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COMPARISON OF ACCURACY WITH SPHERE VERSUS SPHERE-CYLINDER TECHNIQUE FOR NEUTRALIZATION OF REFRACTIVE ERROR WITH RETINOSCOPE

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Retinoscopy; refractive error; sphere technique; sphere-cylinder technique; neutralization; accuracy; astigmatism.

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Abstract

Background *Retinoscopy is an important objective method used for assessing refractive error and determining an appropriate refractive correction. Accurate neutralization requires appropriate assessment of the spherical and cylindrical components of the refractive error. The Sphere technique primarily considers spherical power, whereas the Sphere-Cylinder technique incorporates both spherical and cylindrical components. However, there is a need to evaluate which technique provides greater accuracy during retinoscopic neutralization.*

Objective *To compare the accuracy of the Sphere technique and Sphere-Cylinder technique for neutralization of refractive errors using retinoscopy.*

Methodology *A comparative study was conducted to assess the accuracy of the two retinoscopic neutralization techniques. Participants underwent refractive assessment using both the Sphere and Sphere-Cylinder techniques. The obtained refractive values were compared with the reference spherical equivalent to determine the accuracy of each technique. The difference between the obtained and reference values was used to assess measurement error. Data were analyzed using SPSS, with descriptive statistics used to summarize the study variables. Normality was assessed using the Shapiro-Wilk test, and the appropriate*

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statistical test was used to compare the two techniques.

Results *The findings demonstrated a statistically significant difference in accuracy between the two techniques. The Sphere-Cylinder technique showed a lower mean absolute error (0.131 ± 0.139 D) compared with the Sphere technique (0.269 ± 0.119 D). The difference between the techniques was statistically significant ($p < 0.001$), indicating greater accuracy of the Sphere-Cylinder technique in the studied sample. The mean difference in error between the two techniques was approximately 0.138 D, favoring the Sphere-Cylinder technique. These findings indicate that consideration of the cylindrical component may improve the precision of refractive error neutralization during retinoscopy.*

Conclusion *The study concluded that the Sphere-Cylinder technique was more accurate than the Sphere technique for neutralization of refractive errors using retinoscopy. Incorporating the cylindrical component during retinoscopic assessment may provide a more complete representation of refractive error and reduce residual refractive error, particularly in eyes with astigmatism.*

INTRODUCTION

Refractive error is one of the most prevalent eye conditions, and a significant cause of diminished visual function globally.[1] It is caused by failure of the optical apparatus of the eye to focus incoming light properly on the retina, causing a loss of visual acuity. The most commonly encountered refractive errors are myopia, hyperopia and astigmatism.[2] The amount of refractive error and its distribution change with age, ethnicity, geographical location and environment. Uncorrected refractive error can impact education, work, visual quality and quality of life.[3] It has, therefore made it important to measure refractive errors accurately and correct them appropriately as a part of primary eye care and optometric practice in the face of the growing burden of refractive error in the world. [4]

Correction of refractive error needs the spherical and cylindrical parts of the optical system to be determined accurately.[5] Whereas a refractive error is approximately equal in all meridians of the eye, spherical refractive error is called astigmatism. For astigmatism, both the amount of the cylindrical error and the direction of the axis are important in determining the prescription needed.[6,7] Therefore, it is important to recognize that an examination that establishes only the spherical component,[8] will not give a complete profile of the refractive status of eyes with clinically significant astigmatism.The importance of the measurement and interpretation of astigmatism has grown due to the fact that small differences in the cylinder power or axis can affect the final spectacle prescription and visual performance. [9]

The spherical equivalent is commonly used to sum up refractive error since it gives one single refractive number that represents the average refractive power of the eye. But the orientation of astigmatism cannot be defined by spherical equivalent.[10] Due to this, modern refractive research often handles the sphere, cylinder and axis as independent quantities and may also employ the power-vector analysis components. A power-vector method can be used to statistically analyze spherical and cylindrical refractive findings and to retain information about the orientation of astigmatism. In studies comparing the various methods of refractive measurement, these are especially helpful because two methods may yield very similar SE but measure the cylinder differently or the axis.[11]

The spherical equivalent is also often used when summarizing refractive error as it gives a single number to represent the average refractive power of the eye.[12] But, spherical equivalent is not enough to specify the direction of astigmatism. This is why modern refractive analysis often involves examining the sphere and

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cylinder and axis individually, and often requires the use of power-vector analysis, for which the components M, J0 and J45 are used. Power-vector methods are used to statistically evaluate spherical and cylindrical refraction, without discarding the orientation of the astigmatism. These are especially useful in comparing various techniques of refraction measurement.[13] It is important to note that two techniques may yield the same SE but different values for cylinder or axis power. Retinoscopy is an established objective technique for the measurement of refractive error, and still serves as an important tool in clinical optometry.[14] A retinoscope is used to help the doctor examine the reflex of the retina and its movement during retinoscopy. The appropriate lenses are then added until the reflex is neutralized. The refractive result is then corrected the working distance of the examiner.[15] Retinoscopy is a more objective method than subjective refraction, as the patient is not required to identify which lens gives him/her the best vision and can therefore be especially useful when subjective responses are unreliable. [16] The use of retinoscopy in children and patients with limited communication is particularly helpful. Subjective refraction procedures may be difficult for children to understand and they might not be able to hold their focus or give consistent answers.[17] Retinoscopy is an objective method that offers a point of reference from which to estimate the refractive error, and then fine-tune the error by subjective methods if they are appropriate.[18] In children there is a good level of agreement between retinoscopy and other objective methods of measurement of refractive errors, with some variation in each of the spherical, cylindrical and spherical equivalent measurements that occurs from one to another.[19] Cycloplegic retinoscopy has also been reported as being useful in isolated paediatric cases where the AR measurement is discordant with clinical findings [20]. Retinoscopy is accurate due to the following factors. These include: working distance for examiner, fixation for patient, illumination, retinoscope alignment, retinal reflex, trial lenses and examiner experience.[21] Also, the refractive state measured may be affected by the accommodation of the eye, especially in children and young adults.[22] Thus, the final refractive effect may be affected due to the variations in the method of neutralization. A small mean difference was found for sphere, cylinder and spherical equivalent with limits of agreement showing clinically significant intra and inter-examiner difference for cycloplegic retinoscopy in young children [23]. They also found that in 71% of the refractions with astigmatism ≥0.75 D, the examiners were within ±20° of each other when it came to the cylinder axis. [24] Retinoscopic neutralization is more complicated than that of a purely spherical refractive error because of the presence of astigmatism.[25]

Methodology

This comparative cross-sectional study was conducted to assess and compare the accuracy of spherical versus sphere-cylinder neutralization techniques in retinoscopy by comparing their results with subjective refraction which was considered as the gold standard. The study was conducted in the Eye Care Department, Department of Ophthalmology, District Head Quarter Hospital Vehari, Punjab, Pakistan over a period of four months after the approval of the research synopsis. A total of 40 participants were included in the study and this number was considered adequate to compare the accuracy of both techniques and to ensure reliable statistical analysis. A non-probability consecutive sampling technique was used and all patients who fulfilled the inclusion criteria and attended the eye clinic during the study period were recruited until the required sample size was achieved. Patients aged between 10 to 35 years, both males and females, patients with refractive errors including myopia, hyperopia or astigmatism, patients cooperative for retinoscopy examination and patients whose visual acuity was measurable with standard charts were included in the study. Patients with ocular pathologies such as cataract, keratoconus or retinal disease, history of ocular surgery, presence of strabismus or nystagmus, media opacities affecting the retinoscopy

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reflex and uncooperative patients were excluded from the study. Data was collected in a clinical setting using a standardized procedure after obtaining approval of the research proposal. A pre-designed data collection instrument and structured questionnaire was utilized to collect data from research subjects and informed voluntary consent was obtained from all participants after explaining the procedure, purpose and benefits of the study and all procedures of ethical compliance contained in the research proposal were followed in accordance with the principles of the Declaration of Helsinki. Detailed history was taken from each subject including any specific history of chronic diseases and demographic characteristics including age and gender. Visual acuity assessment was performed by measuring unaided visual acuity using Snellen chart at a standard distance under standard illumination. Retinoscopy examination was performed in a dimly lit room at a fixed working distance using a streak retinoscope. In technique one, spherical neutralization, the retinoscopic reflex was neutralized using only spherical lenses and the spherical power was recorded. In technique two, sphere-cylinder neutralization, the retinoscopic reflex was neutralized using both sphere and cylinder lenses and sphere, cylinder power and axis were recorded. Subsequently, subjective refraction was performed as the gold standard and best corrected visual acuity was recorded. The results of both retinoscopy techniques were then compared with subjective refraction to record accuracy differences and all findings were entered into a structured data sheet. Data was analyzed using Statistical Package for Social Sciences version 27.0 after checking data validity and cleaning. Descriptive statistics including mean, standard deviation, frequencies and percentages were calculated. Paired sample t-test was used to analyze mean differences between techniques and agreement analysis was performed. A p-value of ≤0.05 was considered statistically significant and data was presented using graphical representations including bar charts, histograms and box plots where appropriate.

RESULTS:

The reference spherical equivalent was evaluated in all 40 participants. The mean value was -1.2125 D with a standard deviation of 2.35241 D. Values ranged from -5.50 D to +2.50 D, with a median of -1.0000 D and a 95% confidence interval for the mean from -1.9648 D to -0.4602 D.

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4.1 Reference Spherical Equivalent

Table 4.1. Descriptive statistics of reference spherical equivalent

Statistic	Value
N	40
Mean (D)	-1.2125
Standard error	0.37195
95% confidence interval for mean (D)	-1.9648 to -0.4602
5% trimmed mean (D)	-1.1806
Median (D)	-1.0000
Variance	5.534
Standard deviation (D)	2.35241
Minimum–maximum (D)	-5.50 to +2.50
Range (D)	8.00
Interquartile range	3.75
Skewness (SE)	-0.178 (0.374)
Kurtosis (SE)	-1.012 (0.733)

The reference spherical equivalent was evaluated in 40 participants. The mean was −1.2125 D (SD = 2.35241), with values ranging from −5.50 D to +2.50 D. The median was −1.0000 D, and the 95% confidence interval for the mean ranged from −1.9648 D to −0.4602 D.

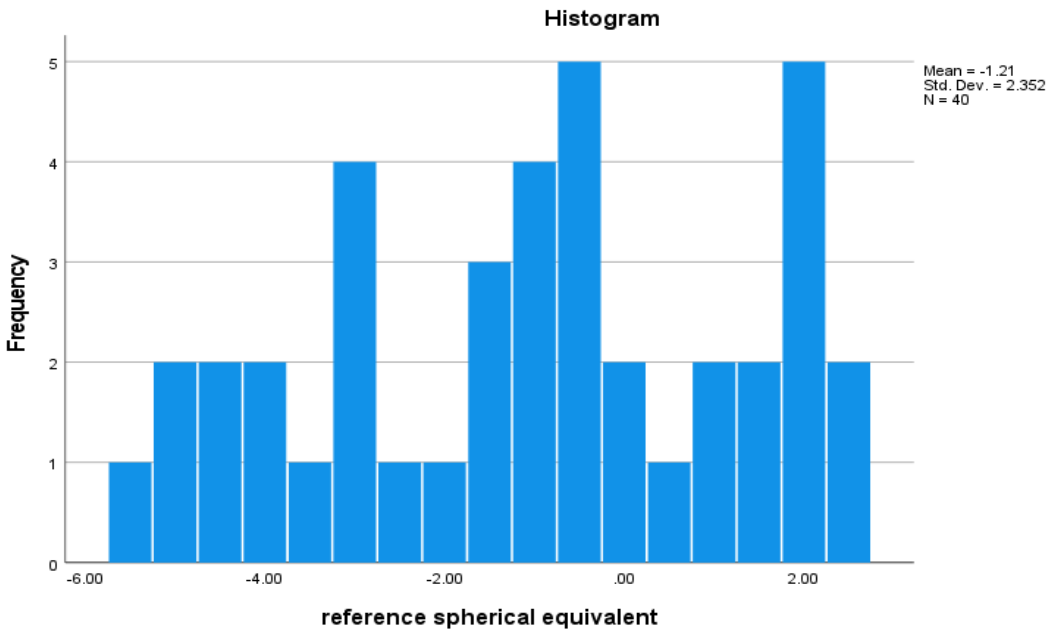

Figure 4.1. Histogram of reference spherical equivalent.

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4.2 Accuracy of Sphere and Sphere-Cylinder Techniques

Table 4.2. Descriptive statistics of technique accuracy

Technique	N	Minimum (D)	Maximum (D)	Mean (D)	SD (D)
Sphere technique	40	0.00	0.50	0.2688	0.11859
Sphere-cylinder technique	40	0.00	0.50	0.1313	0.13853

Accuracy was assessed in 40 observations for each technique. The sphere technique had a mean accuracy value of 0.2688 D (SD = 0.11859), whereas the sphere-cylinder technique had a mean of 0.1313 D (SD = 0.13853). Thus, the reported mean accuracy value was higher for the sphere technique.

Figure 4.2. Histogram of accuracy of the sphere technique.

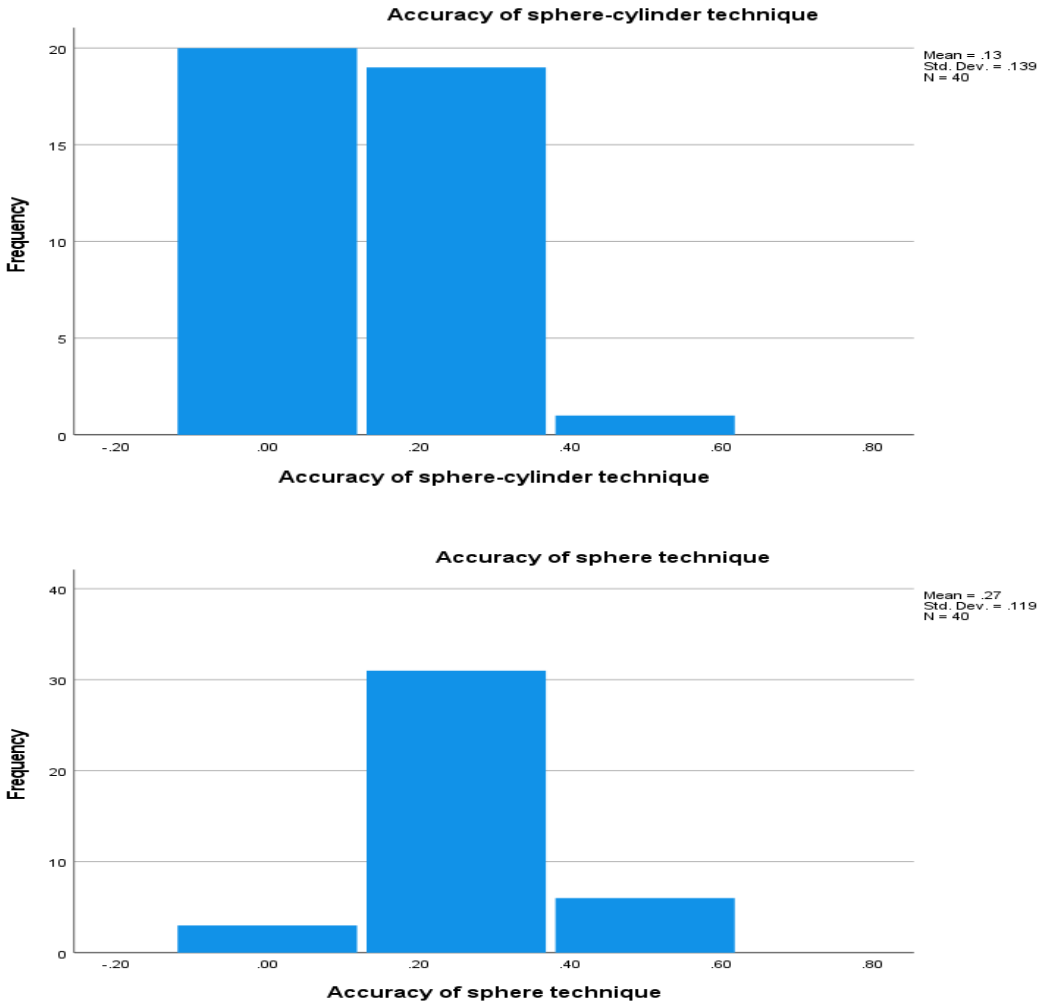

Figure 4.3. Histogram of accuracy of the sphere-cylinder technique.

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4.3 Assessment of Normality

Table 4.3. Shapiro–Wilk tests for normality

Variable	W	df	p-value
Spherical equivalent of both eyes	0.956	40	0.123
Spherical equivalent of right eye	0.953	40	0.100
Spherical equivalent of left eye	0.958	40	0.140

The Shapiro–Wilk test was used to assess the normality of spherical-equivalent measurements. The test was non-significant for both eyes (p = 0.123), the right eye (p = 0.100), and the left eye (p = 0.140). All p-values were greater than 0.05, indicating no statistically significant evidence of departure from normality. Parametric tests were therefore considered appropriate, subject to the other assumptions of each test.

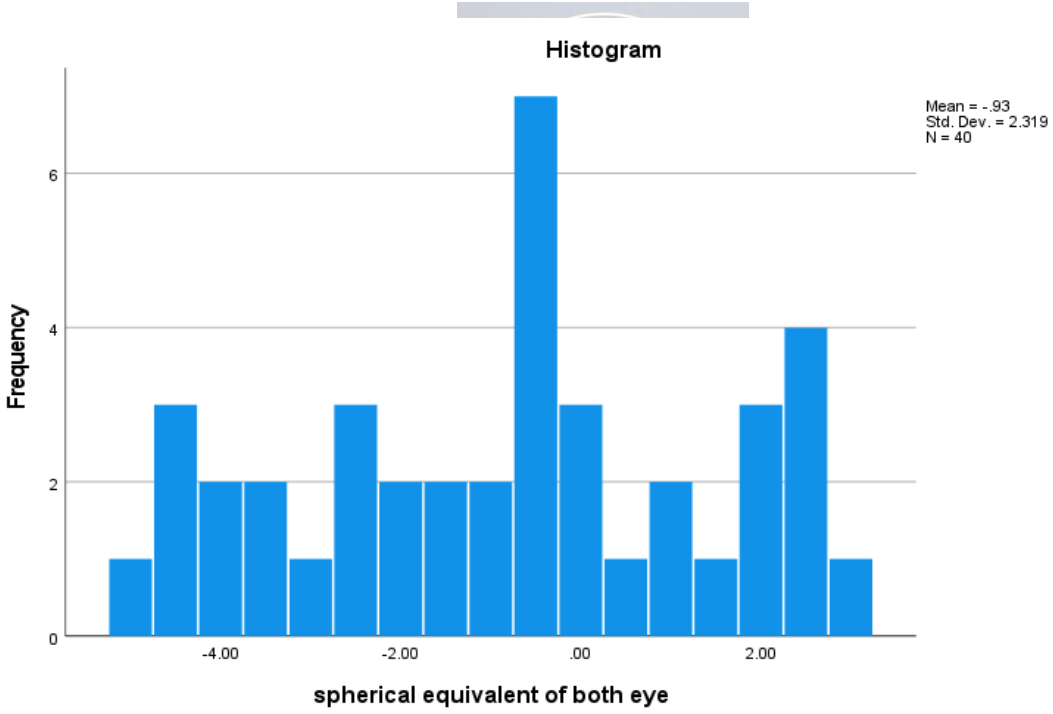

Figure 4.4. Histogram of spherical equivalent of both eyes.

4.4 Independent-Samples t-Test Comparing Mean Accuracy

Table 4.4. Group statistics for mean accuracy

Technique	N	Mean accuracy (D)	SD	SE
Sphere	40	0.269	0.119	0.019
Sphere-cylinder	40	0.131	0.139	0.022

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Table 4.5. Independent-samples t-test comparing mean accuracy

Variance assumption	Levene's F	Levene's p	t	df	Mean difference (D)	SE difference	p-value	95% CI (D)
Equal variances assumed	1.12	0.293	4.77	78	0.138	0.029	<0.001	0.080 to 0.196
Equal variances not assumed	—	—	4.77	75.34	0.138	0.029	<0.001	0.080 to 0.196

The independent-samples t-test compared mean accuracy values between the sphere and sphere-cylinder techniques. Levene's test was non-significant ($F = 1.12$, $p = 0.293$); therefore, the equal-variances-assumed result was used. The difference was statistically significant, $t(78) = 4.77$, $p < 0.001$. The mean difference was 0.138 D (95% CI [0.080, 0.196]), with a higher mean accuracy value reported for the sphere technique.

4.5 Paired-Samples Tests

4.5.1 Right-Eye versus Left-Eye Spherical Equivalent

Table 4.6. Paired comparison of right-eye and left-eye spherical equivalent

Paired comparison	Mean difference (D)	SD	SE	t	df	p-value	95% CI (D)
Right eye − left eye	0.00000	0.25318	0.04003	0.000	39	1.000	-0.08097 to 0.08097

The paired comparison between right-eye and left-eye spherical equivalent showed a mean difference of 0.00000 D. The difference was not statistically significant, $t(39) = 0.000$, $p = 1.000$, and the 95% confidence interval ranged from −0.08097 D to 0.08097 D. These results indicate no measurable systematic difference between the eyes in this sample.

4.5.2 Both-Eye Spherical Equivalent versus Reference Spherical Equivalent

Table 4.7. Paired comparison of both-eye spherical equivalent and reference spherical equivalent

Paired comparison	Mean difference (D)	SD	SE	t	df	p-value	95% CI (D)
Both eyes − reference	0.28750	0.20056	0.03171	9.066	39	<0.001	0.22336 to 0.35164

The paired comparison of spherical equivalent of both eyes with the reference spherical equivalent yielded a mean difference of 0.28750 D. This difference was statistically significant, $t(39) = 9.066$, $p < 0.001$, with a 95% confidence interval from 0.22336 D to 0.35164 D.

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4.5.3 Sphere Technique versus Sphere-Cylinder Technique Accuracy

Table 4.8. Paired comparison of technique accuracy

Paired comparison	Mean difference (D)	SD	SE	t	df	p-value	95% CI (D)
Sphere − sphere-cylinder	0.13750	0.21145	0.03343	4.113	39	<0.001	0.06987 to 0.20513

The paired-samples t-test showed a statistically significant mean difference of 0.13750 D between the sphere and sphere-cylinder techniques, $t(39) = 4.113$, $p < 0.001$. The 95% confidence interval ranged from 0.06987 D to 0.20513 D. The positive difference indicates a higher reported accuracy value for the sphere technique under the difference order used.

4.6 Visual Acuity (LogMAR)

Table 4.9. Descriptive statistics of visual acuity (LogMAR)

Variable	N	Minimum	Maximum	Mean	SD
Visual acuity (LogMAR)	40	0	0	0.11	0.120

Visual acuity in LogMAR units was reported for all 40 participants. The mean was 0.11 (SD = 0.120). The supplied descriptive table reports both the minimum and maximum as 0; these values are inconsistent with the reported mean and standard deviation and should be verified against the original SPSS output before thesis submission.

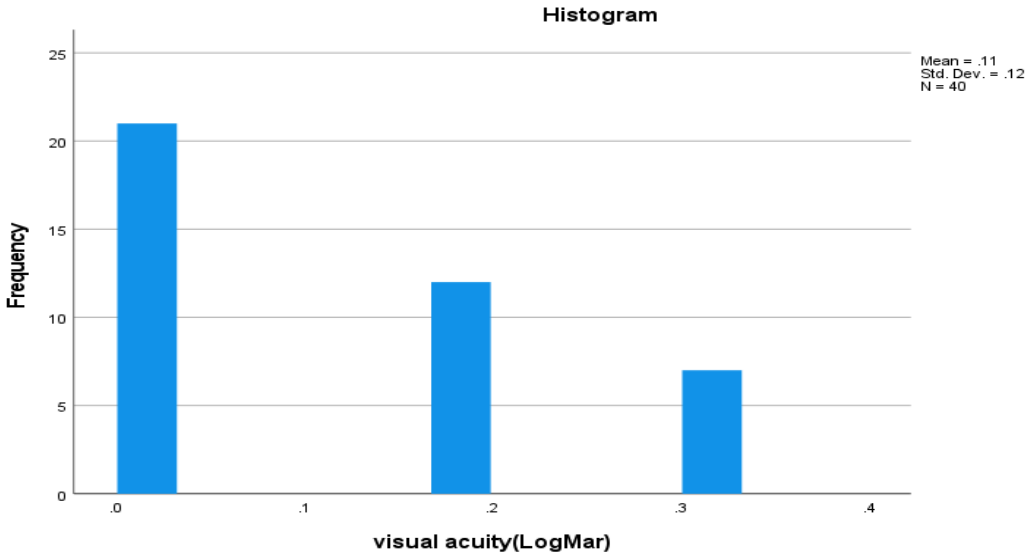

Figure 4.5. Histogram of visual acuity (LogMAR).

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CHAPTER 5
DISCUSSION

The present study was conducted to compare the accuracy of the sphere and sphere-cylinder techniques for neutralization of refractive errors using retinoscopy. The findings demonstrated a statistically significant difference between the two techniques. The mean absolute difference from the reference value was lower with the sphere-cylinder technique (0.131 ± 0.139 D) than with the sphere technique (0.269 ± 0.119 D), with a statistically significant difference between the groups ($p < 0.001$). These findings suggest that incorporating the cylindrical component during retinoscopic neutralization may provide a more accurate estimation of refractive error than relying on spherical correction alone.

The higher accuracy of the sphere-cylinder technique may be explained by the nature of astigmatic refractive errors. When an eye has a cylindrical component, the refractive power differs between the principal meridians. A sphere-only approach provides the same power in all meridians and therefore may not completely neutralize the refractive error. The sphere-cylinder technique, on the other hand, allows the examiner to account for differences between the principal meridians by using both spherical and cylindrical powers. This may result in a smaller difference between the measured value and the reference refractive value.

Retinoscopy remains an important objective method for estimating refractive error because it provides information about the spherical and cylindrical components without requiring a subjective response from the patient. Previous research has demonstrated that retinoscopy can provide reliable measurements of these components when performed using an appropriate clinical technique. Mukash et al. compared retinoscopy, autorefractometry and subjective refraction in children and reported agreement between retinoscopy and autorefractometry for spherical and cylindrical measurements. They also found that cycloplegic retinoscopy provided useful reference estimates for subjective refraction. These findings support the importance of obtaining both spherical and cylindrical components during objective refraction.

Mukash et al. evaluated 54 children using retinoscopy, autorefractometry and subjective refraction. Under cycloplegia, they found that the spherical measurements obtained with retinoscopy and autorefractometry were comparable, whereas differences were observed in cylinder power and spherical equivalent. The authors also reported agreement between retinoscopy and autorefractometry for spherical and cylindrical power. Their results indicate that both components of refractive error need to be considered when evaluating the accuracy of objective refraction. The present study extends this concept by specifically examining the effect of including the cylindrical component during neutralization.[26]

Hashemi et al. involving more than 5,000 school-aged children compared retinoscopy with autorefraction under cycloplegic conditions. Significant differences were found between the methods for spherical and cylindrical components, although the authors considered the observed differences to be clinically small and reported strong agreement between the methods. This study highlights that even when two objective techniques show good overall agreement, differences in individual refractive components can still occur. The present study also found that the magnitude of the refractive error obtained can vary according to the technique used, with the sphere-cylinder approach showing a smaller deviation from the reference value.[27]

A study comparing different refractive instruments with cycloplegic retinoscopy also reported that spherical and spherical-equivalent measurements generally showed good consistency, while cylindrical and axis measurements were less consistent. This finding is relevant to the present study because cylinder power and axis require careful clinical assessment. A sphere-only technique may fail to represent this component adequately, whereas a sphere-cylinder approach is designed to neutralize both components of the refractive

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error.More recent evidence has continued to support the role of retinoscopy as an important reference method for objective refractive assessment. In a 2024 study comparing the Spot Vision Screener and a tabletop autorefractometer with cycloplegic retinoscopy, excellent agreement was reported for spherical equivalent between retinoscopy and both instruments. However, the agreement for cylindrical measurements differed between methods. This suggests that the spherical equivalent alone may not completely describe the agreement of refractive measurements and that the cylindrical component should also be considered when evaluating refractive accuracy.[28]

CONCLUSION

The present study compared the accuracy of the Sphere and Sphere-Cylinder techniques for the neutralization of refractive errors using retinoscopy. The findings showed a statistically significant difference between the two techniques, with the Sphere-Cylinder technique demonstrating a lower mean absolute error than the Sphere technique. This indicates that incorporating the cylindrical component during retinoscopic neutralization may provide a more accurate estimation of refractive error, particularly in eyes with astigmatic components.The findings suggest that although the Sphere technique can provide a useful approximation of refractive status, it may not adequately account for differences in refractive power between the principal meridians. The Sphere-Cylinder technique, by considering both spherical and cylindrical components, provides a more comprehensive approach to neutralizing refractive errors and may therefore reduce residual refractive error.

From a clinical perspective, accurate identification and neutralization of both spherical and cylindrical components are important for obtaining an appropriate refractive correction. Therefore, the Sphere-Cylinder technique may be preferred when astigmatism is suspected or present, provided that retinoscopy is performed using a standardized technique and appropriate working distance.

Overall, the study concludes that the Sphere-Cylinder technique was more accurate than the Sphere technique for neutralization of refractive error in the studied sample. Further studies involving larger and more diverse populations are recommended to confirm these findings and to assess whether the observed difference produces meaningful improvements in subjective visual performance and final spectacle prescription.

REFERNCES

Flaxman SR, Bourne RRA, Resnikoff S, Ackland P, Braithwaite T, Cicinelli MV, et al. Global causes of blindness and distance vision impairment 1990-2020: a systematic review and meta-analysis. Lancet Glob Health. 2017

Holden BA, Fricke TR, Wilson DA, Jong M, Naidoo KS, Sankaridurg P, et al. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. Ophthalmology. 2016

Rudnicka AR, Kapetanakis VV, Wathern AK, Logan NS, Gilmartin B, Whincup PH, et al. Global variations and time trends in the prevalence of childhood myopia, a systematic review and quantitative meta-analysis. Br J Ophthalmol. 2016

Cao H, Cao X, Cao Z, Zhang L, Han Y, Guo C. The prevalence and causes of pediatric uncorrected refractive error: pooled data from population studies for Global Burden of Disease sub-regions. PLoS One. 2022

American Academy of Ophthalmology. Refractive Errors & Refractive Surgery Preferred Practice Pattern®. Ophthalmology. 2022

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LJLLR
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Flitcroft DI, He M, Jonas JB, Jong M, Naidoo K, Ohno-Matsui K, et al. IMI—defining and classifying myopia: a proposed set of standards for clinical and epidemiologic studies. Invest Ophthalmol Vis Sci. 2019

Wolffsohn JS, Flitcroft DI, Jong M, Jones L, Mutti DO, Fulk GW, et al. IMI—myopia control reports overview and introduction. Invest Ophthalmol Vis Sci. 2019

Namba H, Kawasaki R, Sugano A, Nishi K, Murakami T, Nishitsuka K, et al. Cross-sectional and longitudinal investigation of the power vector in astigmatism: the Yamagata Study (Funagata). Cornea. 2018

Revert AM, Conversa MA, Albarrán Diego C, Micó V. An alternative clinical routine for subjective refraction based on power vectors with trial frames. Ophthalmic Physiol Opt. 2017

Thibos LN, Wheeler W, Horner D. Power vectors: an application of Fourier analysis to the description and statistical analysis of refractive error. Optom Vis Sci. 2018

Kaye SB, Harris WF. Analyzing refractive errors with power vectors. Optom Vis Sci. 2004

Harris WF. Algebra of sphero-cylindrical refractive errors and their means. S Afr Optom. 2021

Kaye SB, Harris WF. A new approach to the statistical analysis of refractive error. Optom Vis Sci. 2022

Enaholo ES, Musa MJ, Zeppieri M. Objective refraction technique: retinoscopy. StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023.

Guha S, Shah S, Shah K, Hurakadli P, Majee D, Gandhi S. A comparison of cycloplegic autorefraction and retinoscopy in Indian children. Clin Exp Optom. 2017

Hashemi H, Khabazkhoob M, Asharlous A, Yekta A, Emamian MH, Fotouhi A. Overestimation of hyperopia with autorefraction compared with retinoscopy under cycloplegia in school-age children. Br J Ophthalmol. 2018

Asiedu K, Kyei S, Ampiah EE. Autorefraction, retinoscopy, Javal's rule, and Grosvenor's modified Javal's rule: the best predictor of refractive astigmatism. J Ophthalmol. 2016

Guha S, Shah S, Shah K, Hurakadli P, Majee D, Gandhi S. A comparison of cycloplegic autorefraction and retinoscopy in Indian children. Clin Exp Optom. 2017

Mukash SN, Kayembe DL, Mwanza JC. Agreement between retinoscopy, autorefractometry and subjective refraction for determining refractive errors in Congolese children. Clin Optom (Auckl). 2021

Yalcin E, Sultan P, Yilmaz S, Pallikaris IG. A comparison of refraction defects in childhood measured using Plusoptix S09, 2WIN photorefractometer, benchtop autorefractometer, and cycloplegic retinoscopy. Semin Ophthalmol. 2017

Wilson LB, Melia M, Kraker RT, VanderVeen DK, Hutchinson AK, Pineles SL, et al. Accuracy of autorefraction in children: a report by the American Academy of Ophthalmology. Ophthalmology. 2020

McCullough SJ, Doyle L, Saunders KJ. Intra- and inter-examiner repeatability of cycloplegic retinoscopy among young children. Ophthalmic Physiol Opt. 2017

Nguyen AT, Wayne JL, Ravikumar A, Manny RE, Anderson HA. Accommodative accuracy by retinoscopy versus autorefraction spherical equivalent or horizontal meridian power. Clin Exp Optom. 2018

Doherty SE, Doyle LA, McCullough SJ, Saunders KJ. Comparison of retinoscopy results with and without 1% cyclopentolate in school-aged children. Ophthalmic Physiol Opt. 2019

Atchison DA, Smith G. Optics of the human eye. Edinburgh: Butterworth-Heinemann; 2000.

Mukash J, et al. Agreement Between Retinoscopy, Autorefractometry and Subjective Refraction for Determining Refractive Errors in Congolese Children. Clin Ophthalmol. 2021.

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Hashemi H, et al. Overestimation of hyperopia with autorefraction compared with retinoscopy under cycloplegia in school-age children. Br J Ophthalmol. 2018

Comparison of Spot Vision Screener and Tabletop Autorefractometer with Retinoscopy in the Pediatric Population. 2024