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# Comparative analysis of Bausch and Lomb's IVEX refraction system and a traditional refraction

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## Abstract

Bausch and Lomb's IVEX system, a computerized subjective refractor, was evaluated, A modified Optometric Extension Program (OEP) twenty-one point examination was performed three times on each of forty-nine subjects, Two examinations were performed on the IVEX system, one utilizing a monocular method and one a binocular method of distance refraction. The third examination was performed using a traditional refracting lane and refractor. Individual findings and OEP distance and near prescriptions obtained by the IVEX methods were compared to those obtained by the traditional refraction. A statistically significant difference was found for distance subjective to best visual acuity findings for both monocular and binocular IVEX methods, When comparing the monocular IVEX to the traditional method the distance and near OEP prescriptions were not significantly different. Distance and near OEP prescriptions from the binocular IVEX were significantly different, although the target used may be at least partially responsible for this difference, As a rule, distance sphere findings tended to be slightly more minus with the IVEX examinations, However, these differences may not be clinically significant. Individual test findings were also compared, Many of the IVEX findings compared quite favorably with the traditional refraction findings. However, some individual findings showed differences which warrant further study,



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# COMPARATIVE ANALYSIS OF BAUSCH AND LOMB'S IVEX REFRACTION SYSTEM AND A TRADITIONAL REFRACTION

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by

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## ABSTRACT

Bausch and Lomb's IVEX system, a computerized subjective refractor, was evaluated. A modified Optometric Extension Program (OEP) twenty-one point examination was performed three times on each of forty-nine subjects. Two examinations were performed on the IVEX system, one utilizing a monocular method and one a binocular method of distance refraction. The third examination was performed using a traditional refracting lane and refractor. Individual findings and OEP distance and near prescriptions obtained by the IVEX methods were compared to those obtained by the traditional refraction. A statistically significant difference was found for distance subjective to best visual acuity findings for both monocular and binocular IVEX methods. When comparing the monocular IVEX to the traditional method the distance and near OEP prescriptions were not significantly different. Distance and near OEP prescriptions from the binocular IVEX were significantly different, although the target used may be at least partially responsible for this difference. As a rule, distance sphere findings tended to be slightly more minus with the IVEX examinations. However, these differences may not be clinically significant.

Individual test findings were also compared. Many of the IVEX findings compared quite favorably with the traditional refraction findings. However, some individual findings showed differences which warrant further study.

## INTRODUCTION

Bausch and Lomb has recently designed an integrated vision examination system (IVEX) which performs a complete refraction, including retinoscopy and a subjective refraction. The system allows the clinician to measure all of the variables he normally tests using standard refractive techniques. This computerized system is quite compact, requiring only a table top less than three feet by two feet. Bausch and Lomb suggests that the IVEX system allows the clinician to perform the same eye examination that he uses now ". . .but more quickly with less chance of error, in less than half the space needed for ordinary refraction equipment." (1)

This investigation is designed to determine the effectiveness of the IVEX system as compared to traditional refractive equipment such as refracting lane and refractor. As of this writing no research has been published comparing the IVEX system to conventional methods of refraction. Correspondence with Bausch and Lomb reveals that their research has not yet been published and the company is just initiating research interests with academic or research institutions.

One of the probable concerns of practitioners using an instrument such as the IVEX is the possibility of inducing instrument myopia. Richards (2) states that optical instruments stimulate more accommodation than that necessary for naked eye viewing and that this amount of accommodation varies with the observer. However, Richards' emphasis is with microscopes (instruments with viewing tubes).

Various authors, Schober et al. (3), Henessy (4), and Gordon et al. (5), have found varying results with regard to the causes, effects, and amounts of accommodative stimulation when viewing through optical instruments. However, there seems to be little doubt that accommodation does occur when viewing targets through many optical instruments. This study compares several findings to help quantify differences of accommodative stimulation while viewing targets through the different testing methods.

One of the advantages of the IVEX system is that it allows the practitioner to perform a monocular or binocular refraction. Some of the advantages of binocular refraction include more exact measurement of spherical element, spherical balance, cylindrical element, refractive correction at near, and efficient means of assessing binocularity. (6, 7) Several techniques of binocular refraction have been employed but each technique has disadvantages that have limited their popularity. In the IVEX, two targets are seen as in the septum technique but without the disadvantages of large cumbersome septums and subjects viewing the opposite eye's target. (6) The IVEX also eliminates the reduced contrast problem that occurs with polarizing techniques.

The null-hypothesis was used as the investigators expected to find no significant difference between specific findings obtained using the traditional refractive techniques and those obtained using the IVEX system with monocular targets. It was also hypothesized that there would be on significant difference between specific findings obtained using the traditional refractive technique and those findings obtained using a binocular IVEX examination sequence. The criterion level assigned for significance was .05 using the matched t-test combined with Tukey's[1] method of confidence level adjustment for multiple t-tests. (8) A Pearson

correlation coefficient[2] was also calculated for each comparison.

Of primary concern to the investigators was the final lens prescription for both distance and near. The subjective to best visual acuity (SBVA)[3] was also of concern because it is commonly relied upon by practitioners when prescribing. Although a t-value was computed for each comparison, the investigators were most interested in the six comparisons made for the three aforementioned findings. Therefore, significance will only be stated for these six comparisons.

Table 1. Test titles and target descriptions (listed in the sequence they were taken).

| OEP TEST | TEST DESCRIPTION | TARGET FOR TRADITIONAL EXAM | TARGET FOR MONOCULAR IVEX | TARGET FOR BINOCULAR IVEX |
|---|---|---|---|---|
| #4 | distance retinoscopy | red/green w/ low acuity demand | bichrome target 16* | bichrome target 16* |
| #5 | dynamic retinoscopy at 50cm | low acuity target (20/80) on retinoscope | low acuity target (20/80) on retinoscope | low acuity target (20/80) on retinoscope |
| | control lens for cylinder testing | bichrome target | bichrome target 16* | acuity letters viewed monocularly with binocular fusion borders 22* |
| | distance cylinder test (JCC) | isolated 20/40 line w/CC | isolated 20/40 line w/CC 11* | isolated 20/40 line w/CC 22,23* |
| #7 | maximum plus to first 20/20 | acuity target | acuity target 11* | binocular acuity target 24* |
| #7a | subjective to best visual acuity (SBVA) | acuity target | acuity target 11* | binocular acuity target 24* |
| #8 | distance lateral phoria through SBVA | isolated 20/30 letter | distance lateral phoria target 17* | distance lateral phoria target 17* |
| #9 | base-out to first blur @ far | isolated 20/30 letter | isolated 20/30 letter 11* | isolated 20/30 letter 11* |
| #10 | base-out to break/recov.@ far | isolated 20/30 letter | isolated 20/30 letter 11* | isolated 20/30 letter 11* |
| #11 | base-in to break/recov. @ far | isolated 20/30 letter | isolated 20/30 letter 11* | isolated 20/30 letter 11* |
| #12 | vertical phoria @ far | isolated 20/30 letter | dist. vert. phoria target 18* | dist. vert. phoria target 18* |
| #13b | near lateral phoria through SBVA | near Snellen chart | near Snellen Chart 36* | near Snellen chart 36* |
| #21 | negative relative accommodation (recovery used) | near Snellen chart | near Snellen Chart 36* | near Snellen chart 36* |
| #14a | unfused crossed cylinder(near) | vertical-horizontal cross grid w/ prism dissociation | vertical-horizontal cross grid w/ prism dissociation 39* | vertical-horizontal cross grid w/ prism dissociation 39* |
| #15a | near lateral phoria through unfused crossed cylinder lens | vertical-horizontal cross grid | vertical-horizontal cross grid 39* | vertical-horizontal cross grid 39* |
| #14b | fused crossed cylinder (near) | vertical-horizontal cross grid | vert.-horizontal cross grid 39* | vert.-horizontal cross grid 39* |
| #15b | near lateral phoria through | near Snellen chart | near Snellen chart 36* | near Snellen chart 36* |
| #16a | positive relative convergence | near Snellen chart | near Snellen chart 36* | near Snellen chart 36* |
| #16b | positive fusional reserve | near Snellen chart | near Snellen chart 36* | near Snellen chart 36* |
| #17a | negative relative convergence | near Snellen chart | near Snellen chart 36* | near Snellen chart 36* |
| #17b | negative fusional reserve | near Snellen chart | near Snellen chart 36* | near Snellen chart 36* |
| #18 | vertical phoria @ near | near Snellen chart | near vert. phoria target 41* | near vert. phoria target 41* |
| #20 | positive relative accommodation (recovery used) | near Snellen chart | near Snellen chart 36* | near Snellen chart 36* |
| #19 | amplitude of accommodation (minus to blur at 33cm) | J3 of Jaeger text card @ 33cm | J3 of Jaeger target @ 33cm 34* | J3 of Jaeger target @ 33cm 34* |

*Denotes IVEX catalog target number.

[1]Tukey's method accounts for the fact that performing multiple statistical tests increases the probability that any single test will reach the level of significance by chance alone. This probability is additive so that if six tests are performed with a criterion level of .05 then there is a 30 percent chance that a single test will be significant by chance alone. The investigators, therefore, divided the criterion level (.05) by 6 (the number of comparisons of primary concern). The result (.0083) gives a confidence level that can be used to state that any test meeting the criterion level will be due to a difference in the distributions at least 95 percent of the time.

[2]See Appendix A for method of calculating Pearson correlation coefficient.

[3]For subjective to best visual acuity (SBVA) the examiners used the most plus lens that yielded best visual acuity.

A within-groups study of fifty subjects compared individual findings for each subject in three different examination procedures. These examination procedures were: (1) a traditional monocular refraction, (2) a monocular IVEX refraction, and (3) a binocular IVEX refraction. The tests used were those included in the standard Optometric Extension Program (OEP) twenty-one point examination. Excluded were the phorias normally taken through the near relative accommodation lens findings and the vertical ductions. For each method a distance and near prescription were determined using the OEP analytical procedure. (9)

## SUBJECTS

Subjects were selected from the Pacific University College of Optometry (PUCO) clinic population on a volunteer basis under the following criteria:

1. No contact lens wear within the preceding six months.
2. No apparent ocular pathology.
3. Visual acuity correctable to 20/20 at six meters and forty centimeters.
4. Must be between fifteen to forty years of age.
5. Normal binocular function as determined by the cover test.

No other restrictions applied other than general ability to be examined with the instrumentation involved. The range of refractive errors of the subjects used in the study was from -11.00 D of myopia with 3.00 D cylinder to about +4.00 D of hyperopia.

## METHODS

All subjects were examined with each of the three examination procedures. Equal numbers of subjects were assigned to each of the following testing order groups to help control for learning effects:

1. Traditional - monocular IVEX - binocular IVEX
2. Traditional - binocular IVEX - monocular IVEX
3. Monocular IVEX - traditional - binocular IVEX

4. Monocular IVEX - binocular IVEX - traditional
5. Binocular IVEX - traditional - monocular IVEX
6. Binocular IVEX - monocular IVEX - traditional

Each subject was examined with each of the three methods by one examiner to prevent inter-examiner difference effects. Each examiner examined twenty-five subjects. One subject was discarded from the study due to inability to complete all tests, therefore a total of forty-nine subjects (one hundred forty-seven examinations) were used for comparison purposes. The traditional exam was done in the PUCO clinic rooms with an AO Ultramatic phoropter. Patient to chart distance in these rooms was five meters. Vertex distance was controlled so that each examination on a particular patient was performed at the same vertex distance $\pm$1 mm (as measured by the apparatus on the phoropter and IVEX).

Table 1 shows the examination sequence and referenced test titles, as well as the targets used for the individual tests. Each finding done by the traditional method was compared directly to the findings on the same test by the other methods, i.e. SBVA done by the traditional method was compared directly to SBVA done by the monocular IVEX method and then to SBVA done by the binocular IVEX method. Lens value comparisons were made on the basis of spherical equivalent. Then an OEP (9) analysis was completed on each set of findings to determine a final lens prescription for far and near, and comparisons of these prescriptions were made.

Since the PUCO clinic rooms are only five meters long and the IVEX system is set for optical infinity, an adjustment of .20 D was made on all distant lens values. This was accomplished by subtracting .20 D (1/5 meter) from the spherical component of each distant test done by the traditional testing method.

Comparisons were done on a within-groups basis by calculating the difference between the respective findings for each subject. For each finding a mean difference, standard deviation, matched t-value, and Pearson correlation coefficient was calculated.

Obviously, many of the tests in the monocular IVEX method are exactly the same as the binocular IVEX method (i.e. phorias and ductions). However, they were often done through different sphere and/or cylinder powers and axes and therefore often gave different results. These findings were taken because they were needed for the final prescription analyses and comparisons..

## RESULTS AND DISCUSSION

Of the six comparisons evaluated (see Table 2) four were found to be significantly different at the .0083[1] confidence level. The first comparison is the subjective to best visual acuity (SBVA) done by the traditional method and adjusted for room length (adjusted traditional) vs. the monocular IVEX.

Table 2. Experimental results.

| FINDING | COMPARISON | MEAN DIFFERENCE | STANDARD DEVIATION | DF | t | SIG | r |
|---|---|---|---|---|---|---|---|
| SBVA | Adj T-MIVEX | .172 D | .371 D | 48 | 3.25 | YES | .995 |
| SBVA | Adj T-BIVEX | .282 D | .389 D | 48 | 5.064 | YES | .994 |
| DIST RX | Adj T-MIVEX | .128 D | .332 D | 48 | 2.703 | NO | .995 |
| DIST RX | Adj T-BIVEX | .243 D | .387 D | 48 | 4.395 | YES | .996 |
| NEAR RX | T - MIVEX | .156 D | .485 D | 48 | 2.255 | NO | .990 |
| NEAR RX | T - BIVEX | .209 D | .477 D | 48 | 3.067 | YES | .991 |

Key: Adj = adjusted for room length, T = traditional, MIVEX = monocular IVEX, BIVEX = binocular IVEX, DF = degrees of freedom, SIG = significantly different, r = correlation coefficient

[1] .0083 was determined by dividing .6 into .05 as called for by Tukey's method (see footnote page 3).

Although this comparison was significantly different the mean difference was only .172 D. Figure 1 shows how the findings are spread around zero difference between the findings. This figure shows 10 of the 49 subjects (20%) having no difference, 38 (78%) within ±.25 D, 42 (86%) within ±.37D, and 45 (92%) within ±.50 D. Of further interest is that 28 (57%) were more minus and 11 (22%) were more plus with the monocular IVEX method than with the traditional method. The correlation coefficient for this comparison was .995.

For the same test, SBVA, comparing the adjusted traditional to the binocular IVEX also resulted in a significant difference with a mean difference just over .25 D. Figure 2 shows how these findings lean slightly more heavily toward the minus side than did the SBVA done on the monocular IVEX. The figure shows 11 of 49 (22%) having no difference, 32 (65%) within ±.25 D, 36 (73%) within ±.37 D, and 41 (84%) within ±.50 D. These also compared favorably with a correlation coefficient of .994. The binocular IVEX method measured 31 (63%) with more minus and only 7 (14%) with more plus than the traditional test method. The authors feel that at least part of this increased minus with the binocular testing is due to the target that was used. This target is a divided acuity target where the right eye sees the right side and the left eye sees the left side. It is felt that the target is at least partially to blame because upon occasional checking of the endpoint (by repeating the test with a standard acuity target where both eyes viewed all letters) more plus was found without a drop in visual acuity.

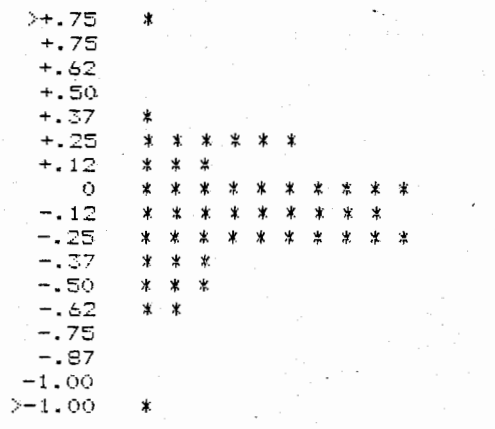


Figure 1. SBVA. Histogram of differences between adjusted traditional and monocular IVEX values for the subjective to best visual acuity (SBVA) finding. Values indicate monocular IVEX values relative to adjusted traditional values.

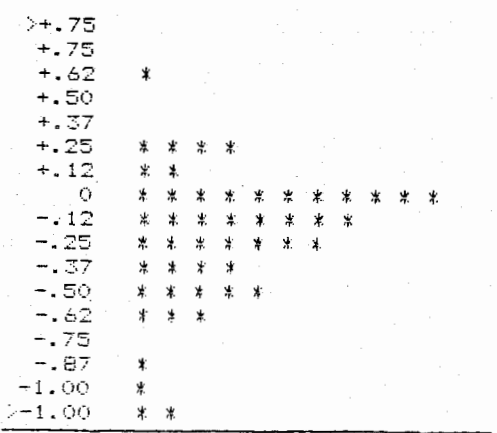


Figure 2. SBVA. Histogram of differences between adjusted traditional and binocular IVEX values for the subjective to best visual acuity (SBVA) finding. Values indicate binocular IVEX values relative to adjusted traditional values.

The next two comparisons compared the adjusted traditional distance prescriptions to the distance prescriptions obtained using findings from the monocular IVEX method and the binocular IVEX method. In each case these values were obtained using an OEP analytical procedure. Figures 3 and 4 show the results of the differences for each subject. Note that both curves are skewed more toward zero than the SBVA comparisons. This is because the OEP analysis system will not allow prescribing a cut (reduction of plus sphere value) below plano to patients with a maximum plus to first 20/20 which is in low plus. A number of subjects were in this category with the traditional finding being more plus. However, when this finding was cut it could not be cut below plano and these subjects ended up with plano distance prescriptions for all methods even though a smaller cut of the maximum plus to 20/20 finding was required to get to plano with the IVEX than with the traditional.

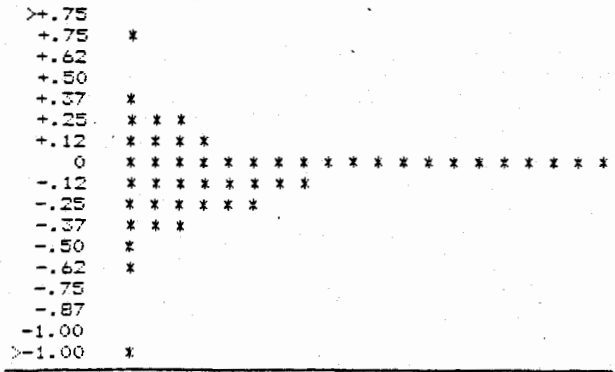


Figure 3. Distance Prescription. Histogram of differences between adjusted traditional and monocular IVEX values for the distance prescription. Values indicate monocular IVEX values relative to adjusted traditional values.

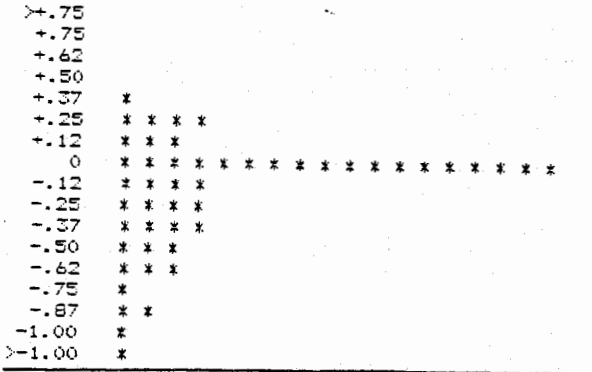


Figure 4. Distance Prescription. Histogram of differences between adjusted traditional and binocular IVEX values for the distance prescription. Values indicate binocular IVEX values relative to adjusted traditional values.

The mean difference for the adjusted traditional vs. the monocular IVEX distance prescriptions was only .128 D with a standard deviation of .332 D. This difference was not significant at the criterion set using Tukey's adjustment for additivity but it was extremely close. From a clinical standpoint this difference is quite small and may not be of great significance. Figure 3 shows that 20 of the 49 subjects (41%) had no difference, 41 (84%) were within ±.25 D, and 46 (94%) were within ±.50 D. Twenty subjects had findings which were more minus in the IVEX whereas nine had IVEX results being more plus. The correlation coefficient for this comparison was .995.

The mean difference for the adjusted traditional vs. binocular IVEX distance prescriptions was .243 D with a standard deviation of .378 D. This difference is statistically significant. The investigators feel that at least some of this difference is due to the target as described earlier (page 7), and not necessarily to the instrument. Figure 4 reveals that 15 of 49 (31%) had no difference, 27 (55%) were within ±.25 D, 37 (75%) were within ±.50 D, and 42 (86%) were within ±.75 D. There was definitely a tendency toward more minus with the IVEX. Of the 49 subjects 23 (47%) showed more minus on the IVEX while only 8

(16%) showed more plus. Still, the correlation coefficient was .996. However, the authors would recommend that the IVEX target utilized in the study not be used in determining distance endpoints.

The final two comparisons evaluated for statistical significance concerned near prescriptions determined by OEP analysis. The traditional near prescription was compared first to that obtained using the monocular IVEX method and then to that obtained using the binocular IVEX method. The traditional vs. monocular IVEX mean difference was .156 D with the IVEX result being less plus. The standard deviation was .485 D. This was not statistically significant using the rigid standards set with Tukey's adjustment. Of the 49 subjects, 10 (20%) showed no difference between the two methods, 29 (59%) were within ±.25 D, 40 (82%) were within ±.50 D, and 44 (90%) were within ±.75 D (see Figure 5). Again the tendency was toward less plus with the IVEX. Ten (25%) were more plus on the IVEX and 29 (59%) were more minus on the IVEX. Although the mean difference was small and the correlation coefficient was at .990 the range is large enough for practitioners to take notice. It would be appropriate for a follow-up study to be conducted in which repeated measures of each method were done. In this way not only might means of the different methods provide more accurate comparison but an assessment of subject variability from examination to examination could be obtained.

The mean difference for the traditional vs. binocular IVEX near prescription was .209 D with the IVEX finding again more minus. The standard deviation was .477 D. This difference is statistically significant. Figure 6 shows that of the 49 subjects, 15 (31%) had no difference between the two methods, 27 (55%) were within ±.25 D, 37 (75%)

were within ±.50 D, and 42 (86%) were within ±.75 D. Eight subjects (16%) were more plus on the IVEX while 23 (47%) were more minus. As with the monocular IVEX, the binocular IVEX tended toward less plus than the traditional for the near prescriptions, with a wide range of findings. Again the correlation coefficient was high at .991. Further studies using repeated measures of the IVEX and traditional methods would again be useful in evaluating these results.

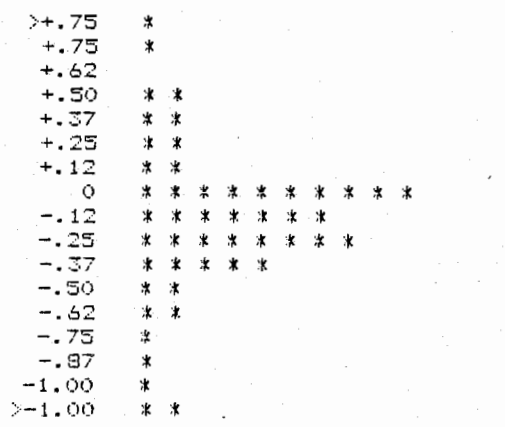


Figure 5. Near Prescription. Histogram of differences between traditional and monocular IVEX values for the near prescription. Values indicate monocular IVEX values relative to traditional values.

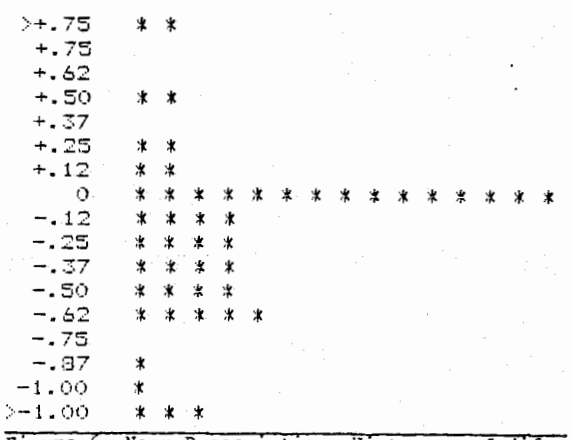


Figure 6. Near Prescription. Histogram of differences between traditional and binocular IVEX near prescriptions. Values indicate binocular IVEX values relative to traditional values.

## ADDITIONAL FINDINGS

Obviously many findings were taken in order to allow a structured case analysis such as OEP. The results of comparing these findings are listed in Tables 3a and 3b.

### Distance Retinoscopy

As in traditional methods of refraction, the IVEX allows retinoscopy to be done through the instrument. Although the investigators subjectively thought retinoscopy was more difficult using the IVEX, the comparisons showed small differences with a slight skew toward more plus with the IVEX. The mean differences were only .051 D and .058 D

with standard deviations of .585 D and .654 D for traditional vs. monocular IVEX and traditional vs. binocular IVEX respectively.

Figures 7 and 8 show the spread of the retinoscopy findings. Comparing the traditional to the monocular IVEX we can see that 23 of the 49 (47%) were within ±.25 D, 31 (63%) were within ±.37 D, and 36 (73%) were within ±.50 D. The correlation coefficient was .986. The traditional vs. binocular IVEX spread is very close to the same as above showing 5 of 49 (10%) with no difference, 20 (41%) within ±.25 D, 29 (59%) within ±.37 D, 34 (69%) within ±.50 D, and a correlation coefficient of .983.

Table 3a. Results of comparisons of sphere and cylinder findings.

| TEST | COMPARISON | MEAN DIFFERENCE | STANDARD DEVIATION | DF | t | r |
|---|---|---|---|---|---|---|
| DISTANCE RETINOSCOPY | T vs MIVEX | -.051 D. | .585 D. | 48 | -.613 | .986 |
| DISTANCE RETINOSCOPY | T vs BIVEX | -.058 D. | .654 D. | 48 | -.623 | .983 |
| DYNAMIC RETINOSCOPY (50cm) | T vs MIVEX | -.379 D. | .745 D. | 48 | -3.562 | .979 |
| DYNAMIC RETINOSCOPY (50cm) | T vs BIVEX | -.395 D. | .76 D. | 48 | -3.635 | .978 |
| SPHERICAL CONTROL LENS | T vs MIVEX | .368 D. | .41 D. | 96 | 8.823 | .992 |
| SPHERICAL CONTROL LENS | T vs BIVEX | .137 D. | .394 D. | 96 | 3.421 | .993 |
| SPHERICAL CONTROL LENS | Adj T vs MIVEX | .168 D. | .41 D. | 96 | 4.022 | .992 |
| SPHERICAL CONTROL LENS | Adj T vs BIVEX | -.063 D. | .394 D. | 96 | -1.581 | .993 |
| CYLINDER POWER | T vs MIVEX | -.005 D. | .285 D. | 97 | -.177 | .937 |
| CYLINDER POWER | T vs BIVEX | -.013 D. | .244 D. | 97 | -.517 | .955 |
| CYLINDER AXIS | T vs MIVEX | -2.37° | 8.933° | 72 | -2.267 | .991 |
| CYLINDER AXIS | T vs BIVEX | -.824° | 16.821° | 73 | -.422 | .969 |
| MAXIMUM PLUS TO FIRST 20/20 | T vs MIVEX | .388 D. | .332 D. | 48 | 8.177 | .996 |
| MAXIMUM PLUS TO FIRST 20/20 | T vs BIVEX | .554 D. | .369 D. | 48 | 10.52 | .995 |
| MAXIMUM PLUS TO FIRST 20/20 | Adj T vs MIVEX | .188 D. | .332 D. | 48 | 3.962 | .996 |
| MAXIMUM PLUS TO FIRST 20/20 | Adj T vs BIVEX | .354 D. | .369 D. | 48 | 6.723 | .995 |
| SUBJECTIVE TO BEST VISUAL ACUITY | T vs MIVEX | .372 D. | .371 D. | 48 | 7.025 | .995 |
| SUBJECTIVE TO BEST VISUAL ACUITY | T vs BIVEX | .482 D. | .389 D. | 48 | 8.659 | .994 |
| SUBJECTIVE TO BEST VISUAL ACUITY | Adj T vs MIVEX | .172 D. | .371 D. | 48 | 3.25 | .995 |
| SUBJECTIVE TO BEST VISUAL ACUITY | Adj T vs BIVEX | .282 D. | .389 D. | 48 | 5.064 | .994 |
| UNFUSED CROSSED CYLINDERS (CC) | T vs MIVEX | .018 D. | .576 D. | 97 | .314 | .986 |
| UNFUSED CROSSED CYLINDERS (CC) | T vs BIVEX | -.016 D. | .658 D. | 97 | -.236 | .982 |
| FUSED CROSSED CYLINDERS (CC) | T vs MIVEX | -.001 D. | .528 D. | 48 | -.014 | .989 |
| FUSED CROSSED CYLINDERS (CC) | T vs BIVEX | .083 D. | .636 D. | 48 | .919 | .987 |
| AMPLITUDE OF ACCOMMODATION | T vs MIVEX | -.628 D. | .914 D. | 48 | -4.804 | .978 |
| AMPLITUDE OF ACCOMMODATION | T vs BIVEX | -.725 D. | 1.12 D. | 48 | -4.53 | .966 |
| POSITIVE RELATIVE ACCOMMODATION | T vs MIVEX | -.214 D. | 1.113 D. | 48 | -1.348 | .962 |
| POSITIVE RELATIVE ACCOMMODATION | T vs BIVEX | -.215 D. | 1.071 D. | 48 | -1.403 | .966 |
| NEGATIVE RELATIVE ACCOMMODATION | T vs MIVEX | .138 D. | .429 D. | 48 | 2.257 | .993 |
| NEGATIVE RELATIVE ACCOMMODATION | T vs BIVEX | .164 D. | .431 D. | 48 | 2.668 | .994 |
| DISTANCE PRESCRIPTION | T vs MIVEX | .306 D. | .347 D. | 48 | 6.188 | .996 |
| DISTANCE PRESCRIPTION | T vs BIVEX | .421 D. | .406 D. | 48 | 7.264 | .994 |
| DISTANCE PRESCRIPTION | Adj T vs MIVEX | .128 D. | .332 D. | 48 | 2.703 | .995 |
| DISTANCE PRESCRIPTION | Adj T vs BIVEX | .243 D. | .387 D. | 48 | 4.395 | .996 |
| NEAR PRESCRIPTION | T vs MIVEX | .156 D. | .485 D. | 48 | 2.255 | .990 |
| NEAR PRESCRIPTION | T vs BIVEX | .209 D. | .477 D. | 48 | 3.067 | .991 |

Key: T = traditional, MIVEX = monocular IVEX, BIVEX = binocular IVEX, Adj T = traditional adjusted for room length, DF = degrees of freedom, r = correlation coefficient.

Table 3b. Results of comparisons of phoria and duction findings.

| TEST | COMPARISON | MEAN DIFFERENCE | STANDARD DEVIATION | DF | t | r |
|---|---|---|---|---|---|---|
| DISTANCE LATERAL PHORIA | T vs MIVEX | .125 | 1.965 | 47 | .441 | .710 |
| DISTANCE LATERAL PHORIA | T vs BIVEX | .542 | 2.306 | 47 | 1.627 | .506 |
| BASE-OUT TO FIRST BLUR AT DISTANCE | T vs MIVEX | 5.25 | 6.272 | 47 | 5.799 | .538 |
| BASE-OUT TO FIRST BLUR AT DISTANCE | T vs BIVEX | 4.878 | 6.729 | 48 | 5.074 | .469 |
| BASE-OUT TO BREAK AT DISTANCE | T vs MIVEX | 9.9 | 7.235 | 39 | 8.654 | .638 |
| BASE-OUT TO BREAK AT DISTANCE | T vs BIVEX | 7.59 | 8.506 | 38 | 5.572 | .515 |
| BASE-OUT TO RECOVERY AT DISTANCE | T vs MIVEX | .95 | 7.971 | 39 | .754 | .449 |
| BASE-OUT TO RECOVERY AT DISTANCE | T vs BIVEX | 1.707 | 9.605 | 40 | 1.138 | .248 |
| BASE-IN TO BREAK AT DISTANCE | T vs MIVEX | 2.714 | 2.614 | 48 | 7.268 | .733 |
| BASE-IN TO BREAK AT DISTANCE | T vs BIVEX | 2.673 | 2.286 | 48 | 8.188 | .765 |
| BASE-IN TO RECOVERY AT DISTANCE | T vs MIVEX | 1.939 | 2.41 | 48 | 5.631 | .734 |
| BASE-IN TO RECOVERY AT DISTANCE | T vs BIVEX | 2.224 | 2.303 | 48 | 6.762 | .772 |
| DISTANCE VERTICAL PHORIA | T vs MIVEX | .038 | .422 | 45 | .612 | .315 |
| DISTANCE VERTICAL PHORIA | T vs BIVEX | .016 | .439 | 45 | .252 | .312 |
| NEAR LATERAL PHORIA | T vs MIVEX | -.823 | 3.277 | 47 | -1.74 | .841 |
| NEAR LATERAL PHORIA | T vs BIVEX | -.161 | 3.516 | 47 | -.318 | .849 |
| LATERAL PHORIA THROUGH UNFUSED CC | T vs MIVEX | -1.193 | 3.52 | 43 | -2.248 | .764 |
| LATERAL PHORIA THROUGH UNFUSED CC | T vs BIVEX | -1.443 | 3.279 | 43 | -2.919 | .793 |
| LATERAL PHORIA THROUGH FUSED CC | T vs MIVEX | -1.048 | 3.339 | 46 | -2.152 | .723 |
| LATERAL PHORIA THROUGH FUSED CC | T vs BIVEX | -.964 | 3.224 | 47 | -2.071 | .773 |
| POSITIVE RELATIVE CONVERGENCE (BLUR) | T vs MIVEX | -.762 | 5.876 | 41 | -.84 | .632 |
| POSITIVE RELATIVE CONVERGENCE (BLUR) | T vs BIVEX | -1.202 | 6.545 | 41 | -1.191 | .570 |
| POSITIVE FUSIONAL RESERVE (BREAK) | T vs MIVEX | -1.424 | 6.384 | 32 | -1.282 | .354 |
| POSITIVE FUSIONAL RESERVE (BREAK) | T vs BIVEX | -1.547 | 6.755 | 31 | -1.295 | .360 |
| POSITIVE FUSIONAL RESERVE (RECOVERY) | T vs MIVEX | -3.727 | 5.039 | 32 | -4.249 | .773 |
| POSITIVE FUSIONAL RESERVE (RECOVERY) | T vs BIVEX | -4.313 | 6.949 | 31 | -3.511 | .577 |
| NEGATIVE RELATIVE CONVERGENCE (BLUR) | T vs MIVEX | 2.646 | 5.748 | 47 | 3.189 | .584 |
| NEGATIVE RELATIVE CONVERGENCE (BLUR) | T vs BIVEX | 3.204 | 5.295 | 48 | 4.236 | .720 |
| NEGATIVE FUSIONAL RESERVE (BREAK) | T vs MIVEX | 2.913 | 4.516 | 45 | 4.375 | .749 |
| NEGATIVE FUSIONAL RESERVE (BREAK) | T vs BIVEX | 3.553 | 4.318 | 46 | 5.642 | .783 |
| NEGATIVE FUSIONAL RESERVE (RECOVERY) | T vs MIVEX | -1.761 | 4.653 | 45 | -2.567 | .737 |
| NEGATIVE FUSIONAL RESERVE (RECOVERY) | T vs BIVEX | -.766 | 5.394 | 46 | -.973 | .716 |
| NEAR VERTICAL PHORIA | T vs MIVEX | .09 | .462 | 46 | 1.343 | .488 |
| NEAR VERTICAL PHORIA | T vs BIVEX | .053 | .486 | 46 | .75 | .399 |

Key: T = traditional, MIVEX = monocular IVEX, BIVEX = binocular IVEX, DF = degrees of freedom, r = correlation coefficient. Mean differences and standard deviations are in prism diopters.

The information in Table 4 and Figures 7, 8, and 9 show that retinoscopy through the different methods show little differences and that through the traditional method the investigators' retinoscopy was only slightly different (mean difference of -.1 D) from the SBVA finding. Figures 10 and 11 show that the retinoscopy findings in the IVEX instrument are relatively more plus than the SBVA. The mean difference (retinoscopy minus SBVA) for monocular and binocular methods respectively is .323 D and .44 D, with standard deviations not varying by much (see Table 4). Because no plans were made to statistically evaluate the validity of retinoscopy through the IVEX that question

still remains, but indications are that retinoscopy is reliable and valid, and that the difference in SBVA being more minus than retinoscopy is due to patient responses (subjectively requiring more minus to SBVA with the IVEX). This again is an area where further study should be undertaken.

Table 4. Comparisons of retinoscopy and subjective findings.

| FINDING | MEAN DIFFERENCE | STANDARD DEVIATION | t |
|---|---|---|---|
| T-RET VS T-SBVA | -.1 D | .407 D | -1.72 |
| MIVEX-RET VS MIVEX-SBVA | .323 D | .459 D | 4.937 |
| BIVEX-RET VS BIVEX-SBVA | .44 D | .505 D | 6.1 |
| T-RET VS MIVEX-RET | -.051 D | .585 D | -.613 |
| T-RET VS BIVEX-RET | -.058 D | .654 D | -.623 |

Key: T = traditional, RET = retinoscopy, SBVA = subjective to best visual acuity, MIVEX = monocular IVEX, BIVEX = binocular IVEX

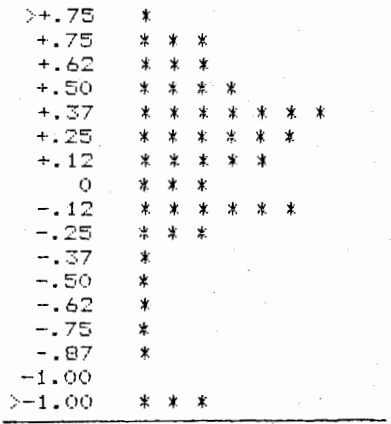


Figure 7. Distance Retinoscopy. Histogram of differences between traditional and monocular IVEX retinoscopy findings. Values indicate monocular IVEX values relative to traditional values.

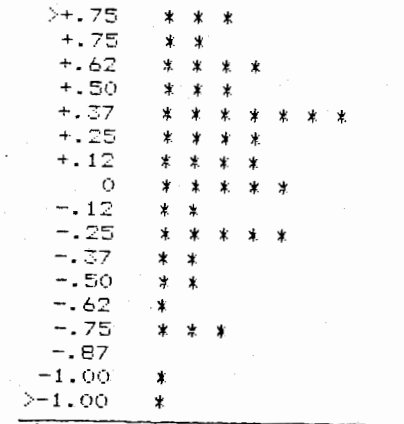


Figure 8. Distance Retinoscopy. Histogram of differences between traditional and binocular IVEX retinoscopy findings. Values indicate binocular IVEX values relative to traditional values.

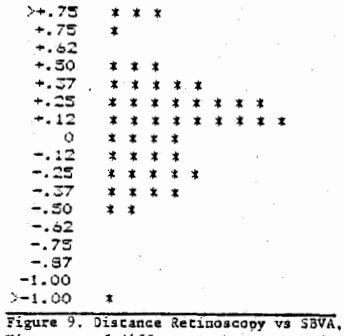


Figure 9. Distance Retinoscopy vs SBVA. Histogram of differences between traditional retinoscopy and traditional subjective to best visual acuity (SBVA) findings. Values indicate SBVA values relative to retinoscopy values.

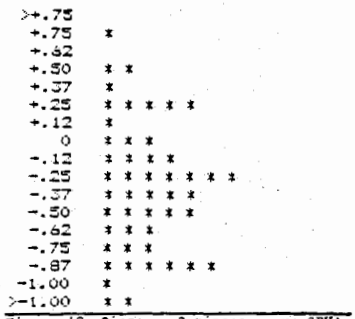


Figure 10. Distance Retinoscopy vs SBVA. Histogram of differences between monocular IVEX retinoscopy and monocular IVEX subjective to best visual acuity (SBVA) findings. Values indicate SBVA values relative to retinoscopy values.

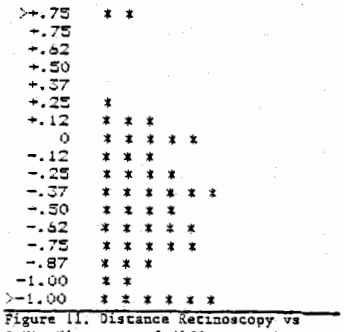


Figure 11. Distance Retinoscopy vs SBVA. Histogram of differences between binocular IVEX retinoscopy and binocular IVEX subjective to best visual acuity (SBVA) findings. Values indicate SBVA values relative to retinoscopy values.

## Spherical Control Lens

Also of interest is the spherical control lenses through which cylinder power and axis testing was done. The traditional and monocular IVEX methods both used the bichrome targets to arrive at this value. These showed a mean difference of .168 D (IVEX more minus) with a .41 D standard deviation (using the adjusted traditional finding), and a correlation coefficient of .992. In comparing the adjusted traditional and binocular IVEX the mean difference was -.063 D (IVEX more plus), standard deviation of .394 D, and correlation coefficient of .993. In this latter comparison the targets differed. The binocular IVEX target was an acuity target with fusion borders and suppression control. Figures 12 and 13 show how the data are spread around zero difference. Comparing the traditional to the monocular IVEX 19 of the 97 eyes (20%) had no difference, 61 (63%) were within $\pm$.25 D, 72 (74%) were within $\pm$.37 D, and 81 (84%) were within $\pm$.50 D. Similarly, for the traditional and binocular IVEX, 10 of the 97 eyes (10%) had no difference, 56 (58%) were within $\pm$.25 D, 75 (77%) were within $\pm$.37 D, and 81 (84%) were within $\pm$.50 D.

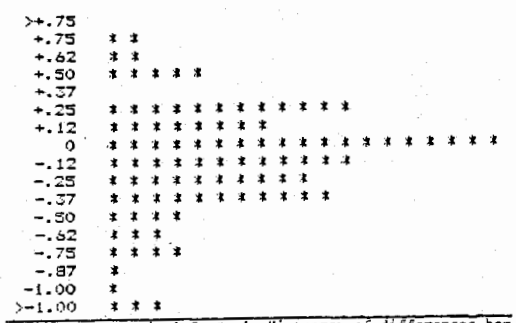


Figure 12. Spherical Control. Histogram of differences between adjusted traditional and monocular IVEX spherical control findings for cylinder testing. Values indicate monocular IVEX values relative to adjusted traditional values.

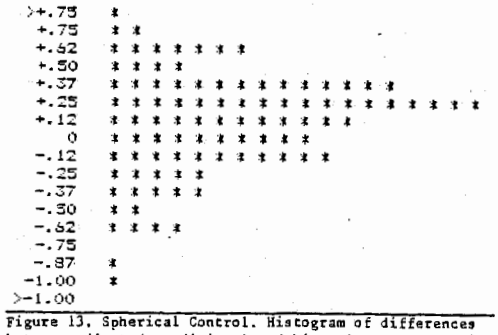


Figure 13. Spherical Control. Histogram of differences between adjusted traditional and binocular IVEX spherical control findings for cylinder testing. Values indicate binocular IVEX values relative to adjusted traditional values.

## Cylinder Power

The cylinder power tests also showed mean differences of nearly zero with standard deviations only about .25 D for the different test methods. This indicates IVEX cylinder tests are quite valid using the traditional test as a standard. This validity is also represented in Figures 14 and 15 by the small amount of spread around zero difference. Comparing the traditional to either the monocular IVEX or the binocular IVEX the results are very nearly the same. Both comparisons having about 50 percent of the population with no difference and about 90 percent within ±.25 D. The correlation coefficients were .937 and .955 for the traditional vs. monocular IVEX and traditional vs. binocular IVEX respectively.

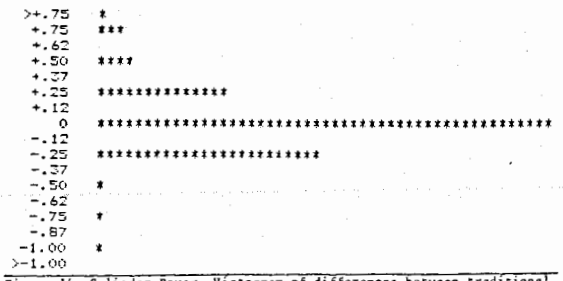


Figure 14. Cylinder Power. Histogram of differences between traditional and monocular IVEX cylinder powers. Values indicate monocular IVEX values relative to traditional values.

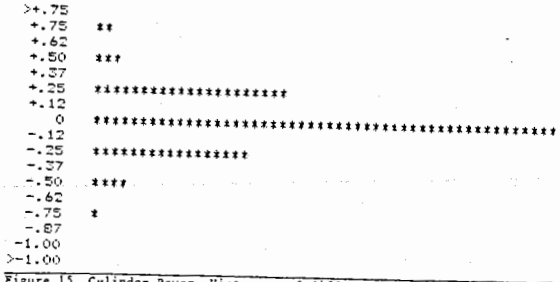


Figure 15. Cylinder Power. Histogram of differences between traditional and binocular IVEX cylinder powers. Values indicate binocular IVEX values relative to traditional values.

Distance Lateral Phoria

The distance lateral phoria tests also varied only slightly with mean differences of .125$^{\Delta}$ and .54$^{\Delta}$ for traditional vs. monocular IVEX and traditional vs. binocular IVEX respectively. The standard deviations were both approximately 2$^{\Delta}$. This compares favorably with Haynes (10) data. Haynes data is from a reliability study comparing first and second examinations on 60 subjects. He found a standard deviation of just less than 3$^{\Delta}$ for this finding (see Appendix B for a table of these values). This is especially interesting because of the difference in targets used. In the traditional method the investigators used a single 20/30 letter doubled with Risley prisms. The IVEX uses a target with the right eye viewing a horizontal series of small white balls with numbers over them, and the left eye views just a vertical arrow with three balls over the tip. The balls can be fused thus somewhat stabilizing the arrow. The phoric posture is determined by which number the arrow is seen pointing to. The correlation coefficients were not so near 1.00 in these comparisons. For the traditional vs. monocular and then binocular IVEX the values were .710 and .506 respectfully.

Vergences

The vergence findings had much larger variability as shown by the mean differences and standard deviations in Table 3b. However, these standard deviations are comparable to those found in Haynes' reliability study. These findings are used in OEP case analysis and therefore have a direct effect on the final prescription. The investigators were forced to use an isolated letter for the distance duction tests because the IVEX does not have a target where a vertical line of small acuity letters can be isolated. The isolated 20/30 letter used resulted in

many complaints by subjects, of being slightly blurred or barely doubled even before any prism was induced. Furthermore, the IVEX makes sudden $1^{\Delta}$ jumps ($.5^{\Delta}$ in front of each eye), therefore the target momentarily doubles and is rapidly re-fused. This happens with every prism diopter power change until a full break, without fusion, is realized. This is as opposed to the relatively smooth prism diopter changes that are made with rotary prisms. Some patients voiced complaints about the momentary doubling with the IVEX during these tests.

Near Lateral Phoria

The near phoria tests need special note because the investigators did not use the IVEX near phoria target. Because of some preliminary questionable results using this target, the reduced Snellen chart with prism dissociation was used in its place. This allowed the investigators to compare this finding without the confounding variable of target difference. The variance was small with the mean difference being $-.8^{\Delta}$ and $-.2^{\Delta}$, the standard deviations being $3.3^{\Delta}$ and $3.5^{\Delta}$, and correlation coefficients of .841 and .849 for the traditional vs. monocular IVEX and traditional vs. binocular IVEX respectively. The standard deviations found with the IVEX are just slightly smaller than those found by Haynes.

Near Crossed Cylinders

Near crossed cylinder (CC) findings are often heavily relied upon for near prescriptions. Whether done under fused or unfused conditions, the comparisons have similar results. In comparing the traditional to the monocular IVEX (fused condition) the mean difference was -.001 D, the standard deviation was .528 D, and the correlation coefficient was .989. The values for traditional vs. binocular IVEX were mean difference of .083 D, standard deviation of .636 D, and correlation coefficient of

.987. These standard deviations are just slightly higher than those obtained from Haynes' reliability study. The ranges of variation of the traditional and monocular IVEX comparison show 8 of 49 (16%) to have no difference, 25 (51%) within ±.25 D, and 38 (78%) within ±.50 D. Comparing the traditional to the binocular IVEX the ranges were only 1 of 49 (2%) at no difference, 23 (47%) within ±.25 D, 35 (71%) within ±.50 D, and 42 (86%) within ±.75 D. Figures 16 and 17 show the crossed cylinder histograms.

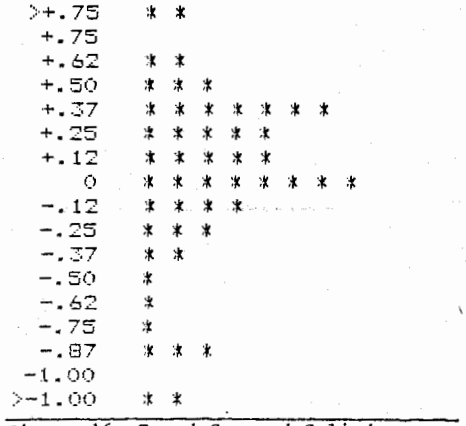


Figure 16. Fused Crossed Cylinders. Histogram of differences between traditional and monocular IVEX fused crossed cylinder findings. Values indicate monocular IVEX values relative to traditional values.

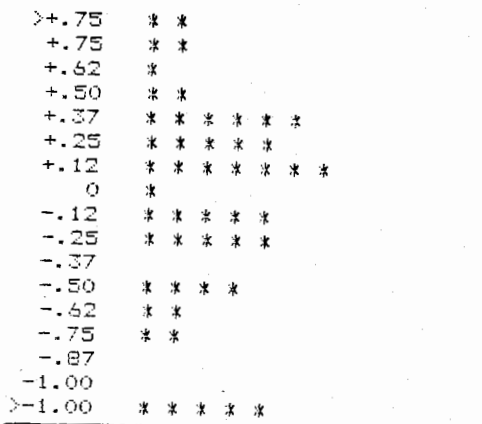


Figure 17. Fused Crossed Cylinders. Histogram of differences between traditional and binocular IVEX fused crossed cylinder findings. Values indicate binocular IVEX values relative to traditional values.

## Amplitude of Accommodation

Amplitude of accommodation showed a large difference between the traditional and IVEX examination methods. The mean difference between the traditional and monocular IVEX was .628 D and the standard deviation was .914 D (compared to .81 D found by Haynes). The correlation coefficient was .987. Most subjects obtained a smaller result in the IVEX examination. Figures 18 and 19 show that only 17 of the 49 subjects (35%) were within ±.50 D. Of all the subjects 34 (69%) had an endpoint in more plus on the IVEX with 17 (35%) having findings greater than

±.75 D more plus.

Comparison of the traditional and binocular IVEX gave similar results. The mean difference was .725 D, with a standard deviation greater than 1.00 D, but the correlation coefficient was .966. Only 9 (18%) were within ±.25 D and 16 (33%) were within ±.50 D. More plus was shown on the binocular IVEX than the traditional method with 35 of the 49 (71%) subjects, and 21 (43%) being greater than .75 D more plus.

These results indicate that the IVEX measures a smaller amplitude of accommodation than the traditional method. A large range of values was obtained for the differences. A follow-up study utilizing repeated measures of each examination would be helpful in analyzing possible subject variability.

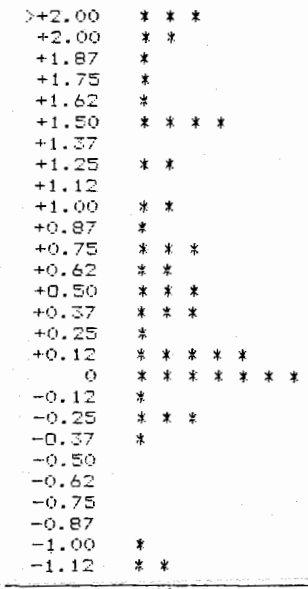


Figure 18. Amplitude of Accommodation. Histogram of differences between traditional and monocular IVEX amplitude of accommodation findings. Values indicate monocular IVEX values relative to traditional values.

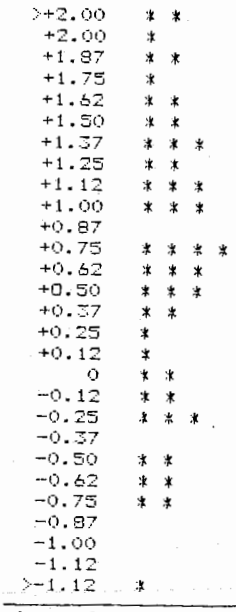


Figure 19. Amplitude of Accommodation. Histogram of differences between traditional and binocular IVEX amplitude of accommodation findings. Values indicate binocular IVEX values relative to traditional values.

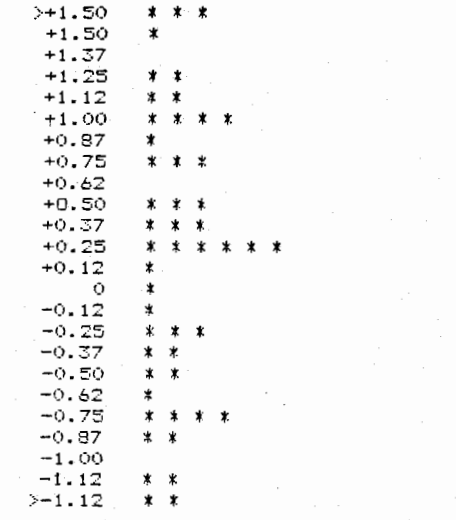


Figure 20. Positive Relative Accommodation. Histogram of differences between traditional and monocular IVEX positive relative accommodation findings. Values indicate monocular IVEX values relative to traditional values.

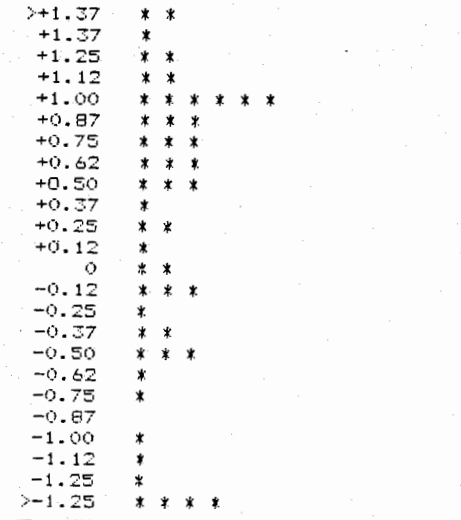


Figure 21. Positive Relative Accommodation. Histogram of differences between traditional and binocular IVEX positive relative accommodation findings. Values indicate binocular IVEX values relative to traditional values.

## Positive Relative Accommodation

The differences of both IVEX methods from the traditional for positive relative accommodation were spread over a wide range (see Figures 20 and 21). The mean difference between the traditional method and the monocular IVEX was .214 D with the IVEX method yielding a mean in more plus. The standard deviation was 1.113 D, and the correlation coefficient was .962. Only 1 of the 49 subjects (2%) had no difference between the two methods, 22 (45%) were within ±.50 D, and 30 (61%) were within ±.75 D. The IVEX yielded more plus on 29 (59%) of the subjects with 13 (26%) having greater than .75 D more plus on the IVEX.

The binocular IVEX yielded similar results. The mean difference between the traditional and binocular IVEX methods was .215 D with a standard deviation of 1.071 D, and a correlation coefficient of .966. More plus was found on 29 of the 49 subjects (59%) using the IVEX. Greater than .75 D difference was found on the IVEX with 16 (33%) of these subjects. Six (12%) of the subjects had greater than 1.00 D more

minus on the IVEX. Standard deviations for the positive relative accommodation comparisons were again slightly higher than those found by Haynes.

Negative Relative Accommodation

Figures 22 and 23 reveal that less plus was found with both IVEX methods than the traditional method for the mean difference of negative relative accommodation. The mean difference between the traditional method and the monocular IVEX was .138 D with a standard deviation of .429 D, and a correlation coefficient of .993. Of the 49 subjects 29 (59%) were within ±.25 D and 43 (88%) were within ±.50 D in the two methods. More plus on the IVEX was found with 12 (24%) subjects and more minus with 24 (49%) subjects.

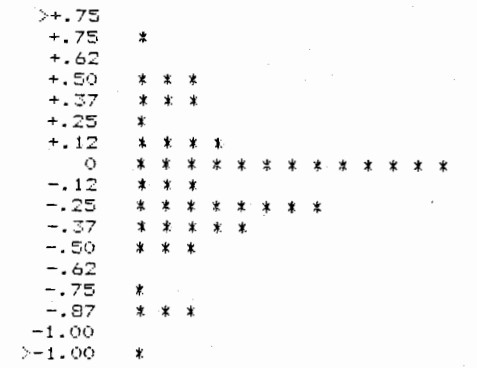


Figure 22. Negative Relative Accommodation. Histogram of differences between traditional and monocular IVEX negative relative accommodation findings. Values indicate monocular IVEX values relative to traditional values.

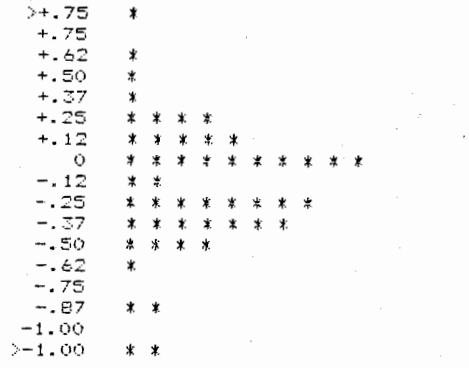


Figure 23. Negative Relative Accommodation. Histogram of differences between traditional and binocular IVEX negative relative accommodation findings. Values indicate binocular IVEX values relative to traditional values.

The mean difference between the traditional and binocular IVEX methods was .164 D with a standard deviation of .431 D and a correlation coefficient of .994. Of the 49 subjects 42 (86%) were within ±.50 D. Only 2 subjects had a difference of greater than .87 D between the two methods. More plus was found on the IVEX with 13 (26%) of the subjects, and more minus was found with 26 (53%) of the subjects. These results

indicate that less negative relative accommodation is measured with the IVEX although the mean difference is quite small. Approximately 25 percent of the subjects measured more minus with the IVEX methods. The small mean difference and amount of variability would suggest the difference between the two methods is not clinically significant. Standard deviations for the negative relative accommodation compare favorably to those found by Haynes.

It is also of interest to look at groups of findings such as phorias, vergences and near sphere findings such as those listed in Appendix B. If one takes the differences of the standard deviations and shows how many result in positive and how many result in negative values (i.e. distance lateral phoria; Haynes - traditional vs. monocular IVEX or $2.89^{\Delta} - 1.97^{\Delta} = +.92^{\Delta}$), it can be seen that the phorias have about equal numbers of positive and negative differences. Similar results are found in the vergences group. However, the near sphere findings result in nearly all negative differences. This may indicate that there is more accommodative activity when viewing near targets in the IVEX. Further study involving repeated tests on individuals and/or comparisons with presbyopic persons would be beneficial in fully evaluating near testing with the IVEX.

Histograms of some of the findings not specifically mentioned can be seen in Figures 24 through 29. Furthermore, the data from the other tests is included in Table 3 for completeness and convenience.

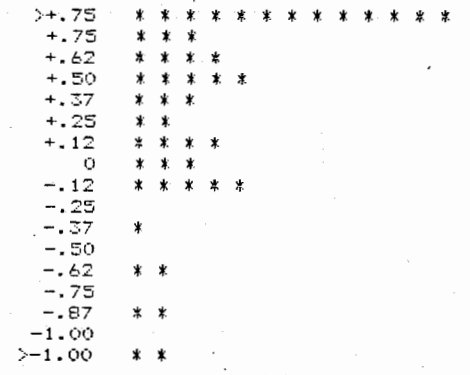


Figure 24. Dynamic Retinoscopy. Histogram of differences between traditional and monocular IVEX dynamic retinoscopy (50cm) findings. Values indicate monocular IVEX values relative to traditional values.

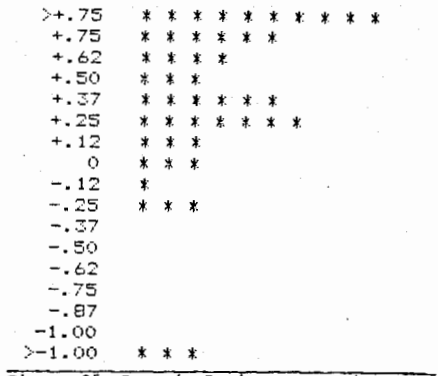


Figure 25. Dynamic Retinoscopy. Histogram of differences between traditional and binocular IVEX dynamic retinoscopy (50cm) findings. Values indicate binocular IVEX values relative to traditional values.

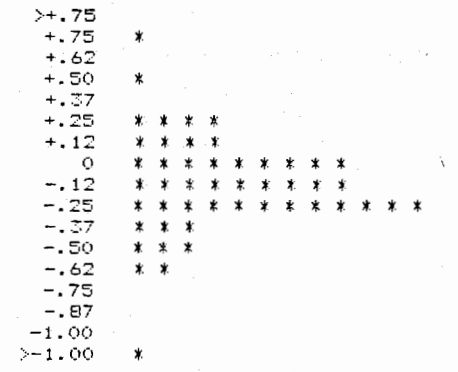


Figure 26. Maximum Plus to 20/20. Histogram of differences between adjusted traditional and monocular IVEX maximum plus to 20/20 findings. Values indicate monocular IVEX values relative to adjusted traditional values.

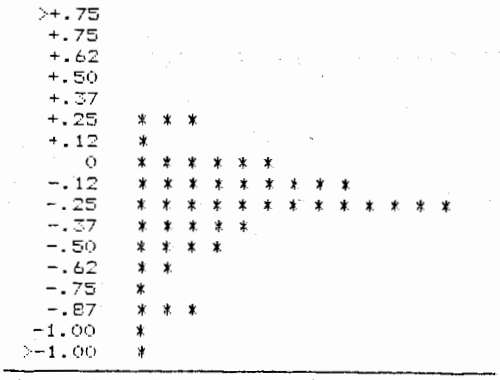


Figure 27. Maximum Plus to 20/20. Histogram of differences between adjusted traditional and binocular IVEX maximum plus to 20/20 findings. Values indicate binocular IVEX values relative to adjusted traditional values.

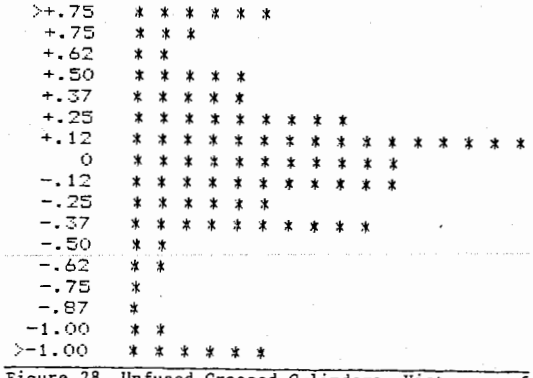


Figure 28. Unfused Crossed Cylinders. Histogram of differences between traditional and monocular IVEX unfused crossed cylinder findings. Values indicate monocular IVEX values relative to traditional values.

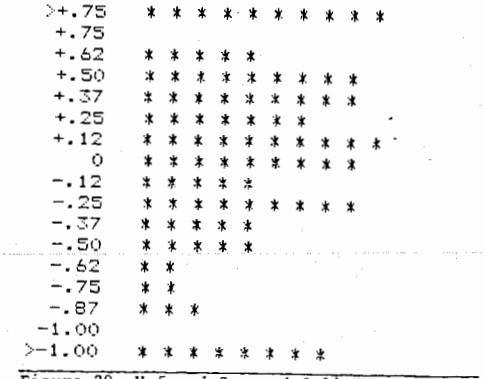


Figure 29. Unfused Crossed Cylinders. Histogram of differences between traditional and binocular IVEX unfused crossed cylinder findings. Values indicate binocular IVEX values relative to traditional values.

SUMMARY

The major focus of this study was to determine if the IVEX system could be used to determine an appropriate final prescription for patients. In order to determine this, examinations on the IVEX system were compared to a traditional refraction using a phoropter and refracting lane. The investigators feel that the results of the study indicate that the IVEX can be used to determine an appropriate prescription. The instrument is capable of using a number of targets. Some tests are performed somewhat differently due to the design of the instrument. The results of certain tests indicate that further study is warranted. Other tests appear to give accurate and reliable results when compared to the traditional method.

Three findings were used to evaluate whether the IVEX system is capable of determining an appropriate final prescription. Two of these were: (1) the subjective to best visual acuity, and (2) a distance prescription determined by OEP case analysis. In both situations the traditional finding was adjusted for target distance (.20 D was deducted from each result because the targets were at 5 meters). For the SBVA, comparing the adjusted traditional to the monocular IVEX method resulted in a mean difference that was very small (.172 D more minus on the IVEX) but was statistically significantly different. This difference may not be significant to the practitioner particularly if it is taken into account when prescribing. The difference between the SBVA obtained by the traditional and binocular IVEX methods was slightly larger possibly due to target selection as discussed earlier.

The final distance prescription comparisons obtained by OEP analysis had smaller mean differences than those for the SBVA findings. The

mean difference for the adjusted traditional vs. monocular IVEX was only .128 D. This difference was not statistically significant due to the strict criterion set in the study. The difference between the adjusted traditional and the binocular IVEX was slightly larger and statistically significant. The investigators do not recommend using the binocular target that was used for determining the distance endpoint in the binocular IVEX method. The development of an alternate target slide is necessary in order to take advantage of a truly binocular refraction technique. Although the greater minus obtained with the IVEX may be real, the amount is small and should not create a problem for the practitioner who is aware of it.

The third finding used for evaluation of the IVEX was a final near prescription obtained using OEP analysis. Comparing the traditional findings to both the monocular IVEX and binocular IVEX resulted in a mean difference of less than .25 D and standard deviation of less than .50 D. In both cases the IVEX methods yielded less plus in the final prescription. These differences are small and probably not clinically significant when considering subject variability from examination to examination.

A follow-up study utilizing multiple measures by each examination method would be helpful in determining how much of the variability between results obtained in this study for SBVA and distance and near prescriptions is due to instrument differences and how much might be due to subject variability on repeated measures.

In completing the twenty-one point OEP examination the investigators feel that there are a number of tests in which the IVEX yielded consistent results with the traditional testing methods. These included distance

retinoscopy, cylinder power, lateral and vertical phorias at far and near, near crossed cylinder findings, and negative relative accommodation. Bausch and Lomb claim that retinoscopy is easier through the IVEX than through a phoropter because one can remain on axis at all times with the IVEX. However, the investigators felt that it was more difficult to do with the IVEX due to greater reflections and poorer fundus reflex quality. The mean differences between methods on the crossed cylinder findings were remarkably small. A standard deviation of greater than .50 D was present in each case which is to be expected due to each subject's own variability. Less plus was obtained in the IVEX for negative relative accommodation but the mean difference was only slightly more than .12 D in each case.

The investigators have some reservations about a few tests. These include the vergence findings, amplitude of accommodation, and positive relative accommodation. Although the vergence findings showed high standard deviations they were consistent with results found by Haynes' reliability study. (10) Correlation coefficients for the vergence varied greatly ranging from .248 to .783 (see Tables 3a and 3b in the text). The IVEX did not measure as large an amplitude of accommodation as the traditional method, .62 D less with the monocular IVEX method and nearly .75 D for the binocular IVEX method. The mean difference for the positive relative accommodation comparisons was nearly .25 D less minus with the IVEX. Standard deviations for amplitude of accommodation and positive relative accommodation were large, approximately 1.00 D, but only slightly larger than those found by Haynes.

On the whole, the IVEX system appears to be an adequate system for refraction when compared to a traditional refracting lane and

phoropter. Statistically significant differences between the IVEX and the traditional method were found when evaluating final prescriptions but the correlation coefficients were very near 1.00. Furthermore, the differences were small and may not be clinically significant. Of the additional findings analyzed by the investigators, a number showed remarkably close agreement between the IVEX and the traditional method. However, the results of a few tests suggest differences between the IVEX and the traditional method which warrant further study. The investigators recommend follow-up studies of selected findings or all twenty-one points (OEP) to contain a design which utilizes multiple examinations for each method on each subject. This would allow a more accurate assessment of differences in the methods and subject variability.

Also, because of the tendencies shown in the near sphere findings, it may be wise to have further studies done on specific groups of findings comparing not only differences of traditional testing to the IVEX but also utilizing presbyopic vs. non-presbyopic populations.

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# APPENDIX A

A Pearson correlation coefficient was determined using the following formula.

$$r = \frac{\sigma x^2 + \sigma y^2 - \sigma d^2}{2 \cdot \sigma x \cdot \sigma y}$$

$r$ = correlation coefficient

$\sigma x$ = standard deviation of distribution of findings using traditional method

$\sigma y$ = standard deviation of distribution of findings using the monocular IVEX or binocular IVEX method

$\sigma d$ = standard deviation of distribution of differences obtained by subtracting the subjects' IVEX findings from their traditional finding

## APPENDIX B

Comparisons of standard deviations found by Haynes' reliability study (10) to those found in the present study. Haynes' data was originally calculated from an absolute distribution. Therefore it was modified by dividing the original standard deviations by .6028 to simulate two-tailed data and allow this comparison.

| TEST | HAYNES' MODIFIED STANDARD DEVIATION | STANDARD DEVIATIONS TRADITIONAL VS. IVEX | |
|---|---|---|---|
| | | MONOCULAR IVEX | BINOCULAR IVEX |
| PHORIAS (all values in prism diopters) | | | |
| Distance lateral phoria | 2.89 | 1.97 | 2.31 |
| Near lateral phoria | 4.05 | 3.27 | 3.52 |
| Lateral phoria thru unfused crossed cylinder | 3.27 | 3.52 | 3.28 |
| Lateral phoria thru fused crossed cylinder | 2.32 | 3.34 | 3.22 |
| VERGENCES (all values in prism diopters) | | | |
| Base-out to break at distance | 6.25 | 7.35 | 8.51 |
| Base-out to recovery at distance | 5.97 | 7.97 | 9.6 |
| Base-in to break at distance | 1.97 | 2.61 | 2.29 |
| Base-in to recovery at distance | 2.37 | 2.41 | 2.30 |
| Positive Relative Convergence (Blur) | 4.29 | 5.87 | 6.55 |
| Positive Fusional Reserve (Break) | 6.97 | 6.38 | 6.76 |
| Positive Fusional Reserve (Recovery) | 5.24 | 5.04 | 6.95 |
| Negative Relative Convergence (Blur) | 5.91 | 5.75 | 5.30 |
| Negative Fusional Reserve (Break) | 4.84 | 4.52 | 4.32 |
| Negative Fusional Reserve (Recovery) | 4.26 | 4.65 | 5.39 |
| SPHERE TESTS | | | |
| Unfused crossed cylinders | .55 D | .58 D | .66 D |
| Fused crossed cylinders | .45 D | .53 D | .64 D |
| Amplitude of Accommodation | .81 D | .91 D | 1.12 D |
| Positive Relative Accommodation | .91 D | 1.11 D | 1.07 D |
| Negative Relative Accommodation | .35 D | .43 D | .43 D |