Trial Frame Refraction versus Autorefraction among New Patients in a Low-Vision Clinic

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PURPOSE. To determine the relationship between refractive error as measured by autorefraction and that measured by trial frame refraction among a sample of adults with vision impairment seen in a university-based low-vision clinic and to determine if autorefraction might be a suitable replacement for trial frame refraction.

METHODS. A retrospective chart review of all new patients 19 years or older seen over an 18-month period was conducted and the following data collected: age, sex, primary ocular diagnosis, entering distance visual acuity, habitual correction, trial frame refraction, autorefraction, and distance visual acuity measured after trial frame refraction. Trial frame refraction and autorefraction were compared using paired *t*-tests, intraclass correlations, and Bland-Altman plots.

RESULTS. Final analyses included 440 patients for whom both trial frame refraction and autorefraction data were available for the better eye. Participants were mostly female (59%) with a mean age of 68 years (SD = 20). Age-related macular degeneration was the most common etiology for vision impairment (44%). Values for autorefraction and trial frame refraction were statistically different, but highly correlated for the spherical equivalent power ($r=0.92$), the cylinder power ($r=0.80$) and overall blurring strength (0.89). Although the values of the cross-cylinders J_0 and J_{45} were similar, they were poorly correlated (0.08 and 0.15, respectively). The range of differences in spherical equivalent power was large (−8.6 to 4.9).

CONCLUSIONS. Autorefraction is highly correlated with trial frame refraction. Differences are sometimes substantial, making autorefraction an unsuitable substitute for trial frame refraction. (*Invest Ophthalmol Vis Sci.* 2013;54:19–24) DOI: 10.1167/iops.12-10508

Refraction, the determination of the refractive error of an eye, is an essential part of eye care. Refraction is used clinically to determine the spectacle prescription so that the

best possible acuity can be achieved. Because many patients with low vision report that their glasses do not help, some may believe it appropriate to skip refraction; however, Sunness and Annan¹ found that 11% of new low-vision patients in their practice experienced a significant improvement in visual acuity by refraction. Refraction for most patients is done with the use of a phoropter to maximize efficiency; however, trial frame refraction is preferred for low-vision patients because it allows a more natural viewing posture that is amenable to eccentric viewing when needed. Additionally, the phoropter presents lens changes in 0.25-diopter (D) increments, whereas trial frame refraction allows the examiner to determine the magnitude of difference between the lens choices presented such that the differences are discernible by the patient. Trial frame refraction of low-vision patients is time consuming, taking approximately 15 minutes per patient.²

Over the past few decades, autorefraction has become an important part of routine eye care and clinical trials. It has been shown to be both sensitive and specific for screening refractive error in pediatric patients.¹ In three trials comparing the spherical equivalent (SE) of autorefraction to subjective refraction, the difference was less than or equal to ± 0.50 D between 70% and 74% of the time.^{3–5} Because there are occasionally larger errors, however, the authors concluded that autorefraction cannot replace subjective refraction in routine clinical practice.

Most patients presenting for low-vision rehabilitation do so because of reduced visual acuity, although some present due to impaired visual field or contrast sensitivity, among other reasons. Patients with decreased acuity have a larger apparent depth of focus⁶ because they are less sensitive to blur. Legge and colleagues⁷ have shown that tolerance to defocus increases as visual acuity declines. The “just-noticeable-difference” as it relates to refraction is the smallest lens power change that results in discernible blur. A generally accepted rule of thumb for clinicians is that the observer can discern a difference equal to or greater than the denominator of their Snellen fraction divided by 100.⁸ So, for example, a patient with 20/200 visual acuity would be able to discern a difference of 200/100, or 2.00 D. Although this is a widely accepted standard used for more than 30 years, its origin and validity are unknown.

It remains to be determined whether autorefraction is similar enough to trial frame refraction such that the patient with low vision would be unable to discern a difference between the refractions generated by those techniques. The purpose of this study was to determine the relationship between refractive error as measured by autorefraction and that measured by trial frame refraction among a sample of adults with vision impairment seen in a university-based low-vision clinic. The goal of the study was to determine if autorefraction might be a suitable replacement for trial frame refraction.

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Supported by Grant NEI K 23 EY018864 from the National Eye Institute, and the EyeSight Foundation of Alabama, Research to Prevent Blindness, Able Trust, and Alfreda J. Schueler Trust.

Submitted for publication July 2, 2012; revised November 5, 2012; accepted November 12, 2012.

Disclosure: D.K. DeCarlo, None; G. McGwin Jr, None; K. Searcey, None; L. Gao, None; M. Snow, None; J. Waterbor, None; C. Owsley, None

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METHODS

A retrospective cross-sectional study of all new adult patients seen in a university-based low-vision clinic was undertaken. Institutional review board approval was obtained. This research adhered to the tenets of the Declaration of Helsinki.

Charts for all new adult patients 19 years or older seen over an 18-month period were reviewed and the following information was collected: age, sex, primary ocular diagnosis, entering distance visual acuity, habitual correction, trial frame refraction, autorefraction, and distance visual acuity measured after trial frame refraction. The variables for habitual correction, trial frame refraction, and autorefraction were expressed as sphere power, cylinder power, and cylinder axis. Data collected were from clinical low-vision evaluations that were performed by an optometrist with residency training in low-vision rehabilitation (DKD, MSS). Manual lensometry was used to determine the habitual spectacle correction. Autorefraction was performed using a Nikon Retinomax Autorefractor (Nikon Retinomax K+, Nikon, Inc., Tokyo, Japan) in dim illumination. The instrument prints a maximum of the last eight measurements and displays a representative value for each eye along with a confidence number based on the variance of the readings (range 1–10; higher numbers equal greater confidence). Confidence numbers of 8 or greater are recommended by the manufacturer. The examiner was not masked to the results of lensometry or autorefraction, and was free to choose either as the starting point for refraction. Monocular trial frame refraction was performed using loose lenses with an end point for spherical correction of the most plus that gave the best visual acuity. Astigmatic correction was determined in the minus cylinder form, using a ± 0.50 D or ± 1.00 D hand-held Jackson Cross cylinder lens, depending on which was deemed more appropriate by the examiner. The end point for cylindrical correction was the last cylinder lens in which more power was accepted. Best-corrected visual acuity after trial frame refraction was measured either with a back-illuminated Early Treatment Diabetic Retinopathy Study (ETDRS) chart or a projected Snellen chart, giving patients credit for each line in which more than 50% of letters were read correctly, as is done in clinical practice. Acuity was not recorded after autorefraction.

Variables were summarized using descriptive statistics. Autorefraction and trial frame refraction data were analyzed only for the better eye because frequently in low-vision rehabilitation a significantly poorer seeing eye will receive a less rigorous refraction than the fellow eye. The refraction data were analyzed per the method of Thibos and colleagues,^{9,10} in which the spherocylindrical refractive error is broken down into a power vector. The power vector has three dioptric components: the SE of the refractive error and two cross-cylinders: one at axis 0 (180) degrees (J_0) and the other at axis 45 degrees (J_{45}).¹⁰ The length of the vector from the coordinate origin of the space to the point in dioptric space occupied by the SE, J_0 , and J_{45} coordinates represents the overall blurring strength (B) of the spherocylindrical refractive error. Overall blurring strength is the same for a given vector length, regardless of whether the blur is myopic or hyperopic. The following formulas were used¹⁰:

$$SE = \text{sphere power} + \frac{1}{2} \text{cylinder power}$$

$$J_0 = (-\text{cylinder power}/2)\cos(2^\circ\text{axis})$$

$$J_{45} = (-\text{cylinder power}/2)\sin(2^\circ\text{axis})$$

$$B = \sqrt{SE^2 + J_0^2 + J_{45}^2}$$

The SE, J_0 , J_{45} , overall blurring strength, and cylindrical power were determined for all participants as well as subgroups based on best-corrected visual acuity (better than 20/100, 20/100 to 20/200, and worse than 20/200) and age (45 years or younger and older than 45 years). Agreement between trial frame refraction and autorefraction was determined using intraclass correlations, paired *t*-tests and Bland-Altman plots.¹¹ Differences between autorefraction and trial frame refraction were also analyzed using the absolute value of the difference to yield a greater understanding of the magnitude of the difference. Due to the clinical importance of refractive error, the proportion of

TABLE 1. Demographics and Clinical Characteristics of Study Population, *n* = 440

Sex, <i>n</i> (%)	
Male	180 (40.9)
Female	260 (59.1)
Age, <i>y</i> , mean (SD)	67.6 (20.0)
Primary diagnosis for better eye, <i>n</i> (%)	
Age-related macular degeneration	195 (44.3)
Optic atrophy	40 (9.1)
Glaucoma	41 (9.3)
Diabetic retinopathy	33 (7.5)
Hemianopsia	19 (4.3)
Cataracts	6 (1.4)
Other	106 (24.1)
BCVA, OD, mean $\pm$ SD	0.82 $\pm$ 0.55 logMAR
BCVA, OS, mean $\pm$ SD	0.86 $\pm$ 0.55 logMAR
BCVA, better eye, mean $\pm$ SD	0.59 $\pm$ 0.41 logMAR
BCVA better than 20/100 (<0.7 logMAR), <i>n</i> (%)	276 (62.7)
BCVA 20/100 to 20/200 (0.7 to 1.0 logMAR), <i>n</i> (%)	104 (23.6)
BCVA worse than 20/200 (>1.0 logMAR), <i>n</i> (%)	60 (13.6)
BCVA, worse eye, mean $\pm$ SD	1.10 $\pm$ 0.56 logMAR
Difference between habitual acuity and best-corrected acuity, better eye, mean $\pm$ SD	0.12 $\pm$ 0.20 logMAR
Difference between habitual acuity and best-corrected acuity, worst eye, mean $\pm$ SD	0.06 $\pm$ 0.18 logMAR
BCVA, best-corrected visual acuity.	

each of the vector components as well as the overall blurring power that were within ± 0.50 D and within ± 1.00 D were also determined.

Although power vectors are the most precise representation of a spherocylindrical refractive error, they are not readily used in clinical practice. For that reason, the agreement between trial frame refraction and autorefraction was determined for cylindrical power and axis as well. Statistical significance for all analyses was set at *P* less than 0.05, two-tailed.

RESULTS

A total of 582 new adult patients were seen during the 18-month study period. Fifty-two patients were ineligible because they were seen for reasons other than a low-vision evaluation or they had no manifest refraction performed. Of the 530 eligible patients, 440 had both autorefraction and trial frame refraction performed on their better seeing eye. Demographics and clinical characteristics of the sample are presented in Table 1. Slightly more than half of the participants were female (59%) and mean age was 68 years (SD = 20). Age-related macular degeneration was the most common etiology for vision impairment (44%). Better eye visual acuity improved 0.12 $\pm$ 0.20 log minimum angle of resolution (logMAR) on average between trial frame and habitual correction.

Intraclass correlations between trial frame refraction and autorefraction (Table 2) were high for the SE (0.92), overall blurring strength (0.89), and cylinder power (0.80), but not the crossed-cylinders (J_0 = 0.08; J_{45} = 0.25). The Figure shows Bland-Altman (difference versus mean) plots for SE, overall blurring strength, J_0 , and J_{45} .

TABLE 2. Statistical Summary of the Distribution of the Refractive Components for Trial Frame Refraction and Autorefracton

	Trial Frame Refraction	Autorefracton	Intraclass	P Value
Spherical equivalent, mean (SD)	−0.33 (2.57)	−0.62 (2.69)	0.92	<0.01
J ₀ , mean (SD)	0.01 (0.59)	0.00 (0.62)	0.08	0.89
J ₄₅ , mean (SD)	−0.01 (0.46)	−0.01 (0.59)	0.15	0.84
Overall blurring strength, mean (SD)	1.75 (2.06)	1.98 (2.11)	0.89	<0.01
Cylinder power, mean (SD)	−0.98 (1.13)	−1.28 (1.13)	0.80	<0.01

The SE of the trial frame refraction tended to be more plus on average than that of autorefracton for all participants combined and for all visual acuity subgroup analyses (Tables 2 and 3). Subgroup analysis (Table 3) showed that for the most part, the differences were greater when visual acuity was poorer. There was very little difference between J₀ and J₄₅ for the overall group and for each acuity subgroup. Because the data reflect plus and minus lens powers that offset one another to some extent, the absolute value of the difference was also determined. The mean of the absolute value of the differences ranged from 0.43 D for J₀ among those with vision worse than 20/200 in the study eye to 0.94 D for the SE among those with vision from 20/100 to 20/200 (Table 3). The mean differences were statistically similar between those older than 45 years and those 45 and younger.

Table 4 shows the percentage of trial frame refraction results within ± 0.50 D of the autorefracton measurements for the SE power, J₀, J₄₅, overall blurring strength, and cylinder power, divided into subgroups based on best-corrected visual acuity as well as for the subgroup with Retinomax confidence ratings of 8 or higher. We also present the same analysis for percentage of autorefracton measurements within ± 1.00 D of the trial frame refraction. Restricting values to those with a confidence number of 8 or greater for those with acuity of 20/200 or better resulted in greater percentages of participants with less than ± 0.50 D or ± 1.00 D difference between autorefracton and trial frame refraction. Additionally, there was a general trend that greater proportions of the study population fell outside the ± 0.50 D and ± 1.00 D range for the groups with poorer visual acuity. The range of differences were

FIGURE. Difference versus mean (Bland-Altman) plots for the trial frame refraction versus autorefracton for SE, overall blurring strength, J₀, and J₄₅. Horizontal lines indicate mean and ± 1.96 SD.

TABLE 3. Difference between Subjective Refraction and Autorefraction

Component	Visual Acuity Range	Mean of the Difference	95% Confidence Limits	P Value	Mean of Absolute Value of Difference	95% Confidence Limits
Spherical equivalent	All participants	0.28 D	0.19 to 0.38	<0.001	0.72 D	0.64 to 0.79
	Better than 20/100	0.14 D	0.04 to 0.24	0.007	0.59 D	0.52 to 0.66
	20/100 to 20/200	0.45 D	0.17 to 0.72	0.002	0.94 D	0.71 to 1.16
	Worse than 20/200	0.68 D	0.41 to 0.95	<0.001	0.92 D	0.70 to 1.14
J ₀	All participants	0.01 D	−0.07 to 0.08	0.89	0.50 D	0.44 to 0.56
	Better than 20/100	0.00 D	−0.09 to 0.10	0.94	0.51 D	0.43 to 0.58
	20/100 to 20/200	0.09 D	−0.09 to 0.27	0.32	0.53 D	0.38 to 0.68
	Worse than 20/200	−0.13 D	−0.29 to 0.02	0.09	0.43 D	0.32 to 0.54
J ₄₅	All participants	0.01 D	−0.06 to 0.07	0.84	0.45 D	0.40 to 0.50
	Better than 20/100	0.01 D	−0.07 to 0.09	0.76	0.44 D	0.38 to 0.50
	20/100 to 20/200	0.01 D	−0.13 to 0.15	0.92	0.43 D	0.32 to 0.55
	Worse than 20/200	−0.02 D	−0.21 to 0.18	0.84	0.53 D	0.39 to 0.67
Overall blurring strength	All participants	−0.23 D	−0.32 to −0.14	<0.001	0.61 D	0.54 to 0.69
	Better than 20/100	−0.11 D	−0.20 to −0.02	0.01	0.51 D	0.44 to 0.57
	20/100 to 20/200	−0.40 D	−0.66 to −0.13	0.004	0.84 D	0.61 to 1.07
	Worse than 20/200	−0.46 D	−0.68 to −0.25	<0.001	0.71 D	0.55 to 0.88
Cylinder power	All participants	0.30 D	0.23 to 0.36	<0.001	0.50 D	0.45 to 0.56
	Better than 20/100	0.24 D	0.16 to 0.32	<0.001	0.45 D	0.39 to 0.51
	20/100 to 20/200	0.30 D	0.13 to 0.47	0.001	0.57 D	0.43 to 0.71
	Worse than 20/200	0.56 D	0.38 to 0.73	<0.001	0.63 D	0.46 to 0.79

−8.63 to 4.88 for SE, −3.01 to 6.18 for J₀, −3.32 to 3.48 for J₄₅, and −5.19 to 8.78 for overall blurring strength. Larger errors were not correlated with visual acuity or diagnosis.

Furthermore, if we look at cylinder power, the mean of the absolute value of the difference between trial frame refraction and autorefraction was 0.50 D (Table 3). Differences were significant across all visual acuity groups. On average, the autorefractor measured greater astigmatic refractive error than trial frame refraction (Table 2). More than two-thirds of all participants had a difference of ± 0.50 D (Table 4). Restricting the data set to only those participants with confidence ratings

of 8 or greater improved the proportion within ± 0.50 D and within ± 1.00 D, except for those with acuity worse than 20/200. Cylinder axis was analyzed separately, for all participants and again for participants with at least 0.75 D of cylinder power on trial frame refraction, because higher cylinder powers require more precise axis refinement. The overall mean axis difference was 1.4 degrees (SD ± 20.3). The tolerance permitted for cylinder axis in an ophthalmic lens with cylinder power of 0.75 D is ± 5 degrees.¹² In our sample, we included all prescriptions of at least 0.75 D, and less than half met the ANSI Z80.1 standard (Table 5).

TABLE 4. Frequency of the Difference between Trial Frame Refraction and Autorefraction (Nikon Retinomax) being Less Than ± 0.50 D or ± 1.00 D

Better Eye BCVA	Component	All Confidence Ratings (<i>n</i> = 440)*		Confidence Rating ≥ 8 (<i>n</i> = 281)†	
		< ± 0.50 D	< ± 1.00 D	< ± 0.50 D	< ± 1.00 D
Better than 20/100	Spherical equivalent, <i>n</i> (%)	172 (62)	232 (84)	123 (68)	163 (90)
	J ₀ , <i>n</i> (%)	177 (64)	238 (86)	120 (66)	158 (87)
	J ₄₅ , <i>n</i> (%)	191 (69)	242 (88)	132 (73)	162 (89)
	Overall blurring strength, <i>n</i> (%)	178 (64)	242 (88)	129 (71)	170 (93)
	Cylinder power	214 (78)	252 (91)	159 (87)	176 (97)
20/100 to 20/200	Spherical equivalent, <i>n</i> (%)	43 (41)	74 (71)	30 (44)	50 (74)
	J ₀ , <i>n</i> (%)	74 (71)	90 (87)	51 (75)	58 (85)
	J ₄₅ , <i>n</i> (%)	75 (72)	94 (90)	50 (74)	65 (96)
	Overall blurring strength, <i>n</i> (%)	47 (45)	80 (77)	33 (49)	55 (81)
	Cylinder power	70 (67)	92 (89)	50 (74)	66 (97)
Worse than 20/200	Spherical equivalent, <i>n</i> (%)	24 (40)	41 (68)	11 (35)	21 (68)
	J ₀ , <i>n</i> (%)	40 (67)	54 (90)	19 (61)	27 (87)
	J ₄₅ , <i>n</i> (%)	35 (58)	48 (80)	18 (58)	25 (81)
	Overall blurring strength, <i>n</i> (%)	28 (47)	45 (75)	14 (45)	24 (77)
	Cylinder power	39 (65)	47 (78)	19 (61)	23 (74)

BCVA, best-corrected visual acuity.

* For the whole sample (*n* = 440), there are 276 with better eye BCVA better than 20/100, 104 with better eye BCVA 20/100 to 20/200, and 60 with better eye BCVA worse than 20/200.

† For those with confidence rating ≥ 8 (*n* = 281), there are 182 with better eye BCVA better than 20/100, 68 with better eye BVA 20/100 to 20/200, and 31 with better eye BCVA worse than 20/200.

TABLE 5. Cylinder Axis Agreement between Trial Frame Refraction and Autorefraction

	All Prescriptions with a Cylindrical Component		Prescriptions with a Cylinder Component of at Least 0.75 D	
	All Confidence Ratings	Rating 8 or Higher	All Confidence Ratings	Rating 8 or Higher
No. participants	305	199	242	155
Within ± 5 degrees, <i>n</i> (%)	113 (37)	78 (39)	100 (41)	69 (45)
Within ± 10 degrees, <i>n</i> (%)	168 (55)	118 (59)	145 (74)	101 (65)
Within ± 15 degrees, <i>n</i> (%)	211 (69)	150 (75)	178 (74)	125 (81)
Within ± 20 degrees, <i>n</i> (%)	237 (78)	167 (84)	199 (82)	137 (88)

DISCUSSION

To the authors' knowledge, ours is the first study to compare refractive error as measured by autorefraction (objective refraction) to that measured by trial frame (subjective) refraction among patients presenting for low-vision rehabilitation. This study is important because if the results had been sufficiently similar, autorefraction (which requires substantially less time and clinical expertise) may have been a suitable alternative to trial frame refraction. A clinical rule of thumb based on the work of Emsley¹³ is that each 0.25 D of uncorrected refractive error in a person capable of 20/20 vision decreases visual acuity by one line of Snellen acuity (e.g., from 20/20 to 20/25 or 20/30 to 20/40). One might therefore argue that being within ± 0.50 D of the trial frame refraction is adequate for patients with moderately impaired acuity, as the difference in size of the letters between two Snellen lines is small. Furthermore, one might argue that for patients who are legally blind, an autorefraction within ± 1.00 D should be adequate, as that is within their predicted just noticeable difference for lens power changes. However, approximately 5% of SE values differed by 2 D or more, an unacceptable difference. As can be seen by the ranges of differences obtained, there are some differences considerably larger than 2 D. It is crucial that refractive error be appropriately corrected in patients with low vision to provide the best potential for success with low-vision devices. Most near devices are used in conjunction with the best spectacle correction, including a near add if appropriate. If the patient is over- or under-plussed in their refractive correction, the prescribed devices may not work in the way intended, or perhaps not at all.

Three studies have compared subjective refraction to autorefraction among participants in clinical trials: two for the treatment of diabetic retinopathy^{14,15} and one for subfoveal neovascularization.¹⁶ All three studies evaluated only the SE difference between the two refraction methods. The participants for all three were similar in age to our participants; however, fewer subjects in these studies had severe vision loss. A single site study of participants with diabetic retinopathy compared a Diabetic Retinopathy Clinical Research Network (DRCRN) protocol manual refraction to autorefraction.¹⁴ On average the SE of the autorefraction was slightly more plus (hyperopic) than the SE of the manual refraction, with a median difference of only +0.25 D. However, 38% had an SE difference between the two measures of 1 D or more. Among those with 20/100 or poorer acuity, 62% had an SE difference between the two measures of 1D or more. A larger scale, multicenter study from the DRCRN found similar results, with 30% of participants overall having a difference between subjective refraction and autorefraction of 1 D or greater, increasing to 60% for the subgroup with visual acuity 20/100 or worse.¹⁵ Among participants in the Submacular Surgery Trials, on average the autorefraction was 1.04 D more minus (myopic) than the subjective refraction.¹⁶ The findings of these studies are similar to those of the current study, and further

support the conclusion that autorefraction cannot replace subjective refraction.

Subjective refraction has been studied and found to be a valid and repeatable procedure,^{17,18} even among patients with macular degeneration.¹⁹ It is the clinical standard for determination of refractive error. Goss and Grosvenor,¹⁸ in an extensive review of the reliability of subjective refraction, found that the intra- and interexaminer reliability of subjective refraction in most studies was near 80% agreement within ± 0.25 D and near 95% agreement within ± 0.50 D for sphere power, cylinder power, and SE power. Given the 27 years of combined experience of the clinicians performing the refractions in this study, it is unlikely that differences between objective and subjective refraction were entirely due to variability of the examiners.

Various autorefractor models have been studied and their reliability and validity reported in the literature,^{5,20} including the Retinomax.^{21–24} The Retinomax has primarily been studied in pediatric subjects owing to its potential usefulness in screening because of its portability. One study of adult patients with myopia presenting to a refractive surgery clinic compared the Retinomax with subjective refraction and found that the Retinomax autorefraction was significantly more minus.²¹ All measures were made before surgery but without cycloplegia. The authors attempted to control accommodation by fogging the fellow eye with a +3.00 D lens; however, that eye was not fixating a target so it is unclear whether the fogging technique would have had the desired effect. It is possible that in this sample of pre-presbyopic myopes that the Retinomax had a tendency for instrument-induced myopia, as accommodation during testing would lead to more myopic measurements. In our study, we also found the Retinomax measures to be slightly more minus, however instrument-induced myopia is an unlikely explanation given the large proportion of our sample with presbyopia. Additionally, there were no differences between older (older than 45 years) and younger participants in our study. In another study, Cordonnier and colleagues²³ found the Retinomax to be accurate with respect to SE when compared with a table-mounted autorefractor (Nikon AR 800, Nikon NR 5000, or Topcon RM 6000). So although there are slight differences among autorefractors, the general consensus is that the Retinomax is a reliable instrument, similar to others on the market. We therefore do not expect the differences we found to be attributable to the particular autorefractor model used in this study.

One possible explanation for differences between trial frame refraction and autorefraction is that the participants had a mean age of 68 years, and therefore likely had relatively miotic pupils. Although pupil size was not measured, miosis when present would increase the depth of focus,⁶ potentially affecting the subjective refraction and it would also make use of the autorefractor more difficult.

Study strengths and limitations should be noted. We did not use a standardized research refraction protocol, but rather used

usual-care trial frame refraction procedures. Additionally, the examiners were not masked to the autorefraction or the habitual glasses prescription and typically used one or the other as the starting point for trial frame refraction. This would have likely biased the subjective refraction toward the objective refraction. We also did not record visual acuity after autorefraction, therefore we do not know if it would have been different between the two corrections. Assuming, as is commonly done, that the trial frame refraction is the gold standard for refractive error measurement may therefore be a limitation. A strength of this study is its large sample size of patients presenting for low-vision rehabilitative care, a population not addressed in the previous literature on comparison of refraction methods.

CONCLUSIONS

Refractive error, as measured by autorefraction using the Nikon Retinomax K+, and trial frame refraction were similar in this cohort of adults with vision impairment. In this study, we sought to determine if autorefraction, which is a quick procedure, could replace the time-consuming trial frame refraction in patients with vision impairment presenting for a low-vision evaluation. These patients are difficult and time-consuming to refract, so much so that often refraction is omitted in their routine clinical care for their eye disease or anomaly. So, although a person with severely impaired vision would be unable to detect small errors in their refractive correction, the results we obtained show that there are greater differences between trial frame refraction and autorefraction for patients with poorer vision, making the latter an unsuitable substitute even for patients who are legally blind. However, trial frame refraction and autorefraction do correlate well for SE and cylinder power. Additionally, cylinder axis is within 20 degrees for 78% of participants. Autorefraction is therefore a reasonable starting point for refraction of patients with low vision and may decrease the time required to complete trial frame refraction.

References

1. Sunness JS, El Annan J. Improvement of visual acuity by refraction in a low-vision population. *Ophthalmology*. 2010; 117:1442–1446.
2. Klein R, Klein BE, Linton KL, De Mets DL. The Beaver Dam Eye Study: visual acuity. *Ophthalmology*. 1991;98:1310–1315.
3. Polse DA, Kerr KE. An automatic objective optometer. Description and clinical evaluation. *Arch Ophthalmol*. 1975; 93:225–231.
4. McBrien NA, Millodot M. Clinical evaluation of the Canon Autorefractometer R-1. *Am J Optom Physiol Opt*. 1985;62:786–792.
5. Perrigin DM, Grosvenor T, Reis A, Perrigin J. Comparison of Dioptron Nova refractive data with conventional refractive data. *Am J Optom Physiol Opt*. 1984;61:479–483.
6. Green DG, Powers MK, Banks MS. Depth of focus, eye size and visual acuity. *Vision Res*. 1980;20:827–835.
7. Legge GE, Mullen KT, Woo GC, Campbell FW. Tolerance to visual defocus. *J Opt Soc Am A*. 1987;4:851–863.
8. Benjamin WJ. *Borish's Clinical Refraction*. 2nd ed. St. Louis: Butterworth Heinemann Elsevier; 2006.
9. Thibos LN, Wheeler W, Horner D. Power vectors: an application of Fourier analysis to the description and statistical analysis of refractive error. *Optom Vis Sci*. 1997;74:367–375.
10. Thibos LN, Horner D. Power vector analysis of the optical outcome of refractive surgery. *J Cataract Refract Surg*. 2001; 27:80–85.
11. Bland JM, Altman, DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet*. 1986;1:307–310.
12. American National Standards Institute (ANSI) Z80 Committee on Ophthalmic Optics. *ANSI Z80.1-2010: American National Standard for Ophthalmics-Prescription Ophthalmic Lenses*. Alexandria, VA: The Vision Council; 2010.
13. Emsley HH. *Visual Optics*. 5th ed. London: Butterworth; 1952.
14. Sun JK, Aiello LP, Cavallerano JD, et al. Visual acuity testing using autorefraction or pinhole occluder compared with a manual protocol refraction in individuals with diabetes. *Ophthalmology*. 2011;118:537–542.
15. Sun JK, Qin H, Aiello LP, et al. Evaluation of visual acuity measurements after autorefraction vs manual refraction in eyes with and without diabetic macular edema. *Arch Ophthalmol*. 2012;130:470–479.
16. Orr PR, Cramer LD, Hawkins BS, Bressler NM. Manifest refraction versus autorefraction for patients with subfoveal choroidal neovascularization. *Invest Ophthalmol Vis Sci*. 2001;42:447–452.
17. Rosenfield M, Chiu NN. Repeatability of subjective and objective refraction. *Optom Vis Sci*. 1995;72:577–579.
18. Goss DA, Grosvenor T. Reliability of refraction—a literature review. *J Am Optom Assoc*. 1996;67:619–630.
19. Blackhurst DW, Maguire MG. Reproducibility of refraction and visual acuity measurement under a standard protocol. The Macular Photocoagulation Study Group. *Retina*. 1989;9:163–169.
20. Wesemann W, Rassow B. Automatic infrared refractors—a comparative study. *Am J Optom Physiol Opt*. 1987;64:627–638.
21. Farook M, Venkatramani J, Gazzard G, Cheng A, Tan D, Saw SM. Comparisons of the handheld autorefractor, table-mounted autorefractor, and subjective refraction in Singapore adults. *Optom Vis Sci*. 2005;82:1066–1070.
22. The Vision in Preschoolers Study Group. Impact of confidence number on the screening accuracy of the retinomax autorefractor. *Optom Vis Sci*. 2007;84:181–188.
23. Cordonnier M, Dramaix M, Kallay O, de Bideran M. How accurate is the hand-held refractor Retinomax(R) in measuring cycloplegic refraction: a further evaluation. *Strabismus*. 1998; 6:133–142.
24. Kallay OP, Cordonnier MJ, Dramaix MM. Cycloplegic refractive errors in children: comparison of a standard and a hand-held refractor. *Strabismus*. 1998;6:3–7.