Clinical Procedures: A New Test to Examine the Different Components in Subjective Monocular Refraction

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Abstract

SIGNIFICANCE: Subjective monocular refraction is the basis for determining an optometric prescription. A single testing target for determining the final prescription, by simultaneous viewing with a method to control testing error, simplifies the procedure, since the patient now has a better appreciation of the end-point and relates more easily to the examination.

PURPOSE: The purpose of this study was to identify a test chart and method of examination to improve the efficiency of determining the correction of the astigmatic and spherical components of a prescription. The testing procedure uses an immediate comparison and avoids sequential testing that relies on memory.

A method of avoiding errors, caused by looking away from the optical centre, is included.

This is important in cases of high prescriptions. This method may be suitable for ancillary staff to use in the introductory testing routine.

METHOD: A single, non-movable test chart, independent of the circle of least confusion, is presented. The target is based on the simultaneous resolution of a line in four meridians. A second chart is incorporated into the principal chart. This uses chromatic displacement, caused by the off-centre viewing, of a prism to avoid errors.

RESULT: This testing method, when used in the clinic, has been shown to be efficient and easily understood. A limited independent trial showed that the method is as effective as traditional methods and gives acceptable results when used by ancillary staff. The results obtained by non-experienced individuals are also presented. This may be useful in environments where no professional staff are available.

CONCLUSION: The method described here improves the examination of subjective refraction without the need to change targets. There is no need to consider the circle of least confusion. The target includes tests for axis, cylinder power, spherical power and duochrome. The use of a simultaneous comparison is better received by patients than the sequential test, and is easily understood. The spherical end-point is definite, unless there is hyper-acuity or accommodative spasm. The test improves the ability of the patient to understand, and be comfortable with, the testing method. Binocular balance is not considered here.

KEY WORDS
Refractive errors, Subjective monocular refraction, Errors in viewing.

Monocular refraction is the basis of improving the visual ability of a patient. During refraction the patient is asked to make multiple value-judgments as to the quality of their vision. This decision-making may be tiring and confusing for some patients. Practitioners may also find this to be annoying, as their professional decisions are dependent on the patient's responses, which may not always be consistent.

The aim of this paper is to present a new test that claims to simplify the process, is easier for the patient to comprehend, and reduces the indecision in value-judgements often felt by the patient. The test has a single, non-movable target, and is independent of the circle of least confusion. The target is designed to allow the practitioner to be aware of the parameters of the monocular refractive examination simultaneously, while monitoring and reducing the occurrence of examination-induced errors.

Accepted methods of monocular refraction require that the circle of least confusion lies either before or after the retinal plane. With the Fan and Block or similar test the focal plane is positioned before the retinal plane, termed fogging.[1] On the other hand, the focal plane is placed behind the retinal plane when using the Jackson Cross Cylinder (JCC). This is needed to induce minimal accommodation.[2,3]

The advantage of the Fan and Block method is that it requires the subject to compare two targets seen simultaneously. This is often easier for the patient than sequential comparison with the JCC, which many patients find confusing and tiring. The Fan and Block test has fallen out of favour due to the requirements of a large screen and a movable target.

The end-point of the spherical component is normally determined on a duochrome, or on the reported quality of vision of a visual acuity target.

The use of a single target for all the parameters reduces the need for the practitioner to re-direct the patient from chart to chart.

A further factor that can contribute to errors is differentiating between sharp and clear. Clear vision occurs when the image falls on the retina. Sharp vision may be reported when the distortions of the optical system are reduced by miosis. By placing the image behind the retina, corrected with a small excess minus, minimal accommodation is used to bring the image plane back to the retinal plane. The by-product of this accommodation is miosis, which reduces the peripheral blur of the focal system. The image is usually reported to be smaller. The preference for sharp vision, rather than clear vision, is occasionally noted, especially in post-refractive surgery, cataract surgery and high ametropia. The excess minus, if prescribed, may lead to discomfort.

The advantage of the Kite test presented here is that it is based on simultaneous comparison. The perceived quality of the target is sensitive to small changes in the power and axis of the cylinder correction and the target helps to differentiate between clear and sharp.

In previous generations of test charts there was little possibility of multiple charts. By using computerised charts, many alternative designs can be incorporated into the program. This allows the Kite chart to be flexible in its design.

CAUSES OF ERROR DURING MONOCULAR REFRACTION

Methods for examining monocular refraction have been well recorded in the literature.[3-5] Bennett and Rabbetts[3] discussed the various causes of error in refraction when using the Jackson Cross Cylinder (JCC) and the Fan and Block. They considered the manual dexterity of the practitioner, decision-making by the subject, the neurological response to long-term uncorrected astigmatism, the subject's lack of comfort with comparing memorized images, and variations in the refractive results due to corneal or lenticular distortions. It is assumed that the eye is centred in the trial frame or refractor head, so that that the distance visual point lies on the optical centre of the trial lens. However, this is not always the case. The Kite chart introduces a method for verifying centration which is important in cases of high ametropia.

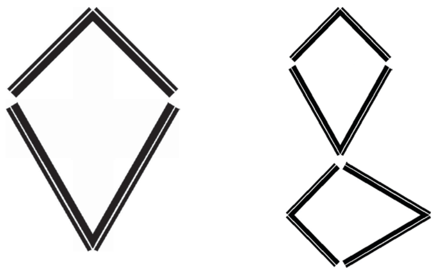
The nominal power of a lens, especially at higher powers, is only accurate when viewed though the optical centre and along the optical axis. If a subject looks at a test chart obliquely, this may result in a cylindrical component of the prescription that is an artefact of the testing technique.[6] Conversely, a patient with an anatomical astigmatism may adjust the angle of viewing through the trial lens to induce a correcting cylinder, resulting in the dispensing of an incorrect prescription.

(The Addendum discusses aberrations resulting from the prismatic effect caused by viewing away from the optical centre of the lens.)

KITE TEST CHART

In 1619, Scheiner[7] proposed a disc with 2 holes bored at a separation of a few millimetres. When the eye is in focus, the rays of light from each hole meet at the retina and the subject perceives a single bright spot of light. If the eye is not in focus, the subject perceives two dull spots. This is the basis of the auto-refractor and auto-focimeter. The Kite test uses this principle, along 4 meridians, extended as a line (Fig. 1).

Figure 1: *The Kite Test Chart. The basic chart for examining monocular refraction.*



The Kite test chart has been designed to provide a single stationary target that allows evaluation of the axis and power of the cylinder, and the spherical power.

The Kite test chart is composed of sets of symmetrical lines. The chevrons are composed of a thick inner line and a thin outer line. There is a gap between the lines equivalent to the 6/6 Snellen line-size. The separation of the lines can be increased in cases of low or reduced vision. One set of chevrons is angled at 90°, and the other is angled at 60°. The chevrons are positioned with their apices along the 90° axis for against-the-rule astigmatism. A second chart positioned along 180° may be used for with-the-rule astigmatism. In theory, the chart can be rotated to any angle, but this is not necessary in most cases. In the against-the-rule astigmatism chart, the lower chevron lines are positioned at 60° and 120°, while the upper chevrons are angled at 45° and 135°. In the with-the-rule chart, the angles are at 45° and 135°, and 30° and 150°.

The chart examines the ability of the subject to simultaneously resolve the thin white line in 4 meridians. A full correction of the axis, cylinder power and spherical component is determined when all 4 white lines are seen simultaneously and are equally clear.

If, at the start of the examination, the subject reports seeing the 4 white lines equally clearly, the presenting state is close to being correct. A small amount of uncorrected ametropia may still exist. This technique is useful as an initial screening method.

METHOD OF EXAMINATION

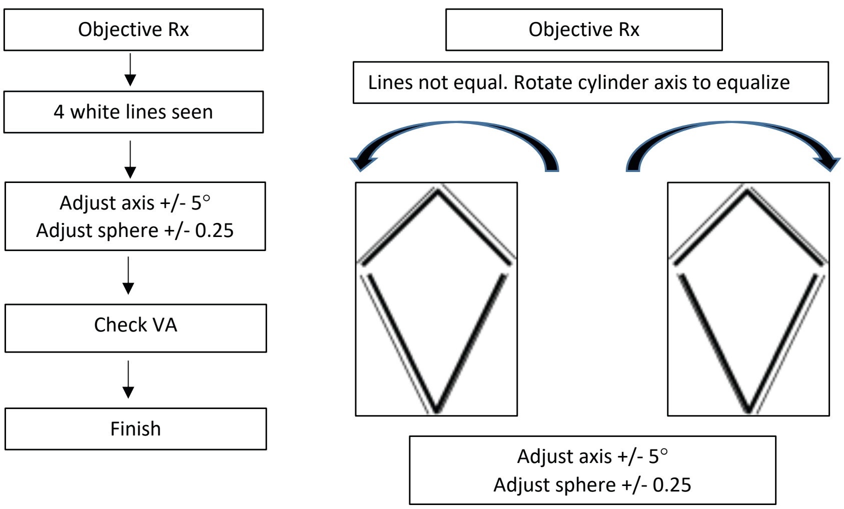
The subject views the target through an objective refraction, which might be from retinoscopy or auto-refraction, the presenting prescription, best sphere or no correction.

If the white line can be seen simultaneously in each of the four directions, without head movement, this indicates that the presenting state is close to the final prescription. This test can be considered to be checking that the visual acuity is 6/6 in 4 meridians.

To verify the result, the cylinder axis can be moved a few degrees in either direction. This confirms that the presenting axis is correct. If the axis is incorrect then the white lines will blur on one side.

After the axis of astigmatism has been determined, a +/- 0.25 DC lens is added to see if the image improves. This is followed by a +/- 0.25 DS lens check. The comparison of the chevrons subtending at 90° is less sensitive than that of the chevrons subtending at 60°. If the correcting cylinder is off-axis from the astigmatic error the subject may report that the lines are not of equal length. This occurs in cases of a higher cylinder correction. There have also been cases of subjects' reporting seeing coloured fringes on the borders of the black and white lines when the axis is not properly positioned. This phenomenon usually occurs with high cylinder corrections and may be related to transverse chromatic aberration from off-axis viewing. Figure 2 explains the technique as a flow chart.

Figure 2: *Flow chart of the examination technique.*



The addition of excess spherical minus will cause the target to be seen as being smaller and darker. This sharper vision will result in the white lines seeming to be thinner, and more difficult to see. On the other hand, the addition of excess plus will cause the chart to appear larger, but the edge of the white line will appear more blurred. The borders on either side of the white line will be fuzzy, resulting in the white line being less defined. With excess spherical plus or excess spherical minus, it is more difficult to see the white line. In cases of hyper visual acuity, such as the ability to see 6/4, this assumption must be evaluated.

In a case where a reasonable result cannot easily be obtained due to trauma or neglect, the best sphere is found, possibly starting with separation of the chevrons at 6/12. A token cylinder, such as -1.00 DC, is introduced and rotated until the best balance is found. This is further refined by adjusting the prescription until the best visual acuity is achieved.

Improvement in the visual acuity may be checked on a Snellen target or by the clarity of the Kite target. If a reasonable improvement is achieved the separation of lines on the Kite target may be reduced from 6/12 to 6/6.

In cases of a high prescription, +/- 5.00 DS, or cylinders above -3.00 DC, the final prescription is adjusted after first checking that the lines on the duochrome are unbroken and that there is no distortion of the Kite lines (Figures.3 and 4).

DISCUSSION OF THE BASIC PREMISE

The astigmatic error of the eye and the correcting cylinder may be considered to be two cylinders of equal and opposite powers. They are positioned to neutralise each other. If the axis of one lens is rotated by a small amount, the image seen through the combination will be distorted. Since this is repeated along the length of the space between the two black lines, the distortion is magnified, improving the subjective response.

When the correcting lens is in a different axis than the anatomical astigmatism, there is a large shift in the position of the blur. This magnifies the qualitative difference in the clarity of the different positions of the white lines. A reduction in the clarity of one or more of the four white lines will occur if there is an error of the axis. The black lines of the paired chevron may also be of unequal length.

A minor error of 5° in either direction of the correct axis creates a small cylindrical error separated by 95° (138-43), which is readily noted by the patient. The resultant power and axis direction are shown in Table 1. When the correcting cylinder is positioned at 85°, the resultant axis is at 43° and one, or both, of the white lines at 120° and 135° will be clearer. This situation is reversed when the axis is moved to 95°. The white lines will now be clearer at 60° and 45°. The rapid switch from one side to the other is readily noted.

Table 1: *Resultant error when combining the anatomical error and a different axis of the correcting cylinder.*

Anatomical error	Correcting cylinder	Resultant error
plano / + 2.00 x 90	plano / - 2.00 x 90	0
plano / + 2.00 x 90	plano / - 2.00 x 85	+ 0.18 / - 0.35 x 43
plano / + 2.00 x 90	plano / - 2.00 x 95	+ 0.18 / - 0.35 x 138
plano / + 4.00 x 90	plano / - 4.00 x 90	0
plano / + 4.00 x 90	plano / - 4.00 x 85	+ 0.35 / - 0.70 x 43
plano /+ 4.00 x 90	plano / - 4.00 x 95	+ 0.35/ - 0.70 x 138

The resultant error increases as the cylinder power increases.

CONTROL MECHANISM TO REDUCE ERRORS IN PRESCRIBING

Viewing away from the optical centre of a high-powered lens creates aberrations.

It is possible to use the differential deviation of different wavelengths caused by the prismatic effect of the lens to ensure that the subject is viewing close to the optical centre of the lens.

The chart includes a duochrome positioned in the 90° and 180° meridians. When a prism is positioned before the horizontal and vertical duochrome, the black lines appear broken and the coloured rectangles appear displaced. This is shown, in an exaggerated manner, in Figure 3. The displacement of the black lines is a product of the induced prism, due to the subject's viewing away from the optical centre. It is not related to the axis or to the power of the cylindrical correction.

Figure 3:. *Control mechanism to reduce viewing errors (exaggerated).*

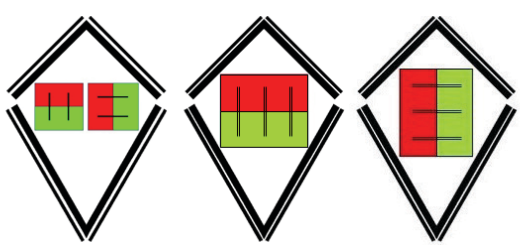
Crown glass has a refractive index of $\eta = 1.515$ for red light (750 nm) and $\eta = 1.523$ for green light (550 nm). The displacement of the red and green targets, when viewed through a 2.5Δ, is 1.17 mm, which is close to being equivalent to a single line on a 6/6 optotype. The breaking effect is seen as Vernier acuity, which is much finer than visual acuity, and hence more sensitive.[8] By placing the line of sight at the optical centre and checking that the black lines are continuous, without a break, the prismatic effect can be controlled. The prismatic effect from the oblique viewing is extremely small (0.0019 mm) when seen at 6 metres and can be ignored (see the Addendum).

A base-down prism will cause the black lines on the green to appear higher than those on the red, while a base-right prism will cause the lines on the green to appear further to the left.

The Kite chart can have different formats depending on the technical design of the test charts.

Including the duochrome reduces the need to change targets to finalize the prescription. Variations in design are shown as examples. In the first example, both horizontal and vertical targets are incorporated. In the second example, two targets are needed, with the duochrome target turned at 90° (Fig. 4).

Figure 4: *Different designs for the Kite test chart.*



INDEPENDENT STUDIES COMPARING THE REFRACTION RESULT USING THE JACKSON CROSS CYLINDER (JCC) TO THAT USING THE KITE TEST

Two studies were performed to validate the concept presented here. In Study 1, undertaken by an experienced practitioner, the Kite test result was compared to that found by the JCC method. A second part of this study included the feasibility that ancillary staff could be trained to examine the patient using the Kite test. This would provide useful information, and would save time, for the practitioner. The result with the Kite test was compared to that obtained with an auto-refractor.

In Study 2, which was initially undertaken for another paper,[9] inexperienced first-year optometry students, within a few weeks of starting the course, examined patients using a Kite test configuration. The rationale for this study was to determine if a non-experienced person could obtain a usable prescription, with limited equipment, using an adapted Kite test. The paper presents a basis for the supply of visual aids to people living in an underdeveloped community.

STUDY 1: COMPARING THE RESULTS OBTAINED BY THE KITE TEST TO THOSE OBTAINED BY THE JCC BY AN OPTOMETRIST AND ANCILLARY STAFF

An experienced private practitioner, with ancillary staff, was recruited to undertake an independent small study of the proposed method. Monocular refraction was determined in patients arriving for a routine examination. The choice of subject on a particular day was at random and represented a cross-section of the population. Young children were excluded. A trial frame was used. To maintain the centration of the lens, the centre of the trial frame was positioned opposite the pupil. It was essential that the subject did not use a head tilt to adjust the point of viewing.

Only the right eye was examined to avoid the confounding effect of using non-independent data from both eyes, as suggested by Ray, O'Day and Armstrong.[10,11]

Visual acuity was measured using the objective refraction obtained by an auto-refractor. The patient was then examined by the ancillary staff using the Kite test. The VA achieved by the Kite test was recorded. The patient was later examined by the experienced practitioner using both the JCC method and the Kite test.

The purpose of the study was to compare the result obtained by ancillary staff using an auto-refractor and the Kite test to that obtained by a qualified practitioner. Could ancillary staff be entrusted to determine the monocular prescription, and by how much did the monocular refraction from the Kite test differ from that obtained with an auto-refractor?

The results obtained by auto-refraction, by the ancillary staff using the Kite test, and by the practitioner using the Kite test and the JCC were all compared.

Results of Study 1

Table 2 emphasizes the problems of high spheres and cylinders when comparing different methods of examination. The better VA was considered to be the "correct" prescription.

Table 2: *Comparing the Auto-refractor, Jackson Cross Cylinder technique to the Kite Test.*

Patient	Auto-refractor	VA	JCC (Optometrist)	VA	Kite (Optometrist)	VA	Kite (Ancillary)	VA
1	-1.25/-4.75 x 135	6/9	-1.00/-4.00 x 140	6/6	-1.25/-4.50 x 140	6/7.5	-1.50/-4.50 x 135	6/7.5
2	-2.00/-0.25 x 150	6/7.5	-2.00/-0.25 x 135	6/7.5+	-2.00/-0.50 x 140	6/6	-2.00/-0.25 x 135	6/6
3	-2.25/-0.50 x 165	6/9	-2.00/-0.50 x 165	6/6	-2.25/-0.25 x 165	6/6	-2.25/-0.50 x 160	6/6
4	-5.00/-2.00 x 170	6/6	-4.75/-1.50 x 175	6/6	-4.75/-1.75 x 175	6/6	-5.00/-1.50 x 175	6/6
5	-6.50/-0.50 x 120	6/6	-6.00/-0.50 x 120	6/6	-6.00/-0.50 x 120	6/6	-6.50/-0.50 x 120	6/6
6	-11.50/-2.75 x 15	6/18	-9.25/-1.50 x 15	6/7.5	-9.50/-1.75 x 15	6/7.5	-10.00/-2.00 x 15	6/9
7	+0.75/-0.50 x 100	6/6	+0.50/-0.50 x 105	6/6	+0.50/-0.50 x 100	6/6	+0.50/-0.50 x 95	6/6
8	+1.25/-1.25 x 90	6/6	+1.00/-1.00 x 90	6/6	+1.00/-1.00 x 90	6/6	+1.00/-1.00 x 90	6/6
9	+3.75/-0.75 x 60	6/9	+2.50/-0.75 x 80	6/6	+3.00/-1.00 x 80	6/6	+3.00/-1.00 x 75	6/6
10	+4.00/-2.00 x 80	6/7.5	+3.50/-1.50 x 75	6/6	+3.50/-1.75 x 75	6/6	+3.75/-1.75 x 70	6/6

Patients 2, 3, 7 and 8 showed small variations in the prescriptions and equal VA results. Patient 1 showed a higher cylinder and lower VA with both the auto-refractor and Kite tests, while the JCC showed a lower cylinder and better VA.

Patient 4 showed equal VA with variations of up to 0.50 in the prescription. Patient 5 showed increased -0.50 sphere by auto-refraction and the ancillary Kite test. This could be explained by the proximal accommodation of an instrument and the confusion of sharp and clear in deciding the end-point of refraction.

Patient 6, who had both high myopia and reasonably high cylinder, showed a large variation between the methods used. The JCC and Kite results obtained by the practitioner were almost equal, while the ancillary staff using the Kite test over-minused the patient by -0.50 DS. The cylinder power was close to that found by the practitioner.

Patients 9 and 10, both of whom had higher hypermetropia, showed a higher reading on auto-refraction, while the JCC by the practitioner showed an under-correction in patient 9, which was not found on the Kite test.

Table 3 compares the mean spheres, divided into myopia and hypermetropia. Comparison of the mean sphere, when tested by the practitioner, showed a difference of less than 0.25 DS in myopes, and almost identical results in hypermetropes.

Table 3: *Comparison of the mean sphere.*

Patient	JCC (Optometrist)	Kite (Optometrist)	Kite (Ancillary)	Difference JCC vs Kite Optom.	Difference JCC vs Kite Ancillary	Difference Kite Optom vs Kite Ancillary
1	-3.00	-3.50	-3.75	+0.50	+0.75	-0.25
2	-2.13	-2.25	-2.13	+0.12	0.00	+0.12
3	-2.25	-2.37	-2.50	+0.12	+0.25	-0.12
4	-5.50	-5.62	-5.75	+0.12	+0.25	-0.13
5	-6.25	-6.25	-6.75	0.0	+0.50	-0.50
6	-10.00	-10.37	-11.00	+0.37	+1.00	-0.63
Ave	**-4.86**	**-5.07**	**-5.32**	**+0.21**	**+0.46**	**0.29**
7	+0.25	+0.25	+0.25	0.0	0.0	0.0
8	+0.50	+0.50	+0.50	0.0	0.0	0.0
9	+2.13	+2.50	+2.50	+0.37	+0.37	0.0
10	+2.75	+2.63	+2.87	+0.12	-0.12	+0.25
Ave	**+1.41**	**+1.47**	**+1.53**	**0.12**	**0.12**	**0.06**

The mean sphere obtained by the ancillary staff, when compared to that obtained by the practitioner using the JCC, showed almost a 0.50 DS difference in myopes.

Table 4 compares the spherical and cylinder components. While the practitioner found almost no difference in the spheres between the two methods (-4.17 vs. -4.29), the ancillary staff tended to over-minus the patient. The JCC gave a lower cylinder power than the Kite test (-1.38 vs. -1.54). In hypermetropic patients, the results were much closer.

Table 4: *Comparison of the Spherical and Cylinder components.*

Patient	JCC (Optometrist)	Kite (Optometrist)	Kite (Ancillary)	JCC (Optometrist)	Kite (Optometrist)	Kite (Ancillary)
	SPHERE			CYLINDER		
1	-1.00	-1.25	-1.50	-4.00	-4.50	-4.50
2	-2.00	-2.00	-2.00	-0.25	-0.50	-0.25
3	-2.00	-2.25	-2.25	-0.50	-0.25	-0.50
4	-4.75	-4.75	-5.00	-1.50	-1.75	-1.50
5	-6.00	-6.00	-6.50	-0.50	-0.50	-0.50
6	-9.25	-9.50	-10.00	-1.50	-1.75	-2.00
Ave	**-4.17**	**-4.29**	**-4.54**	**-1.38**	**-1.54**	**-1.54**
7	+0.50	+0.50	+0.50	-0.50	-0.50	-0.50
8	+1.00	+1.00	+1.00	-1.00	-1.00	-1.00
9	+2.50	+3.00	+3.00	-0.75	-1.00	-1.00
10	+3.50	+3.50	+3.75	-1.50	-1.75	-1.75
Ave	**+1.88**	**+2.00**	**+2.06**	**-0.94**	**-1.06**	**-1.06**

Table 5 considers the difference between the results obtained by an auto-refactor and those obtained by the ancillary staff.

Apart from the high myope, the results were comparable.

Table 5: *Comparing the Auto-refraction to the Kite Test by the ancillary staff.*

Patient	Auto-refractor	VA	Kite (Ancillary)	VA	Sphere	Cylinder	Axis	VA
					Difference			
1	-1.25/-4.75 x 135	6/9	-1.50/-4.50 x 135	6/7.5	-0.25	+0.25	0	+1
2	-2.00/-0.25 x 150	6/7.5	-2.00/-0.25 x 135	6/6	0	0	15	+1
3	-2.25/-0.50 x 165	6/9	-2.25/-0.50 x 160	6/6	0	0	5	+2
4	-5.00/-2.00 x 170	6/6	-5.00/-1.50 x 175	6/6	0	+0.50	5	0
5	-6.50/-0.50 x 120	6/6	-6.50/-0.50 x 120	6/6	0	0	0	0
6	-11.50/-2.75 x 15	6/18	-10.00/-2.00 x 15	6/9	+1.50	+0.75	0	+3
7	+0.75/-0.50 x 100	6/6	+0.50/-0.50 x 95	6/6	-0.25	0	5	0
8	+1.25/-1.25 x 90	6/6	+1.00/-1.00 x 90	6/6	-0.25	+0.25	0	0
9	+3.75/-0.75 x 60	6/9	+3.00/-1.00 x 75	6/6	-0.75	-0.25	15	+2
10	+4.00/-2.00 x 80	6/7.5	+3.75/-1.75 x 70	6/6	-0.25	+0.25	10	+1

The information is more easily understood by comparing the values in Figs. 5-8. Regarding the spherical correction, the auto-refractor over-prescribes the sphere, while the practitioner gives a lower result when using the JCC. The Kite test gave similar results when used by the practitioner and the ancillary. The cylinder results are more haphazard and show no clear direction. The results obtained by the practitioner using the JCC and Kite test show a close correlation in most cases. The ancillary staff tended to over-prescribe. In Fig. 7, the axis results are very close.

Figure 5: *Comparison of the spherical correction*

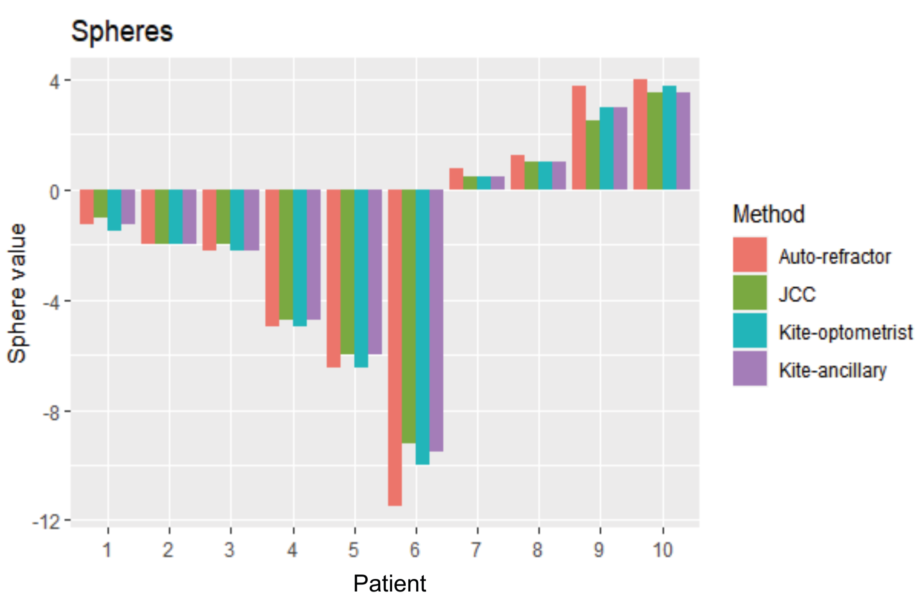


Figure 6:. *Comparison of the cylinder correction obtained by the Auto-refractor, by the practitioner using the JCC, by the practitioner using the Kite test, and by the ancillary staff using the Kite test.*

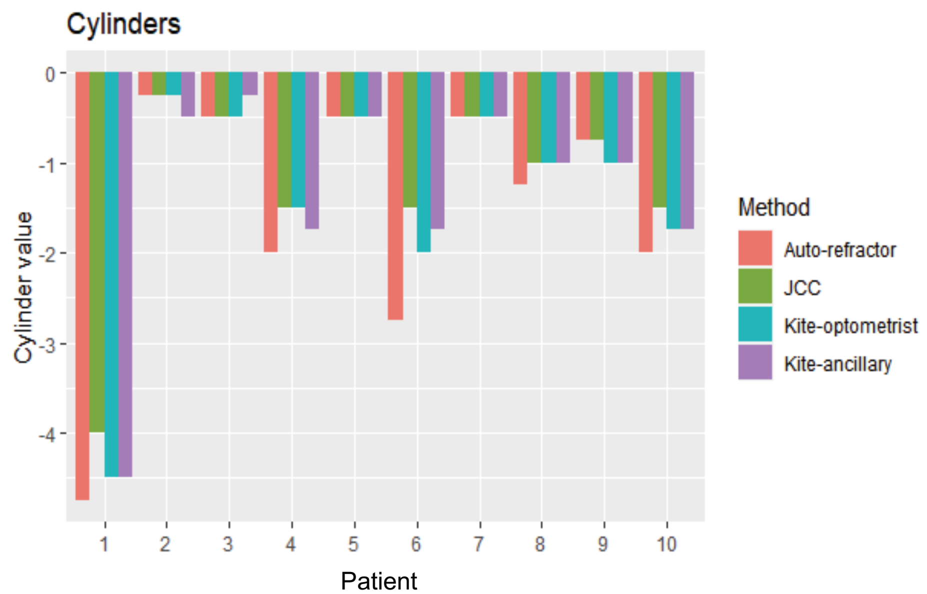


Figure 7: *Comparison of the axis correction obtained by the Auto-refractor, by the practitioner using the JCC, by the practitioner using the Kite test, and by the ancillary staff using the Kite test.*

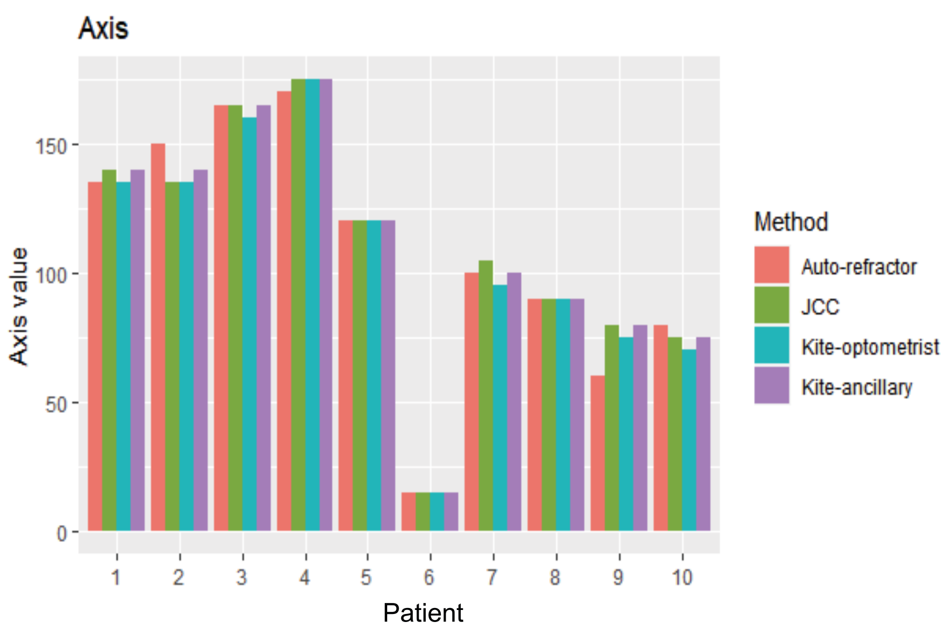


Figure 8: *Comparison of the visual acuity from the Rx obtained by the Auto-refractor, by the practitioner using the JCC, by the practitioner using the Kite test, and by the ancillary staff using the Kite test.*

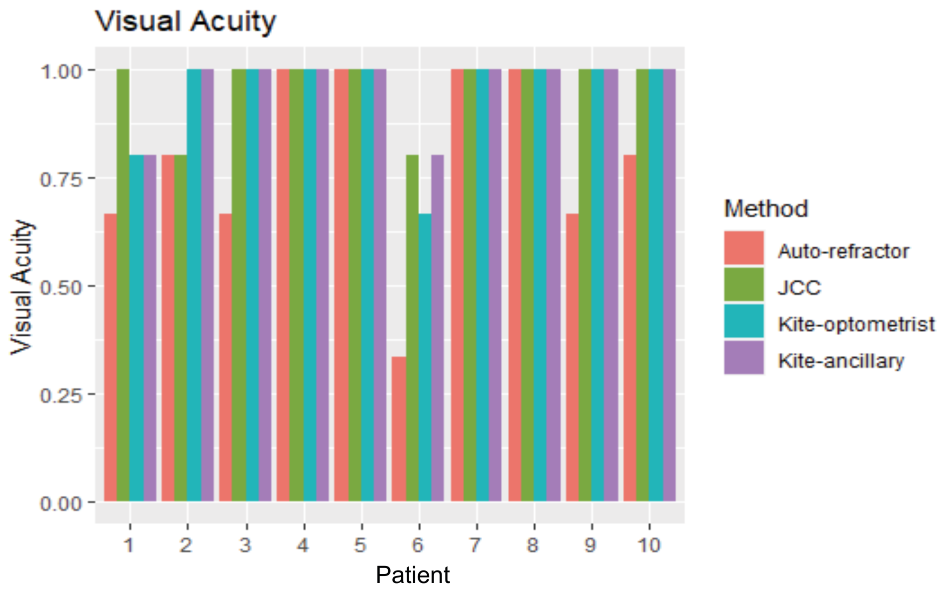


Figure 8 compares the visual acuity obtained. In most cases, the VA values are equal, apart from that obtained with the auto-refractor, which gives a lower VA. Generally, there is a good correlation between the VA values obtained the practitioner and the ancillary staff using the Kite test, while the JCC gives a better result in two cases.

Conclusion for Study 1

The Kite test gives results close to, or equal to, those using the JCC test.

The results obtained by the ancillary staff are closer to the final prescription than those obtained using the auto-refractor, especially in cases of simple ametropia. In a busy practice, if the ancillary staff performs the Kite test as a preparatory test, this may reduce the time needed by the practitioner.

STUDY 2: COMPARING THE REFRACTION RESULTS OBTAINED BY A 1ST-YEAR OPTOMETRY STUDENT USING THE KITE TEST WITH THE RESULTS OBTAINED BY A 4TH-YEAR STUDENT USING THE JCC.

The Kite test was used to determine if a non-experienced person could be trained in a short time to achieve a usable prescription, especially in an under-developed setting, while using primitive equipment and a greatly reduced trial lens set. The non-experienced person (1st year student, within a month of entering the course) received lenses for use with spheres of -0.75, -1.50, -2.25, -3.00, -3.75, -4.50, -5.25, -6.00 and cylinders of -0.75, -1.50, and -2.25. Higher prescriptions could be achieved by adding spheres together. The 4th-year student had a full trial case (for a fuller explanation, see Ref. 9).

Subjects were selected at random when they arrived for a public clinic at the Department of Optometry. The results obtained by the inexperienced students were compared to those obtained by final-year students, who carried out the examination in the public clinic using accepted methods.

Method

Two1st-year students from the Optometry Department were recruited at random and within a short time of entering the course. The two 1st-year students, who had no previous experience in the profession, were to act as refractionists and received 2 hours of training.

Thirty subjects (24 with a mean age (y) of 24.54 ± 4.47 and 6 aged 40-60) were recruited from the public clinic. Subjects with pathology were excluded from the patient base. Two subjects dropped out. Only myopes were considered, as few low hypermetropes attended the public clinic. Although the gender of the subjects was noted it was not considered relevant for this study. The subjects included the Caucasian, Semitic, African and Maghreb ethnicities. Socio-economic factors were the main reason the patients attended the subsidised public clinics. Demographic data were not recorded.

The subjects were first examined by the newly-recruited students using the Kite test in a 6-metre room under standard fluorescent lighting conditions. The prescription found by the proposed system was placed in a trial frame and the visual acuity was measured by an independent second student in the public clinic. The result was masked. A third 4th-year student examined the same patient in the public clinic using the standard refractive technique. This student had no knowledge of the prescription or visual acuity achieved by the initial examinations. The results of the refractions and visual acuity, as found in the public clinic, were compared to the results found by the 1st-year students using the Kite test. A Snellen decimal chart was used to determine the visual acuity. Poorly read lines or occasional wrong answers within a line were accounted for by the addition or subtraction of 0.05.

The deviation of the spherical and cylindrical components, including the axis, and the Snellen decimal visual acuity were compared.

Results of Study 2

As shown in Table 6, the spherical variation was within 0.75 DS, apart from one case of -1.25 DS. The average difference was 0.38 DS. In seven cases there was an equal correction. The cylinder correction was also within a reasonable range, with a difference of 0.29DC. The mean sphere was within 0.46 DS. The axis difference was within 15 degrees, but in three cases there was a 90-degree variation. The VA values were within a similar range.

Figure 9 indicates that the 1st-year students tended to over-minus the sphere. Figure 10 shows a more complex variation in the cylinder prescription. In only a few cases was there an agreement between the two methods. In numerical terms, the difference is not large, usually between -0.50DC and -0.75DC, with one exception of -1.50DC. Figure 11 shows that there is a close relationship between the axis result by the two methods, excluding cases that were 90 degrees off. Figure 12 indicates that the VA achieved by untrained new students, using the Kite test, is comparable to that of an optometrist using the JCC, although slightly less. It would allow the patient reasonable usable vision. Figure 13 shows a reasonable correlation between the visual acuity achieved by the two methods, except in three cases.

Figure 9: *Comparing the spherical component obtained by an optometry student using normal consulting room techniques to that obtained by a non-experienced person using the Kite test.*

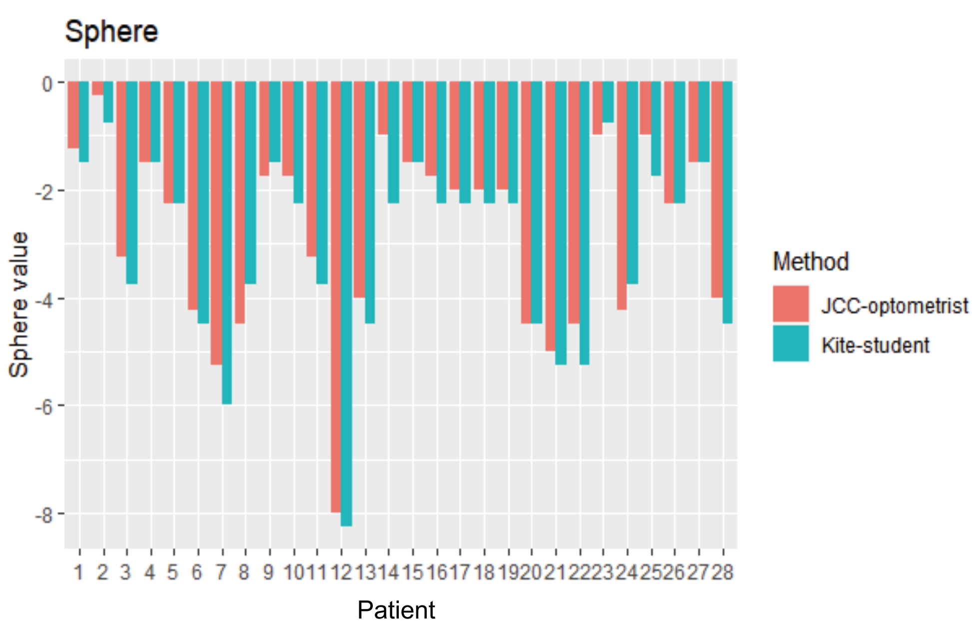


Figure 10: *Comparing the cylinder component obtained by an optometry student using normal consulting room techniques to that obtained by a non-experienced person using the Kite test.*

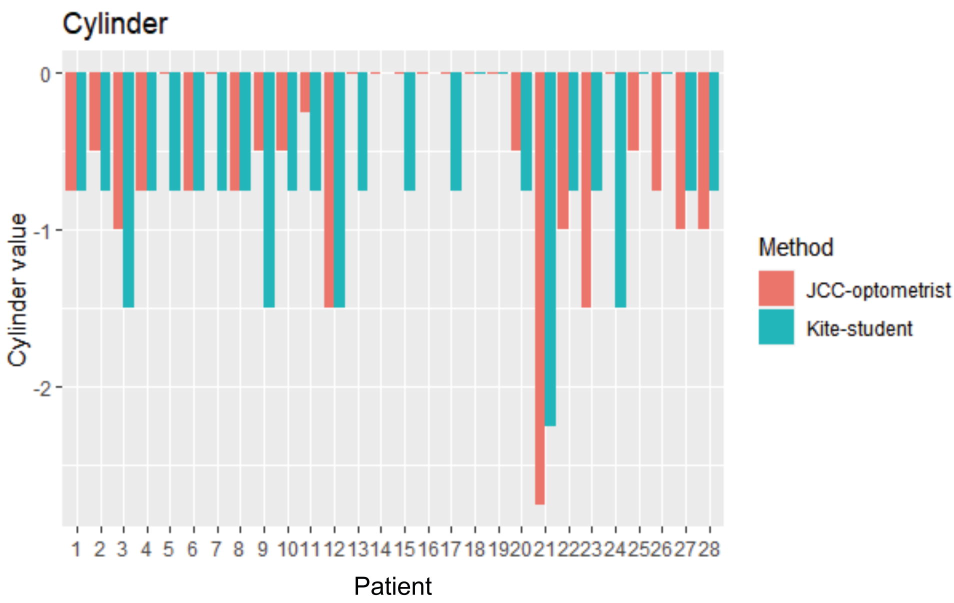


Figure 11: *Comparing the axis component obtained by an optometry student using normal consulting room techniques to that obtained by a non-experienced person using the Kite test.*

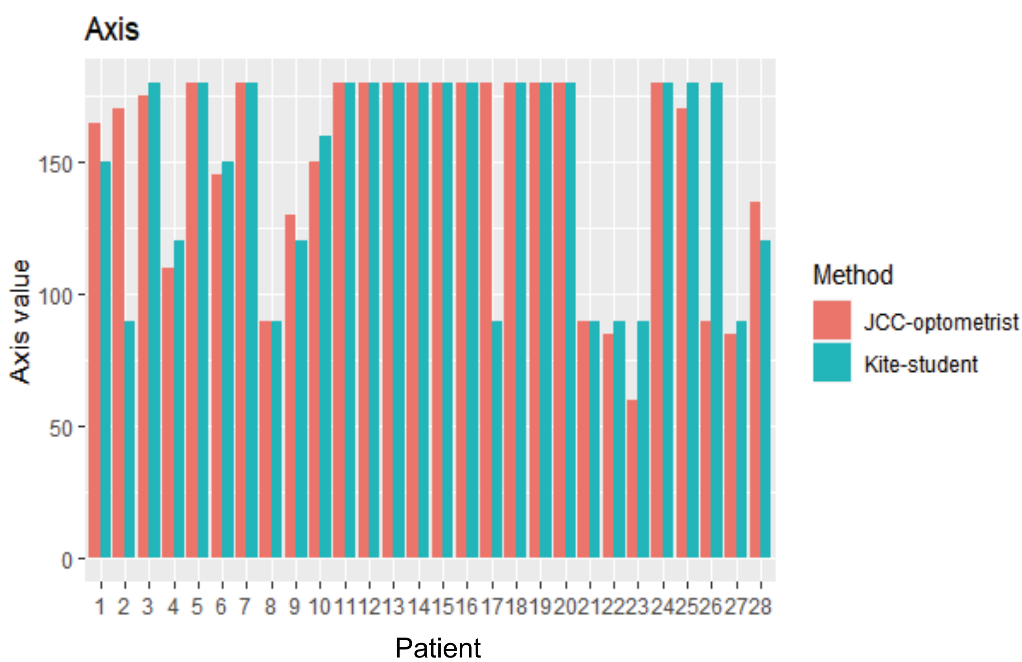


Figure 12: *Comparing the visual acuity obtained by an optometry student using normal consulting room techniques to that obtained by a non-experienced person using the Kite test.*

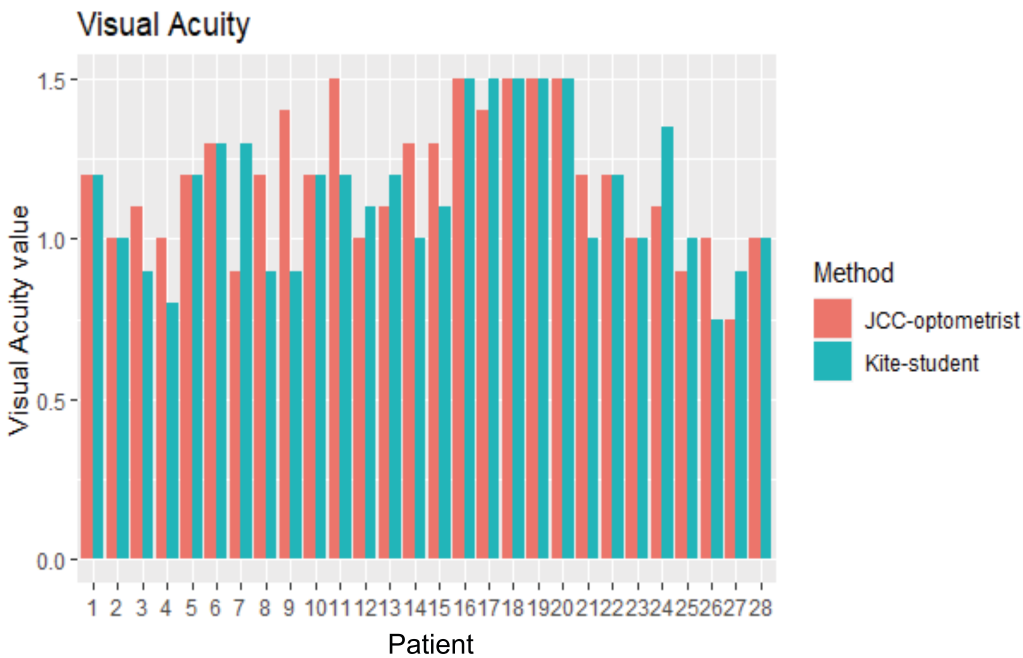


Figure 13: *Different prismatic effects in the horizontal and vertical meridians.*

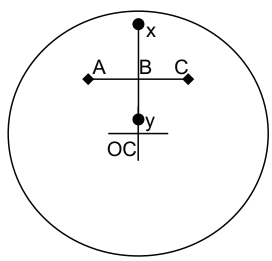


Table 6: *Results for the examination by an optometry student using the JCC, compared to a non-experienced person using the Kite test.*

Patient	Age		Optom JCC	Student Kite		Optom JCC	Student Kite		Optom JCC	Student Kite		Optom JCC	Student Kite		Optom JCC	Student Kite	
			Sphere		Δ	Cylinder		Δ	Mean Sphere		Δ	Axis		Δ	VA		Δ
1	27	F	-1.25	-1.50	0.25	-0.75	-0.75	0.00	-1.63	-1.88	0.25	165	150	15	1.2	1.2	0.0
2	27	M	-0.25	-0.75	0.50	-0.50	-0.75	0.25	-0.50	-1.13	0.63	170	90	80	1.0	1.0	0.0
3	23	F	-3.25	-3.75	0.50	-1.00	-1.50	0.50	-3.75	-4.50	0.75	175	180	5	1.1	0.9	0.2
4	21	F	-1.50	-1.50	0.00	-0.75	-0.75	0.00	-1.88	-1.88	0.00	110	120	10	1.0	0.8	0.2
5	22	M	-2.25	-2.25	0.00	0.00	-0.75	0.75	-2.25	-2.63	0.38	180	180	0	1.2	1.2	0.0
6	25	M	-4.25	-4.50	0.25	-0.75	-0.75	0.00	-4.63	-4.88	0.25	145	150	5	1.3	1.3	0.0
7	22	F	-5.25	-6.00	0.75	0.00	-0.75	0.75	-5.25	-6.38	1.13	180	180	0	0.9	1.3	0.4
8	24	F	-4.50	-3.75	0.75	-0.75	-0.75	0.00	-4.88	-4.13	0.75	90	90	0	1.2	0.9	0.3
9	23	F	-1.75	-1.50	0.25	-0.50	-1.50	1.00	-2.00	-2.25	0.25	130	120	10	1.4	0.9	0.5
10	37	F	-1.75	-2.25	0.50	-0.50	-0.75	0.25	-2.00	-2.63	0.63	150	160	10	1.2	1.2	0.0
11	31	M	-3.25	-3.75	0.50	-0.25	-0.75	0.50	-3.38	-3.38	0.00	180	180	0	1.5	1.2	0.3
12	35	M	-8.00	-8.25	0.25	-1.50	-1.50	0.00	-8.75	-9.00	0.25	180	180	0	1.0	1.1	0.1
13	20	F	-4.00	-4.50	0.50	0.00	-0.75	0.75	-4.00	-4.88	0.88	180	180	0	1.1	1.2	0.1
14	25	M	-1.00	-2.25	1.25	0.00	0.00	0.00	-1.00	-2.25	1.25	180	180	0	1.3	1.0	0.3
15	23	F	-1.50	-1.50	0.00	0.00	-0.75	0.75	-1.50	-1.88	0.38	180	180	0	1.3	1.1	0.2
16	27	F	-1.75	-2.25	0.50	0.00	0.00	0.00	-1.75	-2.25	0.50	180	180	0	1.5	1.5	0.0
17	21	F	-2.00	-2.25	0.25	0.00	-0.75	0.75	-2.00	-2.63	0.63	180	90	90	1.4	1.5	0.1
18	22	F	-2.00	-2.25	0.25	0.00	0.00	0.00	-2.00	-2.25	0.25	180	180	0	1.5	1.5	0.0
19	22	F	-2.00	-2.25	0.25	0.00	0.00	0.00	-2.00	-2.25	0.25	180	180	0	1.5	1.5	0.0
20	24	F	-4.50	-4.50	0.00	-0.50	-0.75	0.25	-4.75	-4.88	0.13	180	180	0	1.5	1.5	0.0
21	21	F	-5.00	-5.25	0.25	-2.75	-2.25	0.50	-6.38	-6.63	0.05	90	90	0	1.2	1.0	0.2
22	25	M	-4.50	-5.25	0.75	-1.00	-0.75	0.25	-5.00	-5.63	0.63	85	90	5	1.2	1.2	0.0
23	40	M	-1.00	-0.75	0.25	-1.50	-0.75	0.75	-1.75	-1.13	0.62	60	90	30	1.00	1.00	0.0
24	47	F	-4.25	-3.75	0.50	0.00	-1.50	-1.50	-4.25	-4.50	0.25	180	180	0	1.10	1.35	0.25
25	57	F	-1.00	-1.75	0.75	-0.50	0.00	0.50	-1.25	-2.25	1.00	170	180	10	0.90	1.00	0.1
26	60	F	-2.25	-2.25	0.00	-0.75	0.00	0.75	-1.88	-2.25	0.37	90	180	90	1.00	0.75	0.25
27	51	F	-1.50	-1.50	0.00	-1.00	-0.75	0.25	-1.00	-1.13	0.13	85	90	5	0.75	0.90	0.15
28	48	M	-4.00	-4.50	0.50	-1.00	-0.75	0.25	-4.50	-4.88	0.38	135	120	15	1.00	1.00	0.0
Average					0.38			0.29			0.46			13.57			0.13

Discussion of Study 2
The results of Study 2 suggest that the Kite test was reasonably effective for producing a workable prescription, even when carried out by a non-experienced, but intelligent, individual. The concept presented in the original paper was that it may be possible for examinations to be carried out in the field by capable, but unqualified personnel, without an infra-structure, and the eyeglasses could be provided immediately. The study confirmed that the Kite test was an effective method of examination.

CONCLUSION
In a busy practice or public/hospital clinic, there may be pressures of time and qualified staff. It would be helpful to know the effectiveness of the presenting prescription and errors noted. This would give the doctor more information. If the initial examination shows equal clarity in all four meridians on the Kite test, the doctor may assume that the patient is reasonably corrected. This can be checked using a +/- 0.25 DS/DC lens.

The correlation between the result obtained by the ancillary staff and the final result obtained by the practitioner is better than that between the latter and an auto-refractor, and requires little extra time and effort. This suggests that, in a practice where ancillary staff provide pre-test information, it may be useful to include the Kite test in the preliminary exam. This may reduce the time and effort needed by the practitioner, who will be able to check the prescription found by the ancillary staff on the Kite test with a +/- sphere and cylinder and slight adjustment of the cylinder axis.

The method suggested here allows for examination of the subjective refraction using a single target, with less of a need to change targets. There is no need to consider the circle of least confusion. The target includes tests for axis, cylinder power, spherical power and duochrome. The ability of a patient to understand and be comfortable with the testing method varies according to his/her personality and perceptual sensitivity. For most patients, the use of a simultaneous comparison is easier than a sequential test, and is more easily understood. The spherical end-point is more easily noted, unless there is hyper-acuity or accommodative spasm.

Various authors[4,5] have compared different methods of examining the monocular refraction. The present results suggest that the Kite test may be sufficiently effective to be included in the pantheon of examination techniques; an independent study will be needed to confirm its usefulness. If the method described here is shown to be effective when performed by ancillary staff, this may ease the workload of the optometrist and ophthalmologist, especially in hospital practice. ●

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Finally, I am grateful to my wife, Ruthie, for editing the paper and her support.

Study 2 was undertaken by two 1st-year undergraduate students from the Department of Optometry, Hadassah College, Jerusalem, Israel, along with two 4th-year students, who were recruited to undertake the study as their final-year project.

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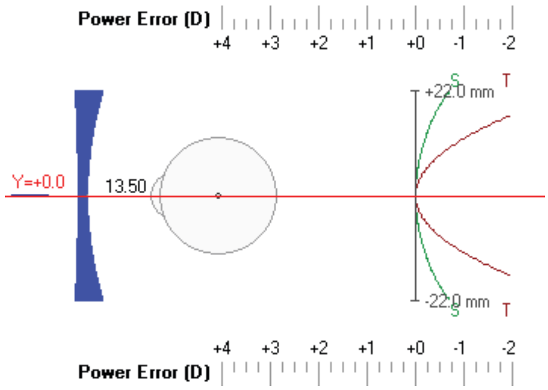
ADDENDUM
Aberrations from the prismatic effect caused by viewing away from the optical centre of the lens.
Error caused by off-centre viewing, without a pantoscopic/hedral angle.
Viewing a target away from the optical centre of a high-powered lens creates a prismatic effect, as described by the Prentice rule. The aberration creates a cylindrical component and a spectral colour aberration (Fig.13).

When the subject looks through the lens at position B, parallel to the optical axis, the prismatic effect along x,B,y is different to that along A,B,C. A circle of light will be elongated by a different amount in the horizontal and vertical meridians. These are the sagittal and tangential powers. This is demonstrated in Fig.14. As the sagittal and tangential powers are not equal, a cylindrical effect is created. (Figure created with Zeiss Spectacle Optics).

Figure 14: *A -8.00 DS, minus base curve meniscus, crown glass lens exhibiting sagittal and tangential aberrations.*



A 5mm off-centre viewing from the optical centre of a +5.00 lens will result in a 2.5Δ prism.

Crown glass has a refractive index of η = 1.515 for red light (750 nm) and η = 1.523 for green light (550 nm).

Apical angle of a prism: 1Δ = 0.57° therefore 2.5Δ = 1.425°

1.515 x Sin 1.425 = 1 x sin r; deviation r = 2.15941°

1.523 x Sin 1.425 = 1 x sin g; deviation g = 2.17057°

Difference in angle = 0.01116°

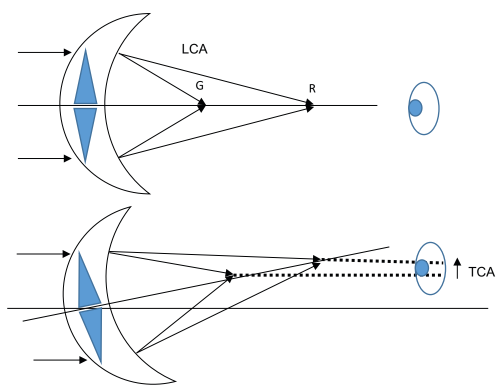
Size of displacement at 6000mm.

Tan 0.01116 = Size of displacement / 6000; Size of displacement = 1.17 mm which approximates to the width of a single line on a 6/6 optotype.

There is a secondary displacement that can be ignored as the effect is minimal, but it is included for completeness. This is related to the pantoscopic angle. A prism causes different angles of deviation of the light depending on the wavelength. There is a displacement of the image that occurs with different wavelengths.

Theoretically, if a high-powered lens is positioned obliquely, the longitudinal chromatic aberration (LCA) due to the prismatic effect will result in a small transverse chromatic aberration (TCA). Figure 15 indicates that the effect is too small to influence the angle of deviation. In practice, a competent practitioner will not allow the trial frame or refractor head to be positioned with a problematic pantoscopic angle.

Figure 15: *Increased pantoscopic angle causing transverse chromatic aberration due to longitudinal chromatic aberration. Prism effect caused by pantoscopic/hedral tilting (10°).*



Prism = 100 x tan a x (t / n) x F

A is the angle of tilt in degrees, t is the centre thickness of the lens in meters, η =refractive index, and F is the front curve in diopters.

Using data from the Zeiss Spectacle Optics designed by Daryll Meister[12].

Power +5.00 DS; Diameter 65Ø mm; Best form lens Front Curve +11.00 DS; Asphericity Sphere 1.00p; Centre thickness 6.9mm; Pantoscopic / Hedral tilt 10°.

Prism r = 100 x 0.1763 x (0.0069/1.515) x 11 = 0.883

Prism g = 100 x 0.1763 x (0.0069/1.523) x 11 = 0.879

Prismatic difference = 0.004Δ = 0.0019mm displacement at 6000mm.

This difference is not significant.

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