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Comparitive study between a modified fixation disparity curve procedure and standard protocol

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Abstract

PROCEDURE AND STANDARD PROTOCOL In this study a comparison was made between the efficacies of a standard fixation disparity curve and a fixation disparity curve created with protocol modified for speed of administration in a traditional clinical setting. The modified curve consists of five points; associated phoria (with 0 prism), three prism diopters each of base in and out, and one additional base in and base out point based on the each subject's vergence ranges. A modified curve and a standard curve were obtained from 40 subjects. Three objective, blind evaluators made assessments of the curves to allow comparisons between the associated phorias, the least amount of prism to the flat zone, prism value to the center of symmetry, curve type, and slope of these two curves. Also assessed was the comfort level of each examiner in using the data from the modified curves and standard curves in making patient care decisions. The analysis of the relationship between the associated phoria values from each curve (modified vs. standard) showed the difference between them to be 2 prism diopters ($p = 0.012$) indicating a significant change in the data sets. When a comparison was made between the 'least amount of prism to flat zone' with each of these methods, the insignificant average difference was -0.122 prism diopters ($p = 0.792$). With respect to the slopes, the relationship between the modified and standard curves showed an insignificant average difference of -0.14 ($p = 0.295$). The "blind" evaluators felt confident making patient care decisions with the standard curve 83% of the time versus only 25% of the time using the modified curve. The analysis of the data collected shows not only that the modified protocol failed to provide reliable data for essential elements of a fixation disparity curve such as associated phoria, least amount of prism to flat zone and curve type, but also raised questions about repeatability of the standard method of fixation disparity testing.

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COMPARITIVE STUDY BETWEEN **A** MODIFIED FIXATION DISPARITY CURVE PROCEDURE AND STANDARD PROTOCOL

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Biographies

Sara Niyati attended Davis High School and then earned A Bachelor of Science in Biology and minor in Spanish from University of California, Davis. Awards she earned during her College Career at UC Davis include a Regents Scholarship from the College. Her future plans include obtaining a residency in Ocular Disease after prospective graduation in May 2005. Sara Niyati grew up in Davis, California for most of her life and has lived in other countries including Iran and Spain for parts of her life.

Joy Poppell graduated from North Pole High School in Alaska, and attended Mississippi State University where she received a Bachelor of Science in Microbiology. Upon graduation in 2005 she plans to pursue a clinical career in Optometry with emphasis in vision therapy; devote creative energy to pottery, photography and theater; and travel as much of the world as time, health and money permit.

Luke Brog was born in Afton, Wyoming and grew up in Freedom, Wyoming. In 1994, he graduated from high school as a member of the National Honor Society. Luke completed his Bachelor of Science in Zoology while attending Idaho State University and was a member of the Golden Key National Honor Society there. Concurrent with his studies, Luke occupied his free time with playing intramural sports and working his way through college. While attending ISU, he met his wife Jennifer Allison and they later married in March of 2001. Luke and Jenn then moved to Forest Grove, Oregon, where Luke completed his optometry degree at Pacific University. During their time in Forest Grove in March of 2003, their daughter Hannah Elise Brog was born. Luke's future plans include starting a private practice in the intermountain west.

Steven Sargent graduated from Snow College with Associates in Science, and then transferred to Utah State University where he majored in biology. Steven will receive his B.A. in Science, Doctor of Optometry, and Masters in Education in Visual and Functional Learning from Pacific University. Once optometry school is completed he plans to return to Utah and open a private practice doing primary care optometry with a specialty in pediatric optometry.

Abstract

COMPARITIVE STUDY BETWEEN A MODIFIED FIXATION DISPARITY CURVE PROCEDURE AND STANDARD PROTOCOL

In this study a comparison was made between the efficacies of a standard fixation disparity curve and a fixation disparity curve created with protocol modified for speed of administration in a traditional clinical setting. The modified curve consists of five points; associated phoria (with 0 prism), three prism diopters each of base in and out, and one additional base in and base out point based on the each subject's vergence ranges. A modified curve and a standard curve were obtained from 40 subjects. Three objective, blind evaluators made assessments of the curves to allow comparisons between the associated phorias, the least amount of prism to the flat zone, prism value to the center of symmetry, curve type, and slope of these two curves. Also assessed was the comfort level of each examiner in using the data from the modified curves and standard curves in making patient care decisions. The analysis of the relationship between the associated phoria values from each curve (modified vs. standard) showed the difference between them to be 2 prism diopters ($p = 0.012$) indicating a significant change in the data sets. When a comparison was made between the 'least amount of prism to flat zone' with each of these methods, the insignificant average difference was -0.122 prism diopters ($p = 0.792$). With respect to the slopes, the relationship between the modified and standard curves showed an insignificant average difference of -0.14 ($p = 0.295$). The "blind" evaluators felt confident making patient care decisions with the standard curve 83% of the time versus only 25% of the time using the modified curve. The analysis of the data collected shows not only that the modified protocol failed to provide reliable data for essential elements of a fixation disparity curve such as associated phoria, least amount of prism to flat zone and curve type, but also raised questions about repeatability of the standard method of fixation disparity testing.

KEY WORDS: Fixation disparity, Sheedy Disparometer, fixation disparity curve, associated phoria.

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To the Pacific University College of Optometry Class of 2005: To those special few that volunteered to participate when we needed more subjects at the last minute, thank you. Thanks also go to every classmate that groaned in sympathy when told the nature of this project.

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Last but definitely not least, our thanks goes out to Dr. Scott Cooper. You have been a wonderful advisor and your boundless patience and unfailing willingness to answer every question and help solve every problem kept us civil and on task. It was your teaching skills and enthusiasm for the topic that inspired this thesis and helped motivate us to find answers.

Introduction

Fixation disparity is a small misalignment of the two eyes that occurs during binocular viewing. Sensory fusion is still present with this deviation though the images are not stimulating corresponding areas of retina. The visual integration of a single retinal point of one eye and a corresponding group of points in the other eye, known as Panum's fusional area, is responsible for the presence of sensory fusion.'

The amount of fixation disparity at any given moment is dependent upon the amount of fusional vergence present at that time and is a function of both testing condition and individual patient characteristics.[2] When bifoveation is slightly less than the fusional demand, an exo fixation disparity is present. Likewise, when bifoveation is slightly more than the fusional demand, an eso fixation disparity is present. Therefore, when testing with greater and greater prism (increased fusional demand), it is expected to see exo fixation disparity develop with base out prism and eso to develop with base in prism as fusional responses fall slightly short.[2,3]

Measurement of fixation disparity is a useful diagnostic tool because it is related to fusional convergence, and stress associated with fusional convergence often results in asthenopia.[2] This misalignment usually measures less than ten seconds of arc.[3] A fixation disparity of more than a few minutes of arc is an indicator of potential binocular vision problems. In other words, the larger the disparity the more likely it is that a patient will experience asthenopic symptoms.[4]

Fixation disparity is measured under binocular conditions through subjective alignment of two bars, called vernier lines, one seen by each eye. Three common methods of obtaining fixation disparity data are the Sheedy Disparometer, the Wesson fixation disparity card, and the Saladin card. These methods permit direct measurement of fixation disparity and can assess changes in the disparity while viewing through prism and lenses. Differing amounts of base in and base out prism are applied and the amount of fixation disparity with each prism is measured. The data gathered from each point can then be plotted to form a curve that can provide much information valuable for diagnosis and treatment decisions.

Fixation disparity curves give the optometric practitioner information about the visual system of a patient. Their main use is in identifying and classifying binocular vision disorders. Aside from being the most reliable method of quantifying the associated phoria, they help to determine probability of success with therapy, predict visual comfort, assess the stability of the accommodative and vergence systems, determine the response of the visual system to prism induced convergence and divergence, and aid in prescribing prism and plus lenses.[2,3] Needless to say it is an extremely useful test for diagnosis and treatment.

Unfortunately, the bulk of optometric practitioners rarely interpret fixation disparity curves, even though much information is gleaned from them. The main reason is that the testing procedure itself is both time consuming and very labor intensive for both the doctor and the patient. This raises the possibility that if the procedure for generating the curve could be shortened significantly (without compromising its effectiveness), creation of fixation disparity curves could be easily incorporated into the examination routine of the average practitioner. This in turn would provide them with a plethora of information in a relatively short amount of time.

Materials and Methods

Before entry into the study, eligible subjects signed an informed consent form approved by the Investigational Review Board (IRB) at Pacific University. Eligibility criteria for enrollment included the following: 1) Snellen visual acuity of 20/20 or better at 40 cm with best correction in both eyes 2) no history of ocular pathology 3) no prior history of amblyopia or strabismus (confirmed with cover test) 4) no prior eye surgery 5) stereopsis of at least 40 seconds of arc as measured with Stereobutterfly 6) no central suppression based on Stereobutterfly and 7) minimum 40 cm relative vergence break of 15 prism diopters base-in (BI) and 15 prism diopters base-out (BO) measured at 40 centimeters in phoropter.

For each of the forty-three prospective subjects, a detailed entrance criteria questionnaire was completed. Part one was completed by the subjects and included history questions such as personal eye history. Part two was completed by the examiner and included the entrance criteria testing listed above. After completion of the entrance testing, subjects' eligibility status was determined using the criteria mentioned above. Using these criteria, forty subjects were accepted and three subjects were excluded from the study.

After subjects were accepted into the study, they participated in the fixation disparity tests. Subjects were randomly assigned to first complete the modified curve or the full point curve testing. All subjects completed both test paradigms. To prevent inter-examiner bias, the two testing methods were performed in separate rooms by different examiners. Further, to minimize single examiner bias, the examiners were assigned to change duties regularly and were blind to previous testing results.

Both curves were generated using the Sheedy Disparometer. This instrument was placed on the phoropter nearpoint rod forty centimeters away from the subject. Standard nearpoint light was applied to the front of the Disparometer and polarized filters were utilized in the phoropter. The subjects' near habitual prescription was used and each subject was asked to focus the letters on the sides of the Disparometer's vernier lines.

The examiner then asked the subject to shift his or her fixation to the vernier lines and immediately notice any disparity (i.e. if the two vertical lines are aligned). Next, the examiner adjusted the Disparometer's settings to bracket a perfect alignment or determine the range of disparities that appeared to be perfectly aligned.

In the full point curve testing, subjects' fixation disparity was initially tested with zero prism. The subjects were then tested at 3 BI followed by 3 BO. Testing was continued in multiples of 3A (i.e. next 6BI followed by 6BO...) until the subject could not fuse (i.e. saw double) or suppressed (i.e. saw one vernier line). Subjects were allowed fifteen seconds to fuse. If they were able to fuse, the testing continued. Otherwise, testing was discontinued and appropriate notations were made. When subjects could not fuse greater prism in one direction (i.e base out), the examiner continued testing in the opposite direction (i.e. base in), alternating with the highest fusible prism in the weaker direction. For example, if the subject could no longer fuse at 15 BO but had just fused 15 BI, he or she was asked to fuse 12 BO before being tested at 18 BI. If the subject could fuse 18 BI, he or she was to fuse 12 BO once again before being tested at 21 BI and so on.

Vergence ranges measured in the entrance evaluation were used to direct the modified curve testing. In this protocol, subjects were tested with five prisms. Measurements were recorded at zero prism, 3 BI, 3 BO, at the first point lower than the base out breaks which was divisible by three (i.e. if the base out break was 19 prism diopters, the fixation disparity was assessed at 18 prism diopters), and finally at the first point lower than the base in break which was divisible by three. If the subject wasn't able to fuse either of the final two prisms, the prism amount was decreased until he or she could fuse the image before testing continued. This prism value was recorded.

All fixation disparity results were provided to three binocular vision experts "blind" to the experimental design for analysis (with ID numbers masked). They were given both the full point curve and the five-point curve generated by each subject. They had no knowledge of the methods of testing or which results belonged to which subject. However, simply due to the need to evaluate five-point fixation disparity curves surely made them aware that they were involved with a study comparing complete fixation disparity curves versus a limited data assessment. The disparity points had been plotted for them to avoid the chance of a clerical error, but no best-fit curve was pre-drawn to avoid biasing their interpretation of the raw data provided. They evaluated each plot using a questionnaire regarding the curve type, associated phoria, prism to flat zone and prism value to the center of symmetry. Two of the three evaluators were also asked to provide numeric ratings of their overall confidence in using each curve for patient care.

Results

Difference between ***the Associated Phoria*** *Average for Standard Versus Modified Curves*

The overall difference between the associated phoria averages from the two methodologies was -2.01 ±6.48 (p=0.012) (n=69) using a paired t-test design. This indicates a significant difference rather than the desired result of equivalent values. There was only a count of 69 subjects because sometimes the evaluator could not determine the associated phoria from the data (see Table A).

This comparison was also performed for each evaluator, to see if any of them provided a better between-method estimate. P values were as follows: Evaluator A=0.352 (n=18); Evaluator B=0.655 (n=18); Evaluator C=0.017 (n=33). With none of these paired t-tests results >0.95, not one of the evaluators provided equivalent associated phoria values between these two methods (see Table A).

Associated Phoria Averages for the Standard Curves versus the Modified Curves

	Total	COUNT
All Evaluators Average difference	-2.01	
All Evaluators STDEV	6.48	
All Evaluators t-test (p=)	0.012	69
Evaluator A t-test	0.352	18
Evaluator B t-test	0.655	18
Evaluator C t-test	0.017	33
Correlation	0.458	

TABLE A

To look for directional trends within the associated phoria estimates, correlation analysis was performed. These results were 0.458 indicating no reliable correlation.

Comparison of the ***Least Amount of Prism to Flat Zone*** *Average for the Standard versus Modified Curves*

The next comparison was for the least amount of prism to "get to the flat zone" between the standard and modified curves. The average difference between the two methodologies was -0.122 ±2.94 (p=0.792) (n=41). Again, sometimes the evaluator could not determine the least amount of prism to the flat zone or there was no flat zone available from the subjects' results, reducing the n (see Table B).

Least Amount of Prism to Flat Zone Average for the Standard Curves Versus the Modified Curves

	Total	COUNT
All Evaluators Average difference	-0.122	
All Evaluators STDEV	2.94	
All Evaluators t-test (p=)	0.792	41
Evaluator A t-test	0.391	4
Evaluator B t-test	0.430	8
Evaluator C t-test	0.637	29
Correlation	0.371	

TABLE B

When analyzing this same feature for each evaluator's results, none of them found statistically equal values between the test methods. The correlation of this prism value between the standard and modified curves was 0.371 (see Table B).

*Comparison of the **Prism Value to Center of Symmetry** Average for the Standard versus Modified Curves*

The overall average difference between the two methodologies for center of symmetry was -0.297 ±3.84 ($p=0.733$) ($n=37$). This count reflects all comparisons except those that the evaluator could not determine. Again, the two test methods did not provide the evaluators with equivalent estimates (see Table C).

When comparing the difference between the standard and modified curves using the paired t-test for each evaluator, Evaluator **A** and B analysis could not be determined because of a low "n"; for Evaluator C, $p=0.602$ ($n=35$). The correlation between standard and modified curves was 0.139 implying somewhat of an inverse trend (see Table C).

Prism Value to Center of Symmetry Average for the Standard Curves Versus the Modified Curves

	Total	COUNT
All Evaluators Average difference	-0.297	
All Evaluators STDEV	3.84	
All Evaluators t-test (p=)	0.733	37
Evaluator A t-test	0	0
Evaluator B t-test	0	1
Evaluator C t-test	0.602	36
Correlation	0.139	

TABLE C

*Did Fixation Disparity Curves Supply Enough Information to Make **Patient Care Decisions?***

The next analysis was to see if all three evaluators thought there was enough information to make patient care decisions on both the standard and modified curves without pairing them by test subject. The evaluators thought there was enough information 30.8% of the time however, 69.2% of the time they did not (see Figure W).

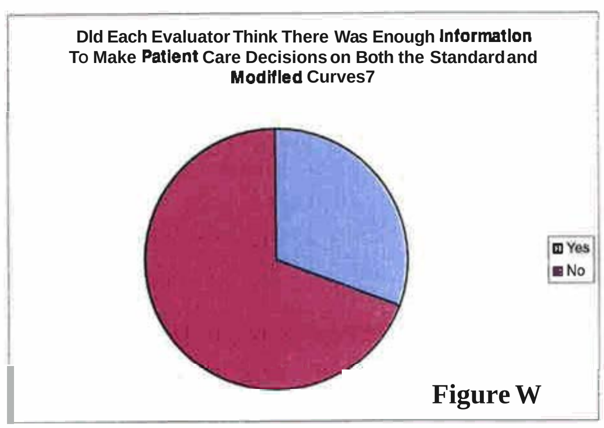

Figure W

Taking the information of all individual subject's standard and modified curves, it was then determined how many times all three evaluators agreed, on each individual curve, there was enough information to make patient care decisions. Not one of the three evaluators agreed there was enough information 30% of the time while 47.5% of the time one of the three agreed. Two of the three agreed 22.5% of the time and all three of the evaluators never agreed (see Figure X).

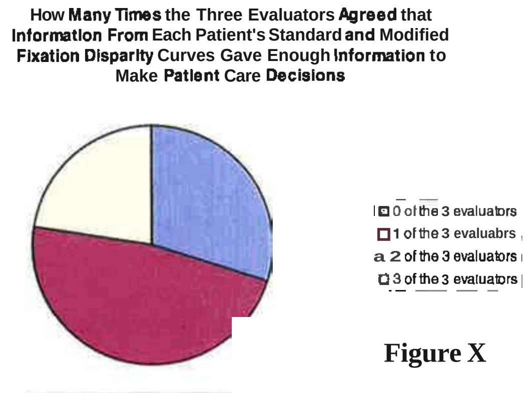

Figure X

Based on the question "Does this fixation disparity curve adequately supply enough information from disparity testing to make patient care decisions?", inter-evaluator agreement was compared for every curve generated. Considering only the standard curves, 82.5% of the time all three evaluators thought they could adequately make patient care decisions. Only 25% of the time did all three evaluators agree they could adequately make patient care decisions on the modified curves (see Figure Y). Amongst the three evaluators, there was no inter-evaluator agreement 46.2% of the time. Two of the three evaluators agreed there was enough information 13.8% of the time and all three agreed 40% of the time. Combining two of three evaluators agreeing and three of three evaluators agreeing, there was overall agreement about adequate data 53.8% of the time.

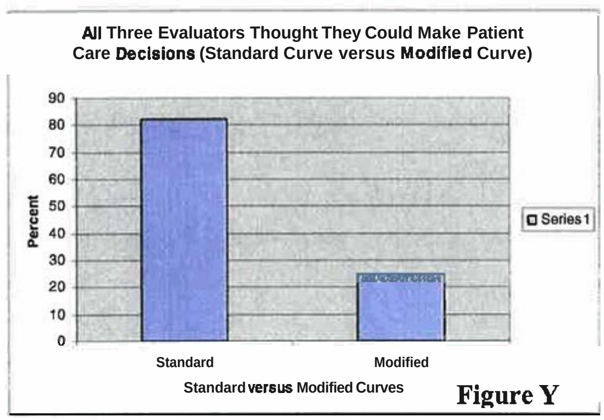

Figure Y

Inter-Examiner Agreement on ***Curve Types***

Combining the 40 standard curves and the 40 modified curves, all three evaluators agreed on the same curve type 15% of the time. Two of the three examiners agreed 46.3% of the time and there was no agreement between the evaluators 38.8% of the time. Stated another way 61.3 percent of the time there was some agreement of curve type.

Of the times where only two of the three evaluators determined the same curve type, the third evaluator picked a curve type that was different 45.9% of the time. The third evaluator could not determine a curve type at all 54.1% of the time.

Inter-Examiner Agreement on Curve Type	**Percent**
No agreement **(0)**	38.8
2 Evaluators Agree (2)	**46.3**
3 Evaluators Agree (3)	**15**
2 AND **3** Combined Agree **(2+3)**	**61.3**
Of the No Agreements Evaluators Actually Determined a Curve Type	9.7
Could Not Determine (CND)	90.3

TABLE D

Individual evaluators only predicted the same curve type for the two methods 33.3% of the time (See Table D).

*Comparison of **Curve Types** between Each Subject's Standard and **Modified** Fixation Disparity Curve*

Taking the information of each individual subject's standard and modified curves, it was then decided whether the same curve type was determined for both testing methods. Fifteen percent of the time, none of the evaluators reported the same curve type for the standard and modified curves. With 72.5% of the subjects, one of the evaluators reported the same curve type for both the standard and modified curves.

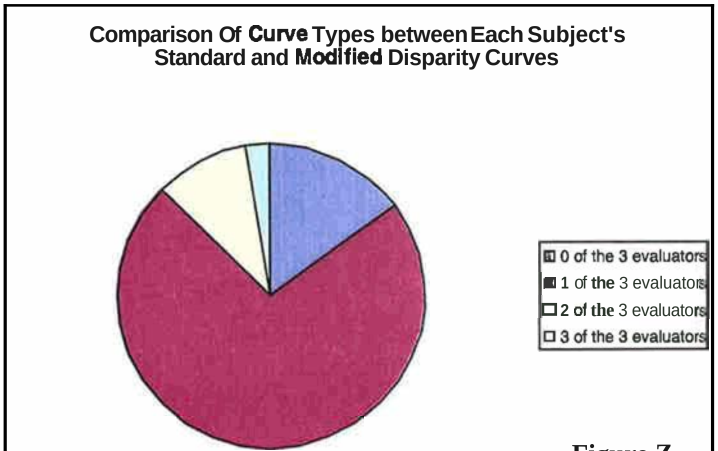

Figure Z

Two of the three evaluators were consistent with 10% of the subjects and 2.5% of the time all three of the evaluators were consistent for both methods (see Figure Z). Using at least 2/3 agreement as a criterion for "the same outcome", the two testing methods only produced agreement 12.5% of the time.

*Correlation between Standard and **Modified** Curve **Fixation Disparity Slopes***

The average slope for the standard curves was -0.66 ±0.786. The average slope for the modified curves was -0.53 ±0.529. The average difference was -0.14 ±0.820 (p=0.295). Correlation was 0.271 respectively. No statistical difference, similarity or direct correlation were found.

Standard Curve Fixation Disparity Slopes and the Modified Curve Fixation Disparity Slopes

Average Difference	-0.14
STDEV Difference	0.820
t-test (p=)	0.295
Correlation	0.271

TABLE E

Average Slope

	Standard	Modified
Average	-0.66	-0.53
STDEV	0.786	0.529

TABLE F

Conclusion

This experimental method failed to reliably deliver some of the essential elements of a standard fixation disparity curve such as associated phoria, least amount of prism to flat zone and curve type. But this experiment also helped raise questions about repeatability of the fixation curve and individual doctor comfort levels in using a fixation disparity curve in patient care. So, while this particular truncated method may not produce the same data as the standard method, many useful items for discussion become apparent.

One of the most common reasons for administering a fixation disparity curve is to obtain a valid associated phoria value. In this study we compared the associated phoria value obtained using the standard protocol and the associated phoria value using the modified protocol to find a difference of 2 prism diopters +/- 6 prism diopters.

Another very common reason for administering a fixation disparity curve is to obtain what is called the "curve type." This information is then used in estimating the patient's probability of success with therapy.[4] It also tells the examiner more about how the patient's visual system reacts under convergence and divergence demands. In this study the evaluator's job was to determine which type of curve was generated using the standard and the modified testing protocols. Once the curve types were determined they were compared for inter-examiner and intra-examiner reliability. Inter-examiner results show that only 61% of the time do 2 or three of the three examiners agree on the curve type. This is too low of a yield for having three very experienced evaluators determining the curve types. Intra-examiner results showed that only 12% of the time did two or three of the three examiners agree on the curve types.

The section of the curve that is tested from 3 base-in, to 3 base-out is used to calculate the slope of the fixation disparity curve. This section of the curve tells us about the stability of vergence during typical "no prism" viewing conditions. The steeper the slope, the less stable their vergence system is to vergence changes; the flatter the slope, the more stable the patient's vergence system. The flatter slopes also correlate to improved visual stability and symptomatology. In this study the protocol for the standard curve calls for test points at zero prism diopters, 3 base-out and 3 base-in and the slope is determined from these points. The protocol for the modified fixation disparity curve also calls for these three same exact points, so in theory there should be no difference in the slopes of the curves. Contrary to theory, we found that the slopes were in fact statistically different using the two methods. This raises the question of repeatability of the fixation disparity curve, or at least using the slope of the curve as a baseline reference point in patient care.

All evaluators were asked if they felt like there was enough information provided from the fixation disparity curves (compared to what is normally provided from fixation disparity testing) to manage patient care. The results showed that the evaluators felt that 83% of the time using the standard protocol they felt that they could adequately manage patient care, while only 25% of the time did the evaluators feel they could manage adequate patient care using the modified protocol. This confirms that this experimental method cannot be considered a replacement for full fixation disparity testing.

The evaluators were also asked to find the center of symmetry, and the least amount of prism to the flat zone. The evaluators were able to find the center of symmetry and least amount of prism to flat zone on average 2 times more often with the standard method verses the modified method. This varied by individual evaluator by as much as 7 times more often being able to find the least amount of prism to flat zone or the center of symmetry. This raises the question of whether or not this is due to the curve not supplying the data needed to find these points, or due to differences in the comfort level of each evaluator with giving an answer using the limited data. Whatever the case may be, with fewer points given to create a fixation disparity curve, the less confident the evaluators were in supplying an answer.

Summary

Taking all of the data and statistics into account we can confidently say that the proposed modified fixation disparity curve can not satisfy the demands of clinical needs of fixation disparity testing. The method fails to provide reliable data essential for the questions of associated phoria, curve type and curve slope. With that being said we also feel that through the study other points of interest have been raised by this study such as repeatability of fixation disparity curves and examiner's level of confidence while interpreting disparity results. We also feel that this is only a pilot study to find a method that would be more clinically useful for the average optometrist. There should be subsequent studies to explore this possibility.

For this study the Sheedy Disparometer was chosen as the device for comparison as it has become the clinical gold standard, even with the apparent lack of test-retest reliability. As this study was drawing to a close, a study concerning test-retest reliability of the Saladin card was published. This study provided evidence in concordance with our findings during a thorough search of optometric literature. While much research has been done comparing results between the different instruments used to measure fixation disparity or the associated phoria, no studies were found that compared the test-retest reliability of these devices, and only one study found compared methods to measure associated phorias.[5-10]

Optometry is becoming more involved with both visual and public health.[5,11-13] To assess patients in a timely and cost effective manner, simple methods of evaluating patients become necessary.[5] No matter how it is accomplished, we feel there is a need to create a method for obtaining fixation disparity curves that is as quick and reliable as possible but that would not decrease the level of confidence that an examiner would have when trying to interpret the results.

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