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Comparison of the cycloplegic refractive measurements with handheld, table-mounted refractometers and retinoscopy in children

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ABSTRACT

BACKGROUND: Handheld autorefractometers are now widely used for screening refractive errors in children. The purpose of the study was to compare the refractive measurements from table-mounted, handheld autorefractometers and retinoscopy in children.

MATERIAL AND METHODS: Measurements in children with poor visual acuity and/or strabismus were obtained with the handheld 2WIN and the table-mounted Nidek ARK-1 refractometers and retinoscopy after the instillation of 0.5% atropine. Data on the sphere, spherical equivalent (SE), and cylindrical vectors at 0 degrees (J0) and 45 degrees (J45) were analysed.

RESULTS: Data were collected from 57 children (mean age, 4.3 years ± 2.0 years). The 2WIN refractometer measured statistically significantly lower SE mean values than the Nidek ARK-1 or retinoscopy (1.67 ± 1.48 D, 2.96 ± 1.95 D, 2.92 ± 1.93 D, respectively). The 95% LOA was the narrowest for sphere, SE, J0, and J45 vector for Nidek ARK-1 refractometer and retinoscopy. The difference between the measurements of 2WIN and retinoscopy and 2WIN and Nidek ARK-1 was more pronounced in higher refractive values for sphere, SE, J0, and J45.

CONCLUSION: The table-mounted autorefractor provided a reading more similar to that of streak retinoscopy than to that of the handheld autorefractor. The differences between the 2WIN and the other two methods were more pronounced in the higher refractive values, so careful interpretation of the autorefraction results would be advised, especially in children with higher refractive values who are at most significant risk for amblyopia.

KEY WORDS: handheld autorefractometer; table-mounted autorefractometer; pediatric vision screening; retinoscopy; refractive error

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INTRODUCTION

Amblyopia is the most frequent visual disorder in children that can lead to a permanent visual reduction. The most common amblyogenic factors are strabismus, refractive errors, and media opacities. Vision screening, early detection, and treatment of amblyogenic factors can prevent amblyopia and visual impairment [1–6]. The timely identification of significant refractive errors in children is therefore essential but can be challenging. Handheld auto-

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refractometers are now widely used for screening refractive errors as they require less patient cooperation than table-mounted autorefractometers [7–14]. The question is whether handheld autorefractometers measurements are comparable to table-mounted ones or retinoscopy, as some studies showed differences in the measurements [9, 12–14].

The purpose of the study was to compare the refractive cycloplegic measurements from a handheld autorefractometer, table-mounted autorefractometer, and streak retinoscopy in a pediatric group of patients with poor visual acuity and/or strabismus.

MATERIAL AND METHODS

Children scheduled for a comprehensive eye examination due to poor visual acuity and/or strabismus in one or both eyes were included in the study. Children under 18 years of age were referred by the pediatrician due to poor visual acuity and/or strabismus in one or both eyes. Children were also examined by the ophthalmologist. Children with poor visual acuity and/or strabismus in one or both eyes in which retinoscopy with 0.5% atropine was indicated were included in the study.

Children with other additional ophthalmological disorders except for refractive error and/or strabismus (e.g. corneal or lens opacities or retinal disease) were excluded from the study. Cycloplegic autorefraction was done by three methods, 2WIN, Nidek ARK-1 refractometers, and retinoscopy. Eyes in which either of the three methods could not be performed (e.g. due to poor fixation, cooperation, or strabismus) were excluded from the study.

The refractive errors of all eyes were measured after cycloplegia with a table-mounted Nidek ARK-1 (Nidek Technologies, Gamagori, Japan; Fig. 1), handheld 2WIN (Adaptica, Padua, Italy; Fig. 2) refractometers and retinoscopy in the same session. The table-mounted refractometer Nidek ARK-1 measurements were obtained after the patient positioned his or her chin and forehead as described by the manufacturer. Active children were held still by their family members for a short while during the measurement. The handheld 2WIN measurements were obtained while the examiner held the device at level with the patient's eyes from a distance of approximately 1 m.

Measurements with the 2WIN, Nidek ARK-1 refractometers, and retinoscopy were obtained after instillation of the 0.5% atropine before the examination for four days, two times a day (in the morning and the evening) and an additional one drop in the morning on the day of the examination.

Only measurements from the right eye of each subject were included in the study. Data on

FIGURE 1. Nidek ARK-1 table-mounted refractometer

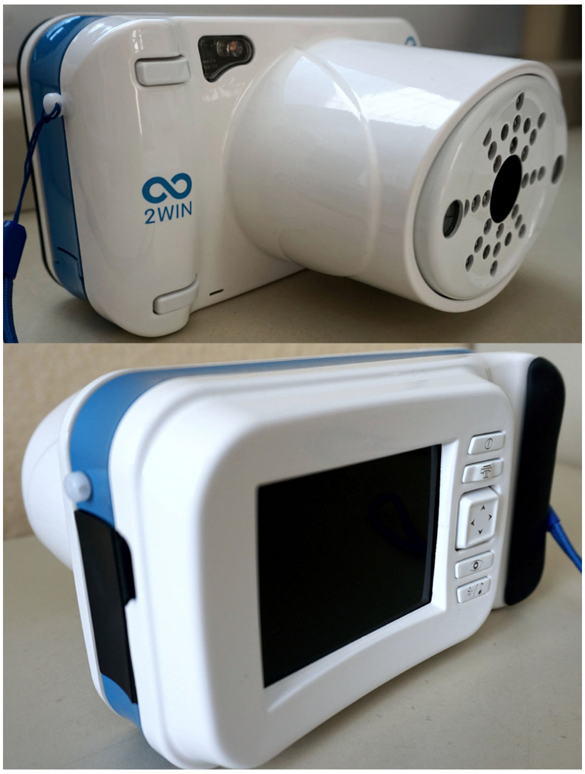

FIGURE 2. 2WIN handheld refractometer

a sphere, spherical equivalent (SE), and cylindrical vectors at 0 degrees (J0) and 45 degrees (J45) were analysed. The averages (in negative cylinder form) gave sphere and spherical equivalent. The cylinder and axis were expressed as vectors. The resulting vector components were Jackson cross-cylinders at 0 degrees [J0 = – (cylinder/2) × cos(2 × axis)] and at 45 degrees [J45 = – (cylinder/2) × sin(2 × axis)]. The calculated values were tabulated descriptively as mean and standard deviation (SD) for all tests. The spherical error, SE, J0, and J45, were compared between the methods using the paired t-test. The Pearson correlation coefficient provided an association between techniques for all refractive components. Statistical significance ($p < 0.05$) was established.

Agreement between methods was assessed for sphere, spherical equivalent, and J0 and J45 vector components using Bland and Altman's plots, showing agreement between the 2WIN, the Nidek ARK-1 autorefractor, and retinoscopy. The mean of the differences between methods and the 95% limits of agreement (LOA) between measurements expressed as mean difference ± 1.96 standard deviation (SD) of differences were calculated. SPSS v.22 statistical software was used for data analysis (IBM SPSS, Version 22.0. Armonk, NY: IBM Corp.).

The study was approved by the Ethics Committee of the Community Health Centre Ljubljana (No. 852-1/2021-2). Written informed consent was obtained from all parents or caregivers.

RESULTS

Data were collected from 57 (mean age, 4.3 years ± 2.0 years) children, 29 girls, and 28 boys. Table 1 shows the range, mean, and SD for sphere, SE, and the J0 and J45 vector components determined by the 2WIN, Nidek ARK-1 refractome-

Table 1. Range of values, the mean and standard deviation of a sphere, spherical equivalent (SE), cylindrical vectors at 0 degrees (J0), and 45 degrees (J45) vector measured by the retinoscopy, Nidek ARK-1, and 2WIN

		Minimum	Maximum	Mean	Standard deviation
Sphere	Retinoscopy	–2.00	7.50	3.46	2.03
	Nidek ARK–1	–2.00	8.25	3.57	2.05
	2WIN	–1.25	7.00	2.00	1.40
SE	Retinoscopy	–2.25	6.50	2.92	1.93
	Nidek ARK–1	–2.25	6.88	2.96	1.95
	2WIN	–1.75	7.00	1.67	1.48
J0	Retinoscopy	–0.70	2.00	0.43	0.57
	Nidek ARK–1	–0.83	2.00	0.46	0.57
	2WIN	–0.62	1.35	0.24	0.39
J45	Retinoscopy	–0.70	2.00	0.43	0.57
	Nidek ARK–1	–0.63	1.51	0.00	0.32
	2WIN	–0.62	1.35	0.24	0.39

SD — standard deviation; PCC — Pearson's correlation coefficient; [a]the p-value calculated by paired t-test; [b]the p-value was calculated for PCC

Table 2. Mean, standard deviation, Pearson's correlation coefficient (PCC) of a sphere, spherical equivalent (SE), and cylindrical vectors at 0 degrees (J0) and 45 degrees (J45) vector measured by the retinoscopy, Nidek ARK-1, and 2WIN

		Mean difference	SD	p-value[a]	PCC	p-value[b]
Sphere	Retinoscopy and Nidek ARK-1	0.11	0.22	0.00	0.99	0.00
	Retinoscopy and 2WIN	1.46	1.25	0.00	0.80	0.00
	Nidek ARK-1 and 2WIN	1.57	1.21	0.00	0.82	0.00
SE	Retinoscopy and Nidek ARK-1	0.04	0.21	0.12	0.99	0.00
	Retinoscopy and 2WIN	1.25	1.15	0.00	0.80	0.00
	Nidek ARK-1 and 2WIN	1.29	1.11	0.00	0.83	0.00
J0	Retinoscopy and Nidek ARK-1	0.03	0.08	0.00	0.99	0.00
	Retinoscopy and 2WIN	0.19	0.45	0.00	0.62	0.00
	Nidek ARK-1 and 2WIN	0.22	0.46	0.00	0.60	0.00
J45	Retinoscopy and Nidek ARK-1	0.43	0.55	0.00	0.34	0.00
	Retinoscopy and 2WIN	0.19	0.45	0.00	0.62	0.00
	Nidek ARK-1 and 2WIN	0.24	0.39	0.00	0.39	0.00

SD — standard deviation; PCC — Pearson's correlation coefficient; [a]the p-value calculated by paired t-test; [b]the p-value was calculated for PCC

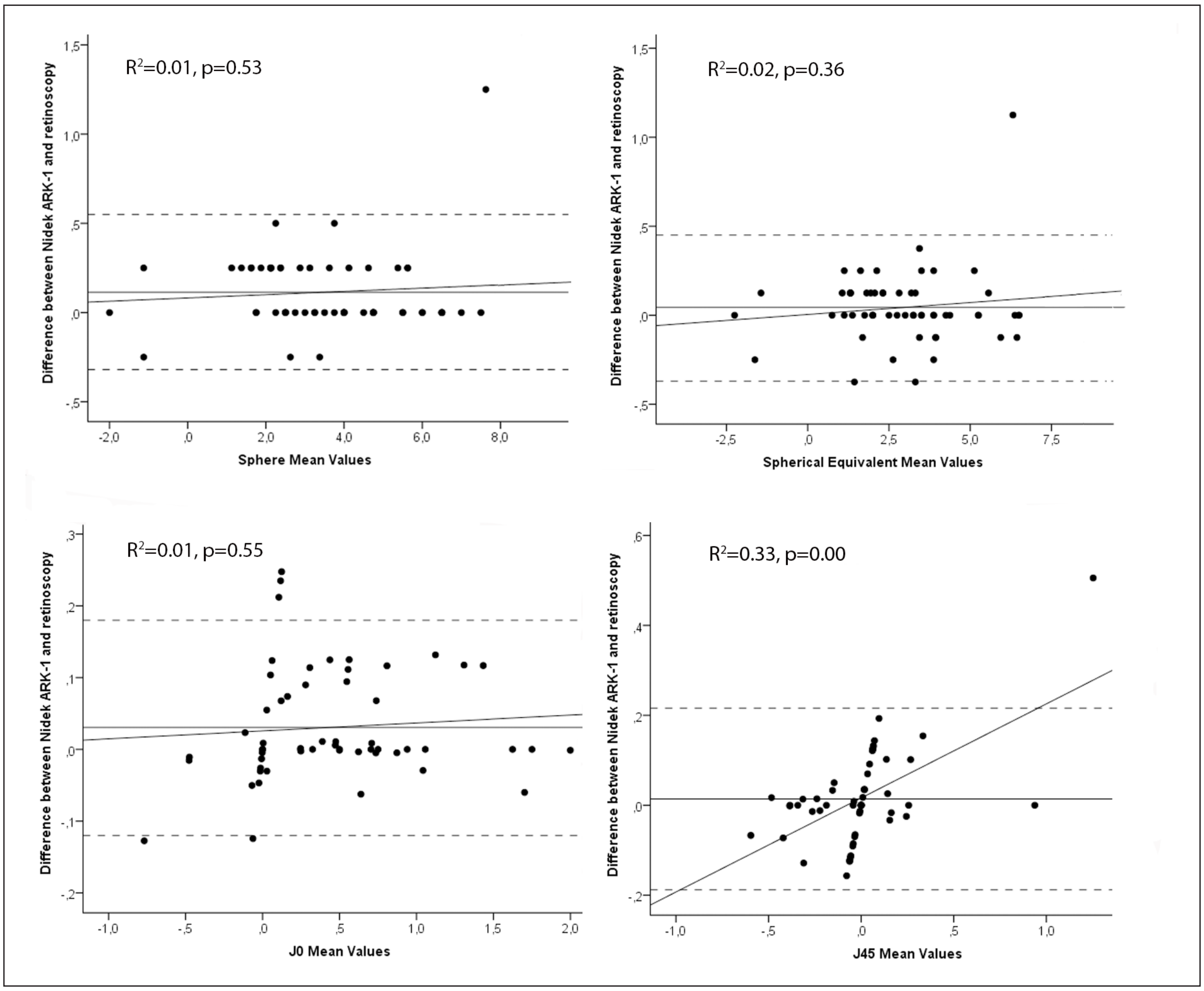

FIGURE 3. Difference between Nidek ARK-1 and retinoscopy for sphere, spherical equivalent (SE), cylindrical vectors at 0 degrees (J0), and 45 degrees (J45) vector. Dashed lines present 95% limit of agreement (LOA), solid horizontal line presents the mean of the differences between methods

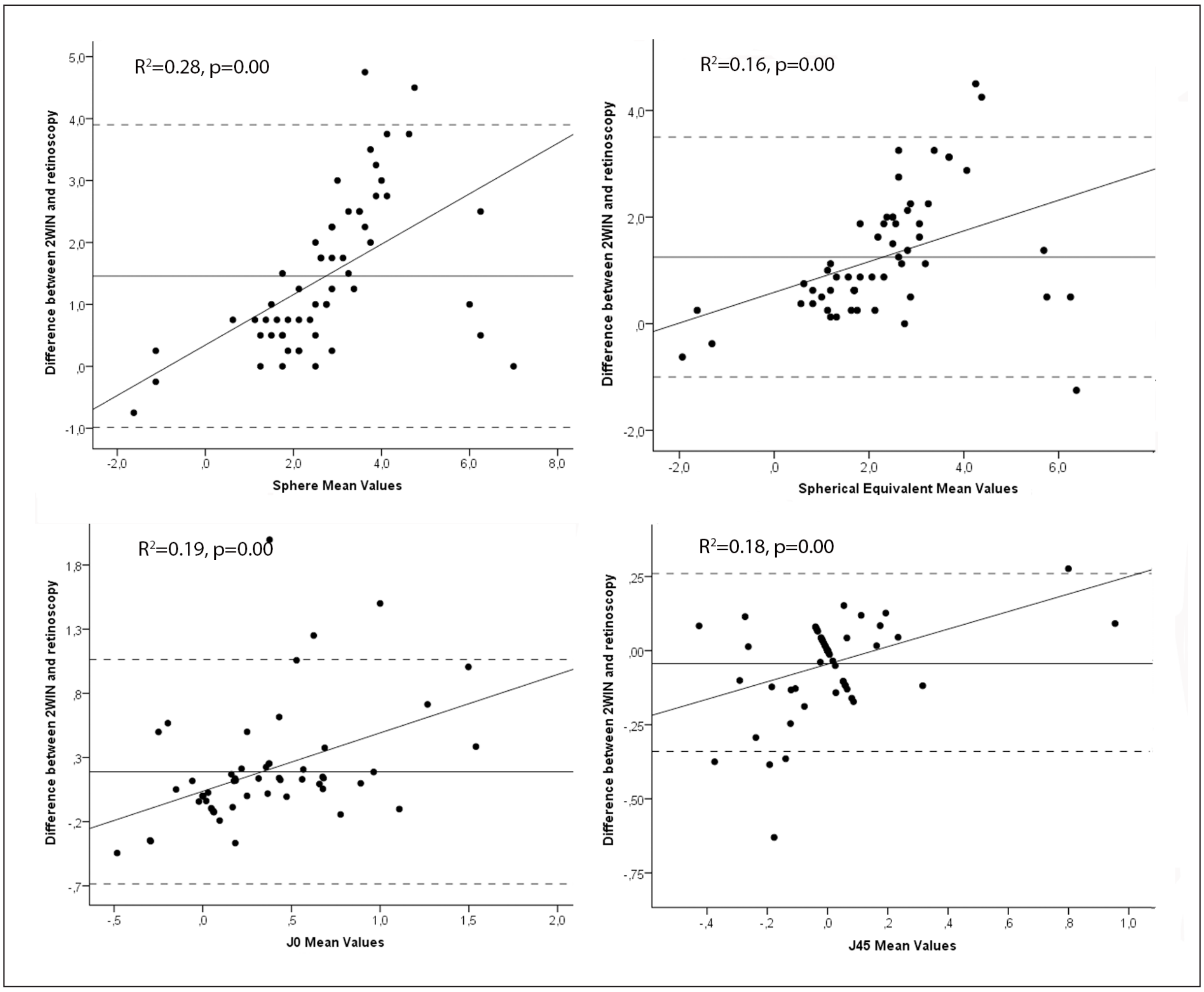

FIGURE 4. Difference between 2WIN and retinoscopy for sphere, spherical equivalent (SE), and cylindrical vectors at 0 degrees (J0) and 45 degrees (J45). Dashed lines present 95% limit of agreement (LOA), solid horizontal line presents the mean of the differences between methods

ters, and streak retinoscopy. The 2WIN refractometer measured lower sphere, and SE mean values than the Nidek ARK-1 or retinoscopy (Tab. 1).

Differences between the measurements were statistically significant between the three methods except for SE between Nidek ARK-1 refractometer and retinoscopy (Tab. 2). The correlation of the three methods for sphere, SE, J0, and J45 vector showed the highest correlation coefficients for Nidek ARK-1 refractometers and retinoscopy in all measurements except for J45 (Tab. 2).

The agreement between the two devices was assessed using the 95% LOA and Bland and Altman plot (Fig. 3–5). The 95% LOA of the two devices for sphere, SE, J0, and J45 vector, is also presented in Table 3. The 95% LOA was the narrowest for sphere, SE, J0, and J45 vector for Nidek ARK-1 refractometers and retinoscopy (Tab. 3 and Fig. 3–5).

The difference between the measurements for 2WIN and retinoscopy and 2WIN and Nidek ARK-1 was more pronounced and statistically significant in higher values for sphere, SE, J0, and J45 (Fig. 4 and 5). The difference in higher values was more pronounced and statistically significant only for J45 values in the measurements between Nidek ARK-1 and retinoscopy (Fig. 3).

DISCUSSION

It is known that the effect of amblyopia treatment decreases with age [3], so correct measurement of refraction defect from a very young age is vital in terms of intervention against a possible case of amblyopia. There is sometimes a cooperation problem with optotype-based screening and retinoscopy in young children, but the measurement

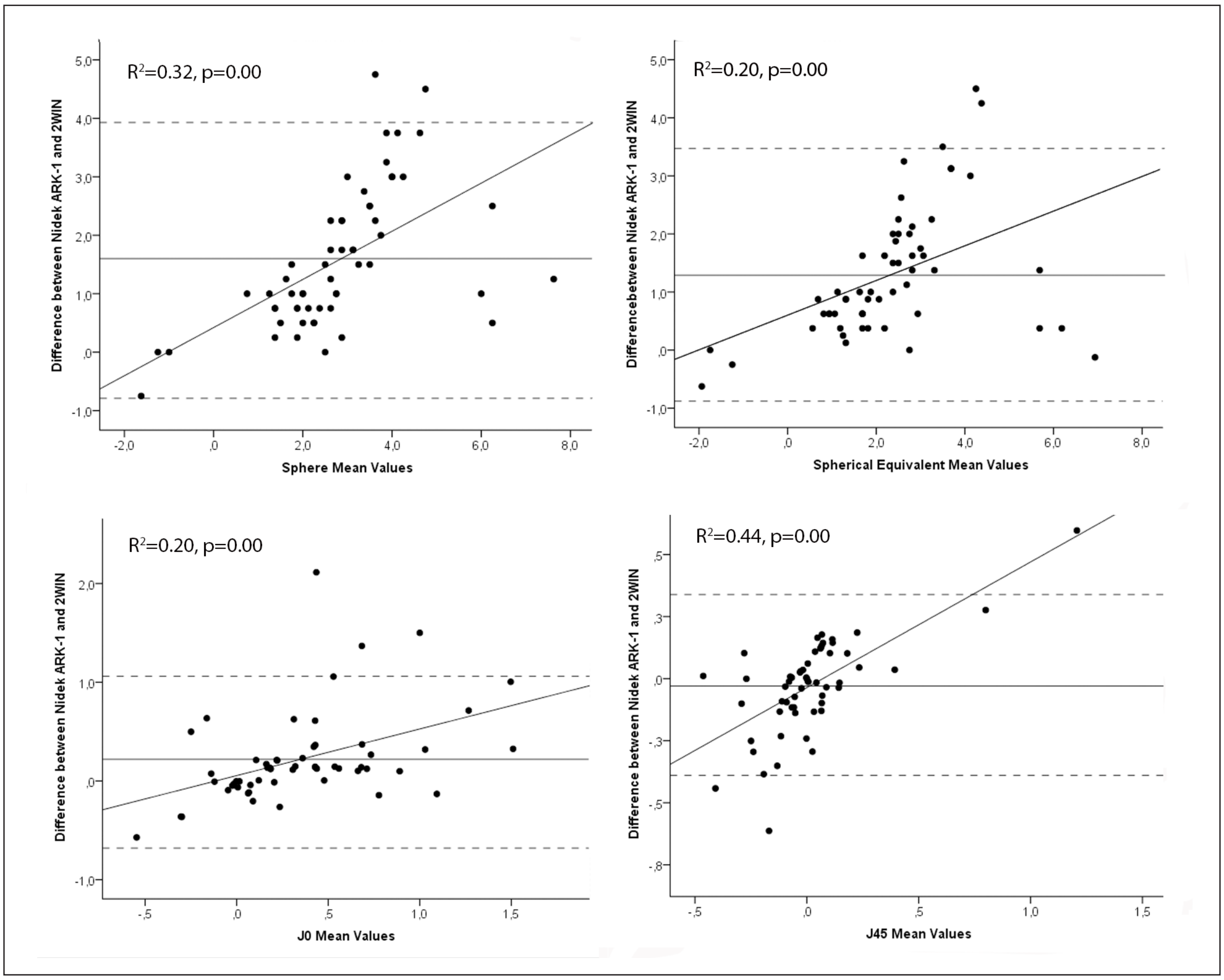

FIGURE 5. Difference between Nidek ARK-1 and 2WIN for sphere, spherical equivalent (SE), and cylindrical vectors at 0 degrees (J0) and 45 degrees (J45). Dashed lines present 95% limit of agreement (LOA), solid horizontal line presents the mean of the differences between methods

Table 3. 95% limit of agreement (LOA) of a sphere, spherical equivalent (SE), cylindrical vectors at 0 degrees (J0), and 45 degrees (J45) vector measured by the retinoscopy, Nidek ARK-1, and 2WIN

	Sphere	SE	J0	J45
Retinoscopy and Nidek ARK–1	–0.32–0.55	–0.37–0.45	–0.12–0.18	–0.19–0.22
Retinoscopy and 2WIN	–0.99–3.99	–1.01–3.51	–0.68–1.06	–0.34–0.26
Nidek ARK–1 and 2WIN	0.79–3.93	–0.88–3.47	–0.68–1.12	–0.40–0.34

of refraction defects in this age group is particularly important. We sometimes use handheld refractometers for this purpose in the pediatric ophthalmological office but doing that in everyday practice, we questioned if the measurements were comparable to those from table-mounted refractometer or retinoscopy.

In the presented study in a pediatric clinical sample, a significant difference was found between the refractive measurements of the handheld 2WIN and table-mounted refractometer measurements, as well as between 2WIN and cycloplegic retinoscopy (Tab. 2). The mean difference between 2WIN and other devices was >1D for the sphere and SE (Tab. 2). The difference was more pronounced in higher sphere and cylinder values, where 2WIN measured lower values than the other two methods (Fig. 4 and 5). In these children with higher refractive values difference was also clinically significant.

Ogbuehi et al. [12] compared subjective refraction, Topcon KR8800, and 2WIN in adults in non-cycloplegic conditions. Despite the absence of a significant difference in mean SE between the 2WIN and subjective refraction, the 2WIN showed a tendency to overestimate moderate-to-high myopia and a more pronounced underestimation of moderate-to-high hyperopia, which was also a concern because significant hyperopia in very young children, which is associated with the development of amblyopia, may be missed. When the Topcon KR8800 autorefractor was compared with the 2WIN videorefractor, the Topcon KR8800 measured statistically significantly more myopic sphere and SE than the 2WIN videorefractor. The mean SE for Topcon KR8800 was –0.96 ± 2.21 and for 2WIN –0.67 ± 1.96 diopters in the first session and similarly in the second session. The mean cylinder powers measured by the Topcon autorefractor were statistically significantly more positive than 2WIN videorefractor measured values.

In another study by Yalcin et al. [13], where cycloplegic 2WIN, Plusoptix table-mounted refractor, benchtop refractometer, and retinoscopy measurements in children were compared, consistency was observed in all methods in terms of the sphere and SE (mean value of the right eye 1.66 ± 2.42), consistency dropped in cylindrical values, and no consistency was found in axis values.

On the other hand, some studies found that table-mounted and handheld measurements were comparable, and the measurement differences were clinically insignificant. Prabakaran et al. [9] reported that the table-mounted autorefractor Canon FK-1 appeared to produce cycloplegic readings more similar to streak retinoscopy in children and suggested it should be used as the instrument of choice where possible. The Retinomax (handheld) values were significantly more »minus, «but this difference was minimal (< 0.3 D) and clinically insignificant. The measurements were lower compared to the presented study. The mean SE measured by streak retinoscopy was 1.09 ± 1.58 D. Most children (41/51, 80.4%) had SE between 0 and +1.5 D.

In a study by Mirzajani et al. [14] in a mainly adult population, non-cycloplegic refraction clinically insignificant differences were found between Nidek table-mounted autorefractometer and handheld autorefractometer where mean standard error (SE) (0.08 ± 1.37) in table-mounted autorefractometer was also lower compared to presented study. In a study [14], a significant difference, although considered clinically insignificant, was observed in the results of the sphere, SE, and J45 vector between the Auto Ref/Keratometer Nidek ARK-510A (table-mounted) and Auto Ref/Keratometer Nidek ARK-30 (handheld). Still, there was no significant difference in J0 vector. The two devices' spherical error and cylindrical power measurements had a significant correlation. Also, the 95% LOA between the two devices was narrow. In the present study, the 95% LOA was the narrowest for sphere, SE, J0, and J45 vector for Nidek ARK-1 refractometers and retinoscopy. The 95% LOA for 2WIN and Nidek ARK-1 refractometer or retinoscopy were wider (Fig. 3–5).

In a study by Akil et al. [11], the mean SE as measured after cycloplegia in a pediatric population by Retinomax K-plus 3, Canon RK-F1, and cycloplegic retinoscopy was 1.57 ± 2.48, 1.57 ± 2.55, and 1.73 ± 2.64 D, respectively. The refractive error components were highly correlated between the two instruments and cycloplegic retinoscopy. A comparison between autorefractors and retinoscopy in the present study also showed a good correlation between the handheld 2WIN, the table-mounted Nidek ARK-1 autorefractor, and streak retinoscopy for sphere, SE, J0, and J45 vectors except for Nidek ARK-1 and retinoscopy and Nidek ARK-1 and 2WIN for J45 vector (Tab. 2).

We found that the 2WIN was portable and easy to use. It had the additional benefit of measuring autorefraction without having a subject positioned on a chin-rest as in a table-mounted refractometer (which is usually difficult for very young children). Measuring, which takes a few seconds, can be challenging in less cooperative children as it needs some fixation. The 2WIN videorefractor has a limited operating range, which might also impact the measurements in higher refractive errors.

The advantages of our study include the assessment of refractive measurement in cycloplegia. Cycloplegia increases the accuracy of autorefractometers [15–18], so the comparison of refractive measurements between refractometers was more reliable. Cycloplegic refraction is especially important in determining correct refractive error in children at risk of refractive amblyopia. In the study, young children were included where obtaining accurate refractive error measurements continues to be challenging. We also assessed some children with high ametropia and a high amblyopia risk.

Disadvantages include a relatively small sample size and the fact that confirmatory cycloplegic refractions were not completely masked from the preliminary autorefraction in every case in a busy clinical practice. Variability in the measurements may also occur given these young children's cooperation, alignment, and fixation inconsistency.

CONCLUSIONS

The table-mounted autorefractor provided a reading more similar to that of streak retinoscopy than to that of the handheld autorefractor. In the higher refractive values, differences between the handheld autorefractor and table-mounted autorefractor or retinoscopy were more considerable and clinically significant in the presented pediatric group. Careful interpretation of the autorefraction results would be advised, especially in children with higher refractive values at the most significant risk for amblyopia. Cycloplegic retinoscopy can be valuable in confirming the accuracy of cycloplegic autorefraction, particularly when autorefraction results are inconsistent with expected findings.

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Conflict of interests

The author reports no competing interests.

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