The use of the stenopaeic slit thoringtons disk

Background: The Thorington method is a refractive technique using the Stenopaeic slit, a trial frame accessory comprised of a disc with a narrow, slit-shaped aperture in the center. It is now rarely used in the subjective refraction to find the principal meridians of astigmatism due to the general perception that the Jackson's cross cylinder method or the Fan & Block method provide a higher degree of accuracy. However, the Thorington method may still be very useful particularly in cases of high astigmatism and poor visual acuity, or in situations where the retinoscopic reflex is difficult to see This study compares the accuracy and efficiency of determining the principal meridians of astigmatism in low vision patients between the Thorington method and and the Jackson's cross cylinder method.

Method: 31 students undertaking the Bachelor of Optometry programme at the University of Auckland were recruited in the study. Following correction of any refractive error of the participant, a dense cataract was simulated using an opaque plastic sheet, and a varying degree of astigmatic errors at different axes were induced with four choices of minus cylinder lens. The principal meridian of the induced astigmatism and the time taken to reach the end-point were recorded for the Thorington method and the Jackson's cross cylinder method, and this was repeated three times with a different inducing cylinder lens each time. The participants were also required to complete a questionnaire on the relative ease of each refractive technique.

Results: There was no clinically significant difference in the discrepancies between the cylindrical components induced and the cylindrical components measured when the two refractive techniques were compared. The Thorington method took, on average, less than half the time to reach the end-point in comparison to the Jackson's cross cylinder method. No clinically significant difference was found in the patient ease between the two refractive techniques.

Conclusion: The Thorington method was found to be just as accurate as the Jackson's cross cylinder method in finding the principal meridian of astigmatism in individuals with reduced visual acuity, while being quicker to obtain the measurement than the Jackson's cross cylinder method. Hence, the Thorington method could be a good alternative to the Jackson's cross cylinder method especially in cases where the patient finds it difficult to discern which of the two JCC views is better.

Introduction

The population is ageing rapidly In New Zealand. It is estimated that more than a quarter of the population will be over 65 years of age by the late 2030s, and by 2051, the 65+ age group will reach 1. 33 million (1). As the population ages, low vision and blindness are becoming a growing health concern. According to the 2000 US Census, the prevalence of 'blindness' (defined as the best corrected visual acuity of worse than 6/60 in the better seeing eye) and 'low vision' (defined as the best corrected visual acuity of worse than 6/12 in the better seeing eye) in the 40+ age group was 0. 78% and 1. 98%, respectively (2). When the figures are put in the context for New Zealand, it may be deduced that there are approximately 30 000 adults with 'blindness' and 80 000 adults with 'low vision'. In particular, studies have identified that 73% of people aged between 65 and 74 years, 91% of people aged between 75 and 84 years, and 95% of people aged 85 or over have cataracts (3). These high numbers pose a great concern especially in New

Zealand due to lengthy public hospital waiting lists of patients requiring cataract surgery (4). This means that there is a fast growing demand for the optometric diagnosis and management of visual impairment such as due to cataract as the majority of patients with 'low vision' or even 'blindness' still have a useful remaining vision. Hence, enhancements in the current refraction techniques will benefit low vision patients through the more effective and efficient correction of ametropia, and this will reduce the socioeconomic costs related to vision loss.

Astigmatism is an optical defect in which vision is blurred due to the inability of the optics of the eye to project a point object into a sharply focused image on the retina. It is a very common refractive error, and approximately 85% of the population have some degree of measurable astigmatism.

The Thorington method is a refraction technique using the Stenopaeic slit. The Stenopaeic slit is a trial case accessory which is comprised of a disc with a narrow, slit-shaped aperture in the center. It is basically an elongated pinhole which removes the peripheral rays in the meridian perpendicular to the slit, isolating the ocular meridian on which to perform the refraction (5). As the orientation of the Stenopaeic slit changes, the retinal blur size in an astigmatic eye changes due to an axial shift of the circle of least confusion (COLC). When the Stenopaeic slit is aligned with one of the principal meridians of astigmatism, it " changes" the spherocylindrical refractive error into a purely spherical one, giving the sharpest image in comparison to other orientations as the refractive error is the smallest in this orientation (6).

The Thorington method is now rarely adopted in the subjective refraction to find the axes of refractive error of an astigmatic eye because of the general perception that the Jackson's cross cylinder (JCC) method and the Fan & Block method provide a greater accuracy. However, these latter techniques can be quite tedious to perform on some patients with reduced vision due to difficulty patients can have with detecting any changes between the views produced by two lenses of differing axis or power. In cases of high astigmatism and poor visual acuity (7), or in situations where the retinoscopic reflex is difficult to see (8), the Thorington method is known to be very useful. According to the early literature, the Stenopaeic slit is also useful for the subjective refraction of patients with significant optical anomalies such as cataract or keratoconus (9).

It is not possible, with two-dimensional optics, to properly account for the optical behaviour of a three-dimensional eye in a three-dimensional world. According to Munoz-Escriva and Furlan (2001), the effect of the Stenopaeic slit in front of an astigmatic eye can be best described within the dioptric power space which is a vector in a three-dimensional space (10). The power of a spherocylindrical lens can be represented as a single vector in a three-dimensional space with independent coordinates (x, y, z) in the form of M (spherical power), J0 (JCC power) and J45 (JCC power) where (11):

M = S + C/2 J0 = -C/2 cos 2Î± J45 = -C/2 sin 2Î±

The vector representation of a lens in a three-dimensional space allows the simple summation of different spherocylindrical lens powers through vector addition, and the assessment of variance in astigmatism through astigmatic decomposition (12). Through another study in 2001, Munoz-Escriva and Furlan looked specifically into the optical effects of the Stenopaeic slit in the dioptric power space when it is not oriented along one of the principal meridians, and deduced an equation to obtain the residual refractive error in front of the astigmatic eye at any slit orientation (13)

There have been a few other studies on the Thorington method in the 1960's and 1970's regarding its methodology and optics, but a study on the clinical efficiency of the Thorington method in comparison with other subjective refraction techniques has not been attempted yet.

The goal of this project is to investigate the efficiency of determining the principal orientation of astigmatism using the Stenopaeic slit for subjective refraction in an eye with poor visual acuity. Due to a wide variety ocular pathology that leads to decreased vision, the current research will only involve low vision secondary to cataract, a common cause of visual impairment in the old age group. This project aims to compare the accuracy and efficiency of determining the principal meridians of astigmatism between the Stenopaeic slit and JCC methods under the simulation of a dense cataract using opaque sheets of plastic, and subjects with normal vision will be recruited to provide data.

The specific aims of this study are: 1) To determine if there is a clinically significant difference in the principal meridians of astigmatism obtained by the two methods. 2) To determine if there is a statistically/clinically significant difference in the time taken for finding the principal meridians of astigmatism between the Thorington method and the JCC method under the simulation of dense cataract. 3) To determine if there is a statistically significant difference in the relative ease between the two methods in the perspective of participants.

Method

Participants

A total of 31 subjects between the ages of 16 and 50 were recruited in this study. The minimum age requirement of 16 was chosen so that all subjects can make a voluntary consent to participate in the research. The maximum age limit of 50 was chosen because older people are more likely to have media opacities and other ocular conditions that may produce a confounding effect on our measurements. All participants were required to have a best corrected visual acuity of 6/6 or better in at least one eye.

A short preliminary examination was conducted on each subject to check for any pre-existing ocular conditions which may adversely affect the visual performance, and to measure the refractive error using Zeiss Humphrey automatic refractor (model 599). The exclusion criteria included significant media opacities such as cataract or corneal scar, and other ocular conditions that may potentially affect the visual performance. The eye with less astigmatism was chosen to obtain data. An over-refraction was performed on the prescription found by the auto-refractor to correct for any residual refractive error.

Simulation of Cataract

An opaque plastic sheet was placed in front of the selected eye to simulate a dense cataract which reduces the best corrected visual acuity to around 6/24.

Inducing astigmatism

A minus cylinder lens was placed in the trial frame to simulate astigmatism. A random number generator was used to assign the power and the axis of astigmatism out of the four options: -1. 00DC x 180, -1. 00DC x 045, -2. 00DC x 180, and -2. 00DC x 045. An appropriate spherical lens was included with the cylindrical lens so that the induced refractive error (mixed astigmatism) has a spherical equivalent of 0. 00D.

Refraction Techniques

The refraction technique to be evaluated first was determined randomly, and the principal meridian of astigmatism and the time taken to reach the end-point using the Stenopaeic slit method and the Jackson's cross-cylinder method were measured. The participants were unaware that they were being timed. The refraction was performed monocularly, with the other eye being occluded throughout the experiment. The low vision simulator remained constant for both techniques.

1) The Thorington method:

A +0. 50DS fogging lens was placed in the trial frame to move the posterior line of focus closer to the retina. A logMAR chart with multiple lines of letters at 6m distance was used as the viewing target. It was confirmed that the participant can read at least two lines above the limit of visual acuity with the low vision simulator and the fogging lens in place. The Stenopaeic slit was initially positioned at 90°, and the participant was instructed to use the knob on the trial frame to keep rotating the slit until the position that gives the clearest view of the letters was found. The axis of the correcting minus cylinder (i. e. the position perpendicular to the slit orientation) and the time taken to reach the end-point were recorded. This was repeated three times, each with a different inducing cylinder lens assigned randomly. Care was taken to align the slit exactly in front of the pupil center at all times.

2) The Jackson's cross-cylinder method:

As for the Thorington method, a +0. 50DS fogging lens was used. A chart with rotationally symmetric dots of the size equivalent to two lines above the limit of visual acuity with the low vision simulator and the fogging lens in place was used as the viewing target. Initially, a ±1. 00D hand-held JCC lens was twirled with the handle first at 45° and then at 180°. The results of these two twirls were used to determine the axis position at which a -1. 00DC correcting lens was placed (the axis position was at the mid-point of the two positions that produced the clearer view of the dots). The spherical equivalent power was maintained by adding a +0. 50DS lens. To check the orientation of the tentative correcting cylinder, the bracketing technique (i. e. changing the axis of the correcting minus cylinder lens in 20° step followed by 10° step and then 5° step on each reversal) was used with a double reversal criterion (i. e. the participant reporting that the target is clearer in the same direction when the axis of the minus cylinder was changed in the opposite direction by an extra 5° on reversal) being used to locate the two edges of the axis range across which the two JCC views were indistinguishable. The final axis was found from the average of the two reversal points found by this double reversal technique. The time taken to obtain the two reversal points was recorded. This was repeated three times, each with a different randomly assigned inducing cylinder.

Questionnaire

At the end of the experiment, the participants were asked to complete a questionnaire to evaluate the two refraction techniques subjectively. The questionnaire was comprised of three questions that were to be answered on a visual analogue scale ranging from 1 to 5. For each refraction technique, the participants were required to assess the ease of understanding the instructions, the ease of making judgments, and the degree of confidence in their responses. Also, the patient was asked which of the two methods was easier overall.

Analysis

The power and axis components of astigmatism were converted into power vectors (J0, J45) in a three-dimensional space as described by Thibos (11). The paired t-test was used to determine whether there is a statistically significant difference in the J0 and J45 between the two refraction techniques. The Levene test was done to check the assumption of equal variances. The Welch's test was used to compare the J0 and J45 found and the J0 and J45 induced for each type of inducing cylinder lens, and determine whether there is a statistically significant difference in discrepancies between the two methods. The correlation coefficient is commonly used to assess the degree of agreement between a new method and a pre-existing method. Nevertheless, a high correlation only means that there is a strong association between two methods, but it does not necessarily indicate a high level of agreement (14). Moreover, the correlation coefficient can provide a useful estimate of agreement between two methods only if the pre-existing method is very low in error. Because all refractive techniques have a variable degree of inherent error, and due to a possibility of residual astigmatism that may be present even after the correction of refractive error, the Bland-Altman (bias) analysis was used to assess the degree of agreement in the vector components between the Stenopaeic slit method and the Jackson's cross-cylinder method (14).

Results

The paired t-test

The assumption of equal variances of each vector component between the Stenopaeic slit method and the Jackson's cross-cylinder method was satisfied as the p-value for the difference in mean variance of J0 between the two methods and the difference in mean variance of J45 between the two methods was 0. 4632 and 0. 7934, respectively. The paired t-test showed that there is no statistically significant difference (p= 0. 8736) in mean J0 found between the two methods (Table 1). The paired t-test also showed that there is no statistically significant difference (p= 0. 5158) in mean J45 found between the two methods (Table 1).

95% Confidence Interval

Mean difference (D)

S. D. (D)

p

Mean-1. 96SD (D)

Mean+1. 96SD (D)

J0

0. 01

0. 80

0. 8736

-0. 15

0. 18

J45

0. 06

0. 88

0. 5158

-0. 12

0. 24

Table 1: Mean difference in vector components between the Stenopaeic slit method and the Jackson's cross-cylinder method, standard deviation, p-value, and 95% confidence interval limits.

The Welch's test

The difference in vector component between the Stenopaeic slit method and the Jackson's cross-cylinder method was grouped into two categories according to the amount of astigmatic refractive error that was induced: 'Low cyl' (-1. 00DC inducing cylinder lens) and 'High cyl' (-2. 00DC inducing cylinder lens). The Levene test showed that the assumption of equal variances of each vector component between the 'High cyl' group and the 'Low cyl' group was not satisfied as the p-value for the difference in mean variance of J0 between the two groups and the difference in mean variance of J45 between the two groups was 0. 00041 and 0. 00003, respectively. The plots of the difference in J0 between the two methods against the difference in J45 between the two methods for 'Low cyl' and 'High cyl' showed that the data are more clustered with the use of -1. 00DC inducing cylinder lens in comparison to the use of -2. 00DC inducing cylinder lens. This suggests that the two refraction techniques are more comparable when the amount of astigmatism is relatively small.

Figure 1: Plots of the difference in J0 versus the difference in J45 for the -1. 00DC and -2. 00DC inducing cylinder lenses.

The differences between the vector components found under each refraction technique and the vector components induced was calculated and were compared separately for each inducing cylinder lens. Table 2 shows that the assumption of equal variances was satisfied for all types of inducing cylinder lens. No statistically significant difference was found in the difference between the vector components found under each refraction technique and the vector components induced for all types of inducing cylinder lens with an exception of -2. 00DC @ 135 (p= 0. 0154).

Mean within group

95% Confidence Interval

JCC

SS

p

Mean-1. 96SD

Mean+1. 96SD

-1. 00DC x 90 J0

-0. 37

-0. 30

0. 5453

-0. 37

0. 15

-1. 00DC x 90 J45

-0. 44

-0. 41

0. 8107

-0. 24

0. 19

-1. 00DC x 135 J0

0. 53

0. 43

0. 3390

-0. 11

0. 30

-1. 00DC x 135 J45

-0. 16

-0. 10

0. 5500

-0. 29

0. 15

-2. 00DC x 90 J0

-0. 68

-0. 52

0. 4934

-0. 61

0. 30

-2. 00DC x 90 J45

-1. 12

-0. 66

0. 0157

-0. 84

-0. 09

-2. 00DC x 135 J0

1. 15

1. 09

0. 7683

-0. 36

0. 48

-2. 00DC x 135 J45

0. 10

-0. 19

0. 1301

-0. 09

0. 67

Table 2: Mean difference between induced and found cylindrical components per method, p-value, 95% confidence interval.

The Bland-Altman analysis

The Bland-Altman analysis demonstrated low levels of bias (Table 3). No obvious relationship was observed on the plots of the difference in J0 or J45 between the two methods against the mean J0 or J45 of the two methods for both high and low cylinder powers (Figure 2). The plots showed no consistent bias. The range between the two limits of agreement for both J0 and J45 was about twice as wide with the high cylinder power compared to the low cylinder power, but Bland and Altman claim that if all data lie within the limits of agreement, there will be no clinically significant difference between the two methods (14).

Limits of Agreement

Bias

S. D. of bias

Mean-1. 96SD

Mean+1. 96SD

Low cyl J0

-0. 01

0. 51

-1. 00

0. 99

Low cyl J45

0. 05

0. 56

-1. 06

1. 15

High cyl J0

0. 04

1. 00

-1. 92

2. 00

High cyl J45

0. 07

1. 11

-2. 10

2. 25

Table 3: Bland-Altman analysis of bias, standard deviation, and 95% limits of agreement.

Figure 2: Plots of difference versus mean of vector component obtained with the Stenopaeic slit method and the Jackson's cross-cylinder method.

Time taken to reach the end-point

The assumption of equal variances of the time taken to reach the end-point for the two refraction techniques was satisfied (p= 0. 1724). The two-sample t-test showed that the true difference in the mean time taken to reach the end-point between the two methods lies between 36. 55 seconds and 45. 26 seconds at the 95% level confidence. The difference between the two means was statistically significant (p <2. 2e-16). Figure 3 shows that the median time taken to reach the end-point was 22. 36 seconds with the Stenopaeic slit method, 63. 26 seconds with the Jackson's cross-cylinder method. The difference in the mean time taken to reach the end-point between the two methods would be larger if the potential outlier in the data for the Stenopaeic slit method was removed.

Figure 3: Box-and-whiskers (Tukey) representation of the time taken to reach the end-point under the two refraction techniques.

Questionnaire

The first question was " how easy was it for you to understand the procedure?", and the response was given on a grade scale from 1 to 5, in an increasing level of ease. There was a moderate evidence (p= 0. 0739) that there is a statistically significant difference in the ease of understanding the procedure between the two refraction techniques. Figure 4 shows that the participants found that the Stenopaeic slit method was relatively easier to understand than the Jackson's cross-cylinder method.

Figure 4: Scores of the ease of understanding the procedure of the two refraction techniques.

The second question was " how easy did you it to make judgments?", and the response was given on a grade scale from 1 to 5, in an increasing level of ease. There was no statistically significant difference (p= 0. 8920) between the two methods, indicating that the ease of making judgments as to deciding which orientation of the Stenopaeic slit gave the clearest view was similar to the ease of making judgments as to deciding which of the two views produced by the Jackson's cross-cylinder was better.

Figure 5: Scores of the ease of making judgments in the two refraction techniques.

The third question was " how confident were you with your responses?", and the response was given on a grade scale from 1 to 5, in an increasing level of confidence. No statistically significant difference was found between the two methods (p= 0. 5470).

Figure 6: Scores of the confidence with responses in the two refractive techniques.

SS

JCC

Question

Mean (SD)

Mean (SD)

p

1

4. 68 (0. 54)

4. 10 (1. 01)

0. 0739

2

3. 30 (0. 94)

3. 32 (1. 01)

0. 8920

3

3. 58 (0. 76)

3. 36 (0. 95)

0. 5470

Table 4: Mean scores of the questions for the two refractive techniques, p-value for the difference between the mean scores.

The participants were also asked which of the two refractive techniques was easier overall, and 18 participants (58. 06%) chose the Stenopaeic slit method while the remaining 13 participants (41. 94%) chose the Jackson's cross-cylinder method.

Discussion

There was no statistically significant difference in the discrepancy between the induced cylindrical components and the measured cylindrical components when the two refractive techniques were compared except for the J45 component of the correction found for the inducing cylinder lens -2. 00 x 180. Nevertheless, it is difficult to determine whether this difference is of any clinical importance as the actual axis of the correcting cylinder is comprised of a combination of the cylindrical components J0 and J45. The mean difference between the induced cylinder axis and the measured cylinder axis for the -2. 00 x 180 inducing cylinder lens was less than 10° for both the Stenopaeic slit method and the Jackson's cross cylinder method. This indicates that the difference in the discrepancy of the measured J45 component from the induced J45 component between the two refractive techniques for this particular inducing cylinder lens may not be clinically significant in the context of low vision patients.

The Bland-Altman plots showed that the two refractive techniques are equally valid with respect to the accuracy and variability of the results.

The time taken to obtain the measurement was, on average 41 seconds shorter with the Stenopaeic slit method than with the Jackson's cross cylinder method. This difference may arguably be clinically significant considering that the measurement of the axis is required for the other eye as well.

This study showed that there was no clinically significant difference in the principal meridians of astigmatism measured by Stenopaeic slit method when compared with the Jackson's cross cylinder method in patients with reduced visual acuity secondary to cataract. The Stenopaeic slit was found to be more than twice as fast as the Jacson's cross cylinder method, but there was no clinically significant difference in the degree of patient ease between the two refractive techniques. Hence, the use of the Stenopaeic slit may still be advocated these days especially in situations where a low vision patient is having immense difficulties in making judgments between the two obscured JCC views.