 (2.67)	18 (28)
Plano	32	21.91 (2.82)	16 (26)

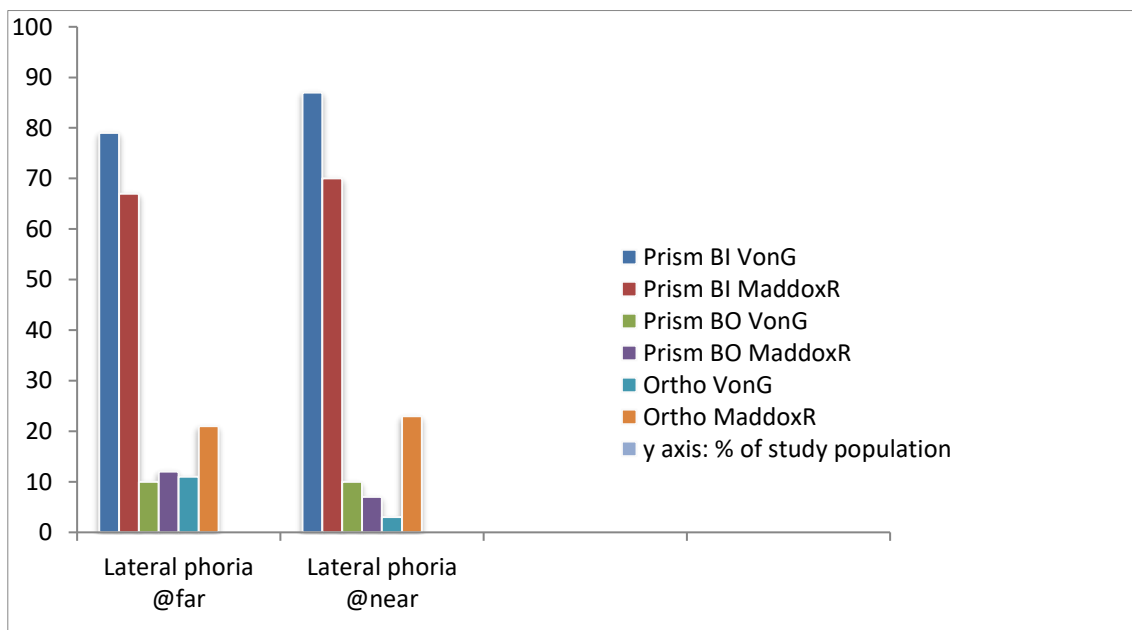


Figure 1: Lateral Phoria distribution at far and at near

The spread of the occurrence of the lateral phorias is presented in Figure 1. For lateral phoria assessment, exophoria (base in prism results) was the most prevalent phoria detected across both Von Graefe and Maddox methods with 79% (Von Graefe) and 67% (Maddox Rod) at far and 87%

(Von Graefe) and 70% (Maddox rod) at near. Base out results (esophoria) followed at 10% (Von Graefe) and 12% (Maddox Rod) at far, then 10% (Von Graefe) and 7% (Maddox rod) at near.

A scatter plot showing correlation for Von Graefe vs Maddox rod lateral measurements

at far distance is shown in Figure 2. A positive correlation was found to exist laterally between the two measurements (Von Graefe and Maddox rod) at far distance, as most of the data points are observed around the straight line upwards. The correlation coefficient ($r = 0.837$, $p = 0.0001$) seen in table 2 indicates a significant strong positive relationship in the lateral measurement between Von Graefe vs Maddox rod measurements at far distance. The table shows that the mean measurement was higher (stronger) at Von Graefe measures (2.133 ± 1.664) than at Maddox rod measures (1.625 ± 0.551). The

difference between the two measurements was found significant in this study ($P < 0.0001$; 95% conf. Int.= 0.324 to 0.691), which is a clear indication that such a difference did not occur by chance. For the male, the mean \pm Standard deviation for Von Graefe at far distance was 1.560 ± 1.578 , while that of the female is $1,672 \pm 1.543$. On the other hand, the mean value for Maddox was found as 1.560 ± 1.578 for male and $1,672 \pm 1.543$ for female. The correlation between the two measurements were positively strong in male (0.907) and in female (0.787).

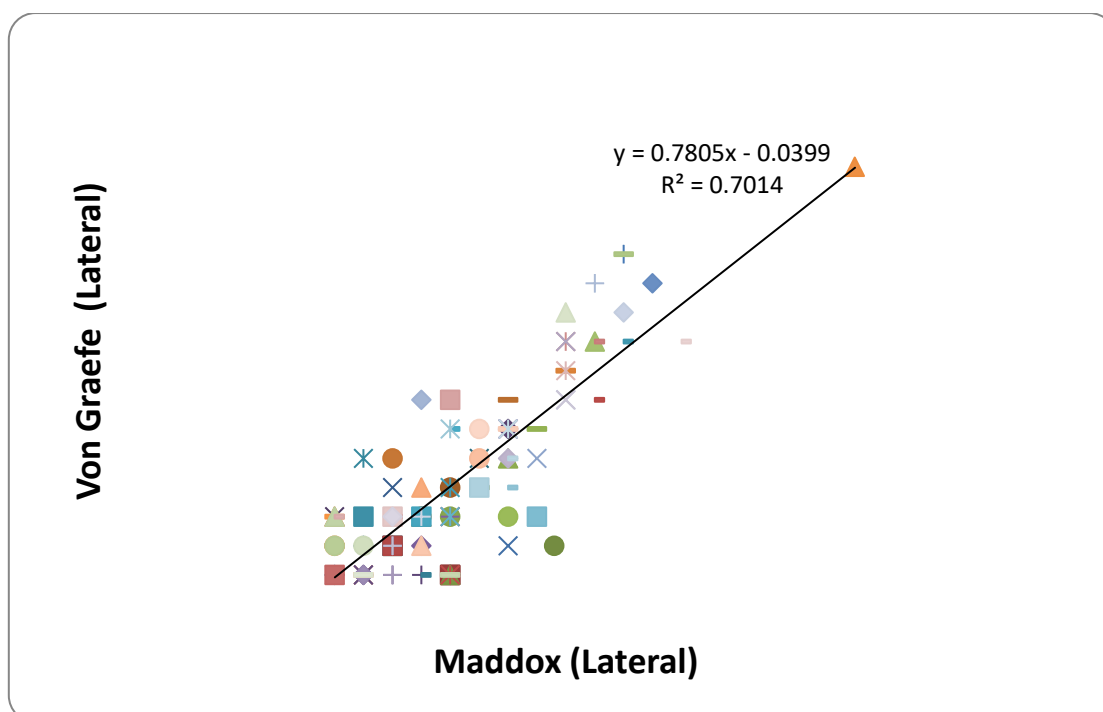


Figure 2: Scatter plot of regression analysis showing correlation for Von Graefe vs Maddox Lateral Measurements at far Distance

Table 2: Von Graefe vs Maddox Lateral Measurements at far Distance

Lateral (far)	Male	Female	Total
Von Graefe: Mean \pm Std. Deviation	1.726 \pm 1.942	2.428 \pm 1.374	2.133 \pm 1.664
Maddox: Mean \pm Std. Deviation	1.560 \pm 1.578	1,672 \pm 1.543	1.625 \pm 0.551
Von Graefe vs Maddox			
Correlation	0.907	0.787	0.837**
P	0.1554	< 0.0001	0.0001
T	1.447	5.961	5.504
95% conf. Interval	-0.066, 0.399	0.502, 1.009	0.324, 0.691

Figure 3 represents the relationship (correlation plot) for Von Graefe vs Maddox rod lateral measurements at near distance.

The figure shows that positive correlation also exists laterally between the two measurements at close distance as most of

the data points are observed around the straight line upwards.

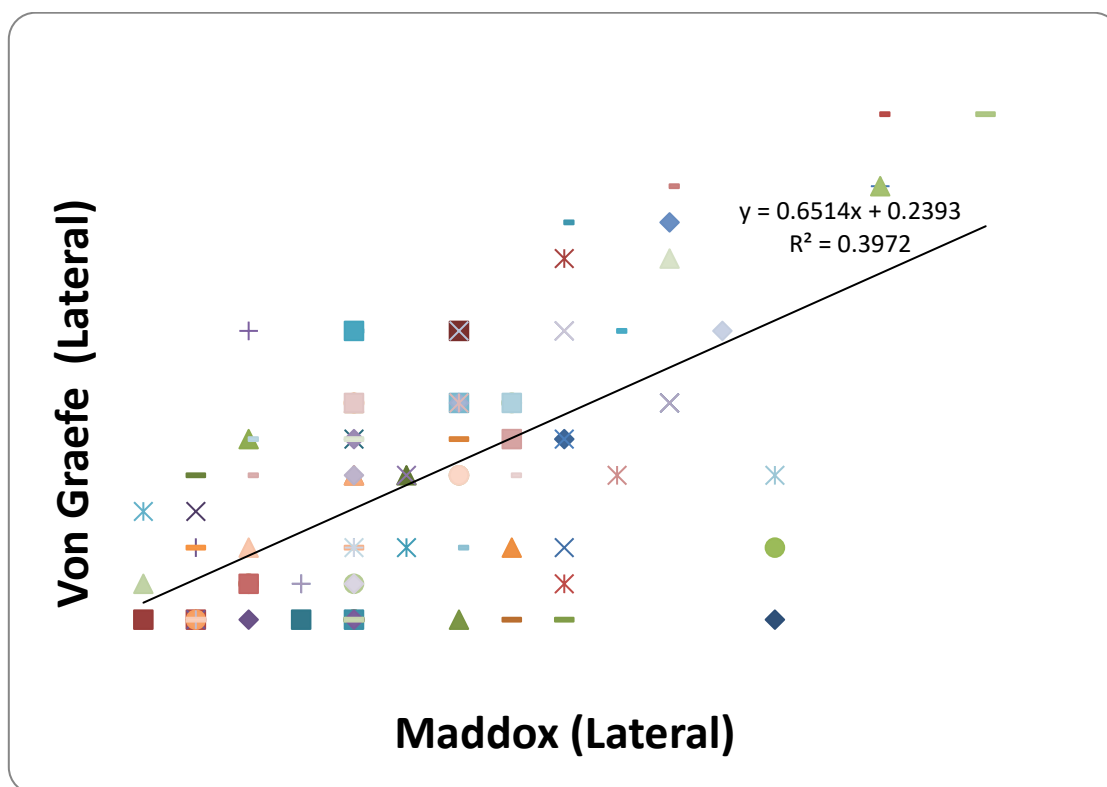


Figure 3: Scatter plot of regression analysis showing correlation for Von Graefe vs Maddox rod Lateral Measurements at Near Distance

Table 3: Von Graefe vs Maddox Lateral Measurements at near

Lateral (Near)	Male	Female	Total
Von Graefe: Mean ± Std. Deviation	2.429 ± 1.540	2.428 ± 1.374	2.680 ± 0.721
Maddox: Mean ± Std. Deviation	1.595 ± 1.420	1,672 ± 1.543	1.985 ± 1.779
Von Graefe vs. Maddox			
Correlation	0.521	0.499	0.630**
<i>P</i>	0.002	0.0076	< 0.0001
<i>T</i>	4.123	2.766	4.616)
95% conf. Interval	0.425, 1.242	0.164, 1.025	0.068, 0.502

The correlation coefficient was found to be positive and significant ($r = 0.630$, $p = 0.011$) as presented in Table 3. The correlation indicates that the relationship is moderately strong but not as in the case of far distance assessment. However, difference exist in mean between Von Graefe (mean = 2.680 ± 0.721) and Maddox (mean = 1.985 ± 1.779), and the difference was found to be statistically significant ($P < 0.0001$; 95% conf int = 0.0678 to 0.5022).

DISCUSSION

A study by Yu and Ha¹² investigated the difference in the values of horizontal

heterophoria measured in 72 college students between results using the Von Graefe Technique and results using the Maddox rod technique. There were 21 orthophoric, 36 exophoric and 15 esophoric participants in their study and their study results did not find definite differences for horizontal heterophoria by any of the two test methods.² Similarly, Schroeder *et al.*¹³ reports on a study by Soderberg (1968) that assessed the phoria of 100 clinic patients at far and at near, using Maddox rod technique and Von Graefe technique, and results suggested that both methods were closely related and could be substituted for each

other. However, for this study, only descriptive statistical methods were applied for the analysis of the results. Similar outcomes are reported from the correlational analysis of the results between the Von Graefe technique and the Maddox rod technique in this study. A positive correlation was established laterally between Von Graefe vs Maddox rod lateral measurements at far distance (Figure 2) and at near (Figure 3), although the Von Graefe results were slightly higher in magnitude than Maddox rod results.

The results from the study by Azuamah *et al.*,¹⁴ showed a significant difference in the lateral phoria values obtained from Von Graefe technique and Maddox wing, with mean exophoria values being 5.67 ± 2.77 and 4.37 ± 2.89 respectively. The mean esophoria values obtained were 1.33 ± 0.82 and 1.00 ± 0.00 respectively showing that, phoria values with von graefe technique and Maddox wing were not the same.¹⁴

Maqbool *et al.*,¹⁵ in a comparative cross-sectional study that included 100 patients, assessed the types of phorias in different degrees of myopic patients and different age groups before and after refractive correction using the Maddox rod method. Their study concluded that after correction the frequency of horizontal phorias are higher than the vertical phorias in magnitude. From the findings of this study, comparing horizontal phoria results and vertical phoria by Von Graefe and Maddox rod testing, similar observation was made; base in and base out values recorded were higher (ranging from 0.5 to 9 prism dioptres) than the base up and base down values (ranging from 0.5 to 3 prism dioptres). Accommodative fluctuations affect the fusion-free ocular position in the vertical direction less than in the horizontal direction, this would account for the disparity between vertical phorias and horizontal phorias.¹⁶

There is a high incidence of orthophoria at distance, while most researchers have reported exophoria of about 0 to 6 prism dioptres at near viewing distance.¹⁷ In their

study, Chen and Dom,¹⁷ conclude that regardless of the types of heterophoria, the amount of heterophoria reduced towards orthophoric position with increasing viewing distance that is, at far. Emmetropes and myopes did not show any significant difference in the degree of heterophoria at different viewing distances or in the type of Heterophoria.¹⁷

The study by Troyer *et al.*⁴ was aimed at understanding the effect of viewing distance, target type, cover protocol, and length of occlusion on phoria estimates for adults and children. Their results showed that the phoria became more exophoric with near viewing distance for each target type and cover protocol tested in both adults and children. They concluded that near testing distance resulted in greater exophoria for both children and adults ($p < 0.001$). Phorias were similar for adults and children for each viewing distance and target, with mean differences of less than 2 prism dioptres. This impact of testing distance on phoria is in agreement with the results obtained in this study as the prevalent phoria results at far and also at near was exophoria (base in prism dioptres) in both Von Graefe and Maddox rod testing methods. However, the near phoria results showed higher values of base out prism dioptres than the distant tests for both Von Graefe and Maddox rod techniques.

CONCLUSION

The most prevalent phoria finding among the young adult population assessed in this study was exophoria, for both Von Graefe and Maddox rod assessment methods. The two phoria assessment methods, Von Graefe and Maddox rod are both reliable in assessment of phoria at far and at near distances, there was no significant difference in the results obtained from the two methods in terms of the type of phoria detected and the testing distance, however, the Von Graefe results were slightly higher than the Maddox rod in the magnitude of the phoria detected. A positive correlational relationship was established between the

Von Graefe method and the Maddox rod method of phoria assessment at far and at near as well.

The results of this study imply that both Von Graefe and Maddox rod techniques can be used interchangeably in the general gross assessment of phoria during binocular vision assessment both at far and at near. There is a significant difference in phoria magnitude when assessed with Maddox rod method compared to Von Graefe method, with Von Graefe results slightly higher. It is suggested that further studies may be carried out for further comparison of phoria assessment methods considering some other factors such as age (comparing between adults and children), near work demand and familiarity with the testing procedures.

The outcomes of this study lead to the recommendation that young adults should be routinely screened for binocular vision status by clinicians due to the high prevalence of exophoria among the study population. Furthermore, when phoria results are very high in magnitude from using the Von Graefe assessment method, the Maddox rod assessment method may be applied by clinicians to compare findings.

Declaration by Authors

Ethical Approval: Approved

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Conflict of Interest: The authors declare no conflict of interest.

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