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ORIGINAL PAPER

Comparison of the PlusOptix S09 and Spot Vision photorefractor to cycloretinoscopy

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Abstract
Purpose The purpose of this study was to compare refraction measurements for children with the PlusOptix S09 and Spot Vision with cycloplegic retinoscopy.
Methods One hundred thirty-six eyes of 68 children (26 boys and 42 girls) were evaluated prospectively. The subjects were separated into two groups. Group 1 comprised the subjects age between 5 and 9 years. Group 2 comprised the subjects age between 10 and 18 years. Photorefraction with PlusOptix S09, photorefraction with Spot Vision and cycloplegic retinoscopy were performed in each patient. Spherical equivalents, spherical power, cylindrical power and axis values were compared between three methods.
Results The mean age of the patients was 7.12 ± 1.5 years in group 1 and 12.24 ± 1.8 years in group 2. Spherical equivalent and spherical power measured with PlusOptix S09 were statistically smaller than measured with cycloplegic retinoscopy for group 1 ($p = 0.001$, $p = 0.001$) and for group 2 ($p = 0.000$, $p = 0.000$). The mean cylindrical power measured with PlusOptix S09 was not statistically different compared to cycloplegic retinoscopy for both groups ($p = 0.314$, $p = 0.05$). Spherical equivalents measured with Spot Vision were statistically smaller than measured with cycloplegic retinoscopy for both groups ($p = 0.000$, $p = 0.012$). Spherical power measured with Spot Vision was statistically smaller than measured with cycloplegic retinoscopy for group 1 ($p = 0.000$), but the difference was not statistically significant for group 2 ($p = 0.084$). The mean cylindrical power measured with Spot Vision was statistically higher than cycloplegic retinoscopy for both groups ($p = 0.000$, $p = 0.012$).
Conclusions PlusOptix S09 and Spot Vision devices give acceptable results for screening, but prescription of spectacles should not be made according to PlusOptix S09 or Spot Vision devices alone.

Keywords Amblyopia · Cycloretinoscopy · Photorefraction · PlusOptix S09 · Spot Vision

Introduction

Amblyopia, which effects 1.6–3.6% of the population, is a preventable visual impairment in children [1]. Significant refractive errors, anisometropia, strabismus and media opacity are the most important risk factors for amblyopia [2]. These risk factors should be detected as early as possible, because the optimal age for amblyopia treatment was demonstrated to be younger than 7 years old [3]. Therefore, the American Association for Pediatric Ophthalmology and

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Strabismus (AAPOS) recommends screening from the birth to detect the risk factors for amblyopia development as early as possible [4]. However, the procedures and details of vision screening used worldwide are contradictory.

Cycloplegic refraction has been the gold standard method to detect refractive error in very young children. However, it has disadvantages because it is time-consuming and requires cooperation. To overcome these shortcomings, photorefraction devices have been improved for screening amblyogenic risk factors. They are convenient as they work at a distance about 1 m, head alignment is not required, and it is claimed that they may eliminate accommodation. So photorefraction might be a good option for detection of refractive errors in young children and disabled patients with limited cooperation.

PlusOptix S09 (Plusoptix GmbH, Nurnberg, Germany) and Spot Vision screener (Welch Allyn, Skaneateles Falls, New York, USA) are marketed as a pediatric photoscreener devices. It has been shown that photorefractive devices have acceptable sensitivity and specificity to be used as screening tool [5–9]. Since PlusOptix was marketed earlier than Spot Vision, there are a lot of studies evaluating refractive outcome of PlusOptix, whereas there are few studies investigating results of Spot Vision.

The purpose of this study was to compare refraction measurements made in children with the PlusOptix S09 and Spot Vision with cycloplegic retinoscopy. We also evaluated correlation of refractive indices (sphere, cylinder, spherical equivalent) of these devices with each other and cycloplegic retinoscopy.

Materials and methods

The present study was approved by the Medical Ethical Committee of Istanbul Medipol University and was in accordance with the tenets in the Declaration of Helsinki. Written informed consent was provided by the parents of the pediatric patients.

One hundred thirty-six eyes of 68 children (26 boys and 42 girls) were evaluated prospectively in the Ophthalmology Department of Medipol University. The subjects were separated into two groups. Group 1 comprised the subjects age between 5 and 9 years. Group 2 comprised the subjects age between 10 and 18 years. Exclusion criteria included strabismus, opacities of the optical media, retinal abnormalities and refraction error exceeding manufacturers' recommendations. PlusOptix S09 has a spherical and cylindrical range of − 7.0 D to + 5.0 D, and Spot Vision has a spherical range of − 7.5 D to + 7.5 D and cylinder range of − 3.0 D to + 3.0 D.

Measurements were performed in following order: photorefraction with PlusOptix S09, photorefraction with Spot Vision in a dark room and cycloplegic retinoscopy (Welch Allyn Elite Retinoscope, Welch AllynInc., NY, USA), 30 min after two times cyclopentolate 1% instillation when pupils were fully dilated. Each patient was tested twice, and the average value was recorded. All subjects also underwent a complete ophthalmologic examination including visual acuity testing with Snellen, cover test, anterior segment and dilated fundus examination.

The PlusOptix S09 device measures refractive error, asymmetry of the corneal reflexes and pupil size in real time with an infrared video. Both eyes are measured at the same time from 1 m away from the child. It has a smile face on the camera as fixation target and warble sound to draw the attention. It has a spherical and cylindrical range of − 7.0 to + 5.0 D in increments of 0.25 D.

The Spot Vision Screener is a handheld, portable photoscreener which is held about 1 m from the subject and displays sound and light to take the attention of child. It uses reflection of infrared lights from the cornea and the retina to detect pupillary diameter, ocular alignment and refractive status. It has a spherical range of − 7.5 D to + 7.5 D and cylinder range of − 3.0 D to + 3.0 D.

Statistical analysis

The sample size was determined depending on power analysis. The normality of the distribution of each of the parameters was checked using the Kolmogorov–Smirnov normality test. Spherical equivalents, spherical power, cylindrical power and axis values were compared between PlusOptix S09, Spot Vision and cycloplegic retinoscopy with Friedman analyses for both groups. Comparisons between PlusOptix S09 and cycloplegic retinoscopy, Spot Vision and cycloplegic retinoscopy and PlusOptix S09 and Spot Vision were performed with Wilcoxon test, and correlations were evaluated with Spearman's correlation analysis. The Bland–Altman method was used to assess the

difference in spherical equivalents with three methods. All statistical analyses were done using SPSS statistical package 19 (SPSS for Windows, Chicago, IL, USA). Statistical significance was set up at $p < 0.05$.

Results

One hundred thirty-six eyes of 68 children (26 boys and 42 girls) were evaluated prospectively in the Ophthalmology Department of Medipol University. Group 1 included 19 girls and 15 boys and group 2 included 23 girls and 11 boys. The mean age of the patients was 7.12 ± 1.5 years (range 5–9 years) in group 1 and 12.24 ± 1.8 years (range 10–18 years) in group 2.

Tables 1 and 2 summarize the mean value of sphere, cylinder, spherical equivalent and axis measured with PlusOptix S09, Spot Vision and cycloplegic retinoscopy for group 1 and group 2. There were statistically significant differences for spherical equivalent, spherical power, cylindrical power among three methods both for group 1 ($p = 0.000$, $p = 0.000$, $p = 0.005$, respectively) and group 2 ($p = 0.000$, $p = 0.000$, $p = 0.002$, respectively). The differences for the axis were not statistically significant for group 1 and 2 among three methods ($p = 0.483$, $p = 0.431$, respectively). Spherical equivalent and spherical power measured with PlusOptix S09 were statistically smaller than measured with cycloplegic retinoscopy for group 1 ($p = 0.001$, $p = 0.001$, respectively) and for group 2 ($p = 0.000$, $p = 0.000$, respectively). The mean cylindrical power measured with PlusOptix S09 was not statistically different compared to cycloplegic retinoscopy for group 1 and 2 ($p = 0.314$, $p = 0.05$, respectively). Spherical, cylindrical power and spherical equivalent measurements by PlusOptix S09 were correlated with measurements of cycloplegic retinoscopy for both groups (Table 3).

Spherical equivalents measured with Spot Vision were statistically smaller than measured with cycloplegic retinoscopy for group 1 and 2 ($p = 0.000$, $p = 0.012$, respectively). Spherical power measured with Spot Vision was statistically smaller than measured with cycloplegic retinoscopy for group 1 ($p = 0.000$), but although the mean spherical power measured with Spot Vision was smaller compared to cycloplegic retinoscopy for group 2 the difference was not statistically significant ($p = 0.084$). The mean cylindrical power measured with Spot Vision was statistically higher than cycloplegic retinoscopy for group 1 and 2 ($p = 0.000$, $p = 0.012$). Spherical, cylindrical power and spherical equivalent measurements by Spot Vision were correlated with measurements of cycloplegic retinoscopy for both groups (Table 4).

Spherical equivalent and spherical power measured with Spot Vision were statistically smaller than PlusOptix S09 for group 1 ($p = 0.000$, $p = 0.005$, respectively). The mean cylindrical power measured with Spot Vision was statistically higher than PlusOptix S09 for group 1 ($p = 0.007$). Spherical power measured with Plus Optix S09 was statistically smaller than measured with Spot Vision for group 2 ($p = 0.019$), but although the mean spherical equivalent measured with Plus Optix S09 was smaller compared to Spot Vision for group 2 the difference was not statistically significant ($p = 0.078$). There was no statistically significant difference between PlusOptix S09 and Spot Vision with respect to cylindrical

Table 1 The mean value of refractive components measured with PlusOptix S09, Spot Vision and cycloplegic retinoscopy for group 1

Refractive component	PlusOptix S09 mean ± SD [min/max]	Spot Vision mean ± SD [min/max]	Cycloplegic retinoscopy mean ± SD [min/max]
Sphere (D)	+ 1.08 ± 1.5 [− 3.00/+ 5.00]	+ 0.79 ± 1.04 [− 3.00/+ 3.25]	+ 1.58 ± 1.7 [− 3.00/+ 5.00]
Cylinder (D)	0.93 ± 0.9 [0/5.00]	1.07 ± 1.0 [0/6.00]	0.88 ± 0.9 [0/5.00]
SE (D)	+ 0.68 ± 1.3 [− 4.00/+ 3.0]	+ 0.31 ± 0.9 [− 3.75/+ 2.75]	1.19 ± 1.7 [− 4.00/+ 5.00]
Axis (degree)	92.8 ± 69.5 [0/180]	86.9 ± 73.0 [0/180]	129.9 ± 63.1 [0/180]

SD standard deviation, *D* diopter, *SE* spherical equivalent

Table 2 The mean value of refractive components measured with PlusOptix S09, Spot Vision and cycloplegic retinoscopy for group 2

Refractive component	PlusOptix S09 mean ± SD [min/max]	Spot Vision mean ± SD [min/max]	Cycloplegic retinoscopy mean ± SD [min/max]
Sphere (D)	− 0.78 ± 2.5	− 0.63 ± 1.9	− 0.28 ± 2.5
	[− 6.25/+ 4.25]	[− 5.50/+ 3.50]	[− 5.00/+ 5.50]
Cylinder (D)	0.70 ± 0.6	0.76 ± 0.8	0.61 ± 0.6
	[0/3.25]	[0/3.50]	[0/3.25]
SE (D)	− 1.07 ± 2.4	− 0.97 ± 1.7	− 0.54 ± 2.4
	[− 6.50/+ 4.0]	[− 5.50/+ 3.50]	[− 5.25/+ 4.75]
Axis (degree)	90.6 ± 74.8	101.8 ± 70.8	118.2 ± 68.2
	[0/180]	[0/180]	[0/180]

SD standard deviation, *D* diopter, *SE* spherical equivalent

Table 3 PlusOptix S09 versus cycloplegic retinoscopy

Refractive component	Sphere (D)	Cylinder (D)	SE (D)
Difference, mean ± SD [min–max]			
Group 1	− 0.50 ± 1.1	0.05 ± 0.4	− 0.51 ± 1.0
	[(− 3.25) to (1.75)]	[(− 1.00) to (1.00)]	[(− 3.25) to (1.50)]
Group 2	− 0.50 ± 1.0	0.09 ± 0.3	− 0.52 ± 1.0
	[(− 3.50) to (1.25)]	[(− 0.75) to (0.75)]	[(− 3.75) to (1.25)]
p value			
Group 1	0.001	0.314	0.001
Group 2	0.000	0.050	0.000
Pearson correlation			
R value			
Group 1	0.779	0.890	0.792
Group 2	0.917	0.851	0.911
p value			
Group 1	0.000	0.000	0.000
Group 2	0.000	0.000	0.000

SE spherical equivalent, *D* diopter, *SD* standard deviation

power for group 2 ($p = 0.151$). Spot Vision was correlated with measurements of Plus Optix S09 (Table 5).

The scatterplots showing PlusOptix S09 versus cycloplegic retinoscopy, Spot Vision versus cycloplegic retinoscopy and PlusOptix S09 versus Spot Vision for spherical equivalent are shown in Figs. 1, 2 and 3.

Discussion

The earlier visual disorders are detected and treated; the more successfully amblyopia can be prevented. Screening methods which are easily applicable and highly accurate play important role in detection of amblyopia risk factors. Hence, it is very important to compare accuracy of these methods with the gold standard cycloplegic retinoscopy. In the current study, we compared the PlusOptix S09 and Spot Vision photoscreener with cycloplegic refraction. We observed that there is a mean difference of approximately 0.5 D between spherical power and spherical equivalent results of the PlusOptix S09 for both group 1 and group 2. The difference was approximately 0.5 D with Spot Vision in group 2 but approximately 1 D in group 1. This result shows us that hyperopia tends to be underestimated and myopia tends to be overestimated by the PlusOptix S09 and Spot Vision compared to cycloplegic retinoscopy. The difference

Table 4 Spot Vision versus cycloplegic retinoscopy

Refractive component	Sphere (D)	Cylinder (D)	SE (D)
Difference, mean ± SD [min–max]			
Group 1	− 0.79 ± 1.0 [(− 3.25) to (1.50)]	0.19 ± 0.3 [(− 0.50) to (1.25)]	− 0.87 ± 1.0 [(− 3.50) to (1.50)]
Group 2	− 0.34 ± 1.0 [(− 3.25) to (1.25)]	0.16 ± 0.3 [(− 0.50) to (1.0)]	− 0.43 ± 1.0 [(− 3.50) to (1.0)]
p value			
Group 1	0.000	0.000	0.000
Group 2	0.084	0.000	0.012
Pearson correlation			
R value			
Group 1	0.839	0.923	0.836
Group 2	0.927	0.913	0.915
p value			
Group 1	0.000	0.000	0.000
Group 2	0.000	0.000	0.000

SE spherical equivalent, *D* diopter, *SD* standard deviation

Table 5 PlusOptix S09 versus Spot Vision

Refractive component	Sphere (D)	Cylinder (D)	SE (D)
Difference, mean ± SD [min–max]			
Group 1	0.28 ± 0.7 [(− 2.25) to (1.25)]	− 0.13 ± 0.3 [(− 0.75) to (1.00)]	0.36 ± 0.7 [(− 2.50) to (1.25)]
Group 2	− 0.15 ± 1.0 [(− 3.50) to (1.75)]	− 0.06 ± 0.3 [(− 0.50) to (1.25)]	− 0.09 ± 1.0 [(− 3.50) to (1.75)]
p value			
Group 1	0.005	0.007	0.000
Group 2	0.019	0.151	0.078
Pearson correlation			
R value			
Group 1	0.869	0.821	0.924
Group 2	0.937	0.932	0.915
p value			
Group 1	0.000	0.000	0.000
Group 2	0.000	0.000	0.000

SE spherical equivalent *D* diopter; *SD* standard deviation

is similar in different age group for PlusOptix S09, but Spot Vision underestimates hyperopia more in younger age group. Concerning the cylindrical results, while PlusOptix S09 gave similar results with cycloplegic retinoscopy, Spot Vision measured cylindrical power significantly higher than cycloplegic refraction. The difference was about 0.2 D for Spot Vision.

Underestimation of hypermetropia has also been reported to be due to accommodation with photorefractor device. Because PlusOptix was marketed earlier than Spot Vision, there are more numerous number of studies with PlusOptix in the literature. The diopters shifting to myopia varied in different reports. Erdurmus et al. [10] found 0.7 D underestimation of

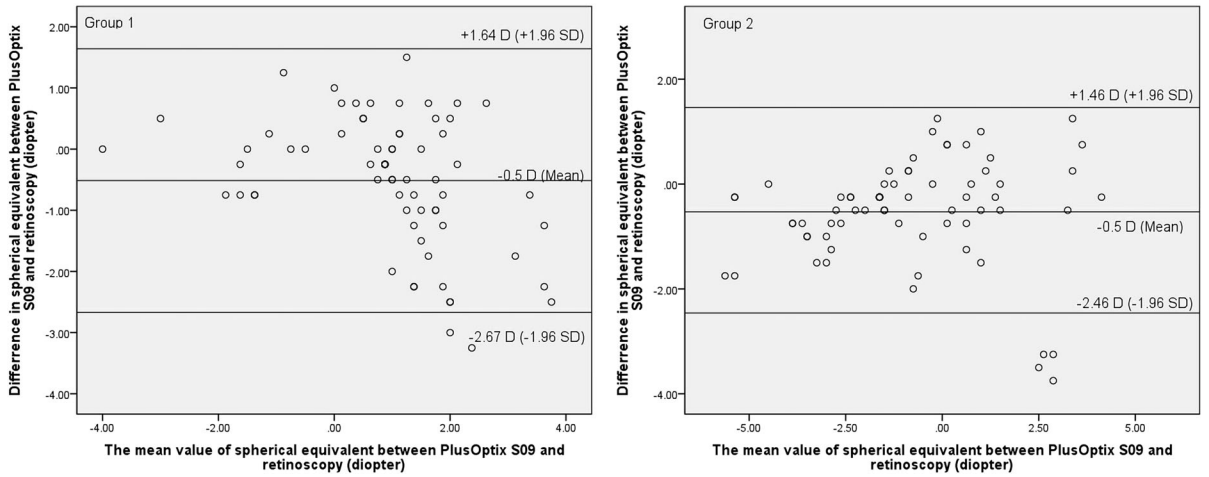

Fig. 1 The scatterplots showing PlusOptix S09 versus cycloplegic retinoscopy for spherical equivalent

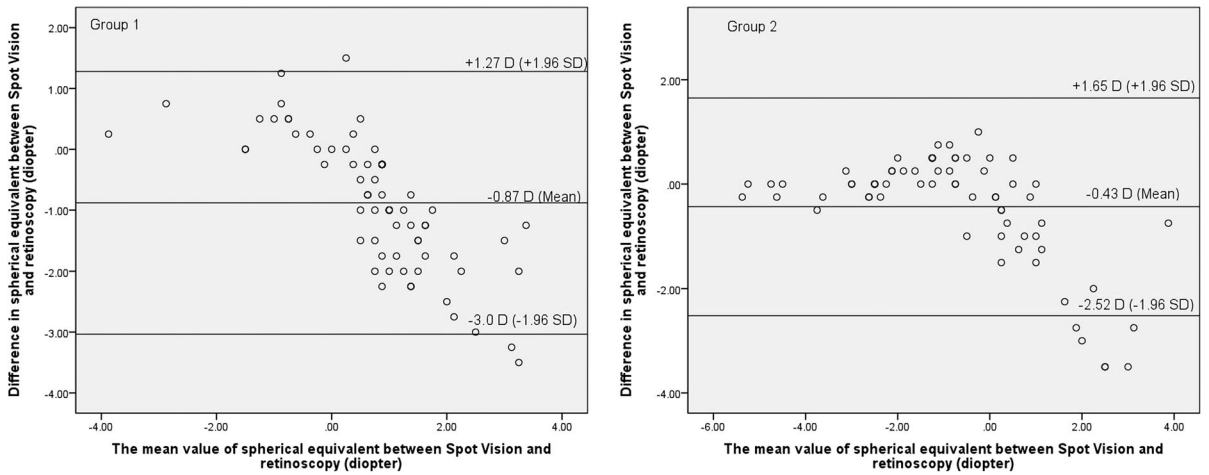

Fig. 2 The scatterplots showing Spot Vision versus cycloplegic retinoscopy for spherical equivalent

hypermetropia by PlusOptix CR03 when compared with cycloplegic retinoscopy. Demirci et al. [11] reported 0.4 D difference in spherical power by PlusOptix S08, and Yan et al. [12] reported this difference as 0.5 D with PlusOptix A09, which are in agreement with the results of our study. On the other hand, Mirzajani et al. [13] and Fogel-Levin et al. [14] reported 0.2 D difference in spherical value of PlusOptix S08 and PlusOptix A12 with cycloplegic retinoscopy, which is lesser than our study and the other mentioned studies.

When accuracy for measurement of astigmatism was evaluated, Mirzajani et al. [11], Yan et al. [12] and Demirci et al. [13] did not find statistically significant difference between PlusOptix and retinoscopy which were consistent with the present study. On the other hand, Erdurmus et al. [10] reported 0.1 D higher cylindrical value with PlusOptix CR03, while Fogel-Levin et al. [14] found this difference as 0.06 D, both results were statistically important.

There are few studies evaluating reliability of Spot Vision in the literature. Peterseim et al. [5] evaluated the success of Spot Vision in detecting amblyopia risk factors and found that sensitivity was 87% and specificity was 75%. Garry and Donahue [7] reported that Spot was 92% sensitive and 41% specific in detecting amblyopia. In a study Peterseim et al. [6] reported that both Spot and Plusoptix A09 measured spherical values smaller than cycloplegic retinoscopy and the differences were higher than our study (0.6 D

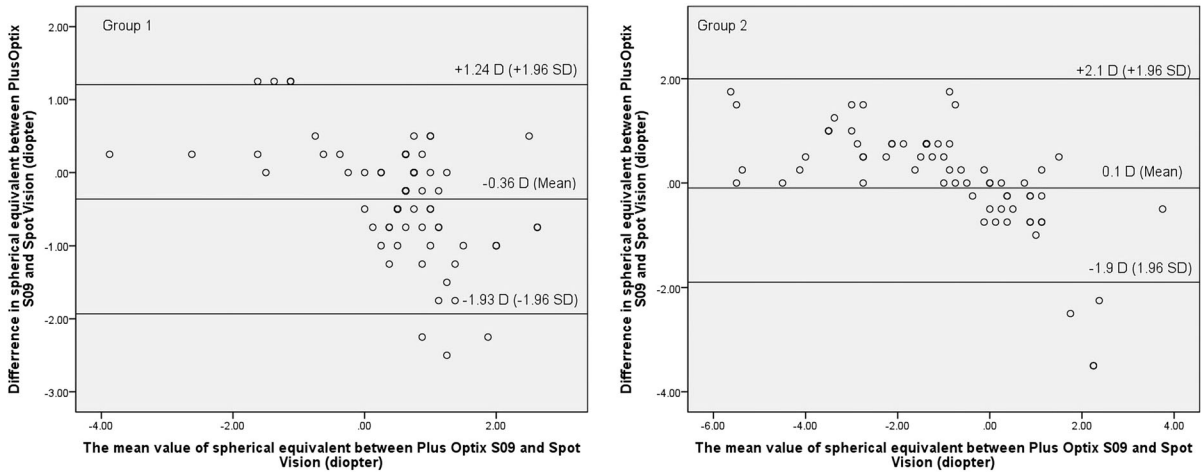

Fig. 3 The scatterplots showing PlusOptix S09 versus Spot Vision for spherical equivalent

for the PlusOptix and 1.3 D for the Spot Vision). Also, they reported larger cylindrical values by about 0.3 D with both PlusOptix and Spot Vision, which is higher than our study.

Limitations of the present study include low number and wide age range of children. Another limitation is that the patients involved in the study had higher prevalence of refractive error than healthy population.

Conclusions

It has been supposed that photorefractor devices eliminate accommodation, but the results of this study show that fixation target of devices may stimulate some degree of accommodation. We measured the refraction about 0.5 D less hypermetropic with Plus Optix S09 in both age groups. The refraction was about 1 D less hypermetropic in age group younger than 10 years old although the difference was 0.5 D in the age group older than 10 years old with Spot Vision. When we consider the high capacity of accommodation, 0.5 D may be acceptable result for screening. Thus, PlusOptix S09 and Spot Vision are good options for screening due to their ease of use and good estimation of refractor error. But more caution should be taken while evaluating children younger than 10 years old with Spot Vision. While evaluating children younger than 10 years old with Spot Vision more caution should be taken. PlusOptix measures both spherical and cylindrical values closer to cycloplegic retinoscopy. One of the advantages of Spot Vision over the PlusOptix S09 is that it is not connected to a computer so that it is more portable. However, because of underestimation of hypermetropia and overestimation of myopia, prescription of spectacles should not be made according to the measurements of PlusOptix S09 or Spot Vision devices alone. On the other hand, it should be keep in mind that the photorefractor devices are limited by their relatively narrow measurable refractive error range and inability to analyze data in case of cataract, pupillary abnormality, strabismus and nystagmus.

Compliance with ethical standards

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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