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ORIGINAL ARTICLE

A Comparison of Autorefractor Performance

KONRAD PESUDOVS, PhD, FAAO and HARRISON SCOTT WEISINGER, PhD

Department of Ophthalmology, Flinders Medical Centre, Flinders University, Bedford Park, South Australia, Australia (KP); and Department of Optometry and Vision Sciences, University of Melbourne, Victoria, Australia (HSW)

ABSTRACT: *Purpose.* To compare the agreement between subjective refraction and autorefraction using two commercially available autorefractors. *Methods.* Prospective data were collected for 190 subjects using either the Nidek ARK-700A (Fremont, CA) or the Topcon KR-8000 (Paramus, NJ) and subjective refraction (masked to autorefraction). Refractions were compared in terms of spherical equivalent using Bland-Altman limits of agreement and astigmatic vector difference using median and 95th percentile. *Results.* The two groups were similar for age, gender, spherical equivalent, and astigmatic power. The differences in spherical equivalent between subjective and autorefraction were significantly different (mean ± SD; Nidek, −0.03 ± 0.36 D; Topcon, +0.11 ± 0.34 D; analysis of variance, F = 7.84; p < 0.01). However, the 95% limits of agreement were similar: Nidek, −0.74 to +0.68 D; Topcon, −0.55 to +0.77 D. The median differences in astigmatic vector difference were also similar: Nidek, 0.27 D and Topcon, 0.25 D. However, the 95th percentile was 0.67 D for Nidek and 1.09 D for Topcon. There was a low frequency of large (>1.00 D) differences in spherical equivalent, 1.1% with each autorefractor. There were five cases with astigmatic vector difference >1 D, all with the Topcon KR-8000 (5.3%). *Conclusions.* Both autorefractors show excellent agreement with subjective refraction. Despite a statistically significant difference in mean spherical equivalent (0.14 D), near identical limits of agreement (0.10 D difference) suggest clinical equivalence. Conversely, for astigmatism, despite similar median scores, major outliers were more likely with the Topcon, reflected in a 0.42 D larger 95th percentile, which suggests a small advantage for the Nidek for avoiding large astigmatic errors. (Optom Vis Sci 2004;81:554–558)

Key Words: autorefractor, autorefraction, refraction, spherical equivalent, vector analysis

It is widely accepted that autorefraction is not sufficiently accurate to substitute for subjective refractions for the purposes of prescribing spectacles.[1] Autorefraction tends to be used to provide a starting point for subjective refraction.[1, 2] Autorefraction is also used to monitor refractive error in longitudinal studies of myopia progression[2] and to screen for refractive errors in children.[3–5] Although there have been numerous studies examining the performance of autorefractors, these reports become redundant when instruments are no longer commercially available.[6, 7] Therefore, we have undertaken a comparative examination of the agreement between subjective refraction and autorefraction for two commercially available autorefractors.

METHODS

The study was cross-sectional in design with two independent subject groups, one for each autorefractor used: Nidek ARK-700A (Fremont, CA) and Topcon KR-8000 (Paramus, NJ). Subjects were prospectively recruited, and informed consent was obtained from all subjects after the nature of the study had been fully explained. The tenets of the Declaration of Helsinki were followed, and the Leeds Regional Ethical Committee approved the study. Inclusion criteria were age ≥14 years and a visual acuity (VA) better than 0.1 logarithm of the minimum angle of resolution (6/7.5). Exclusion criteria were any ocular pathology (including any condition known to interfere with autorefractor performance, e.g., asteroid hyalosis[8]) or abnormality including amblyopia and strabismus, any previous ocular surgery, inability to speak English sufficiently, or insufficient mental ability to comply with subjective refraction with confidence. Only one eye per subject is included in the study. This was chosen randomly except when only one eye fulfilled the inclusion and exclusion criteria.

Manifest refraction was determined using subjective refraction only. One clinician (K.P.) conducted all subjective refraction and autorefraction. Subjective refraction was performed before autorefraction to maintain masking. However, the prescription of any old or previous spectacles was available to the clinician at the time of testing. These were usually used as the starting point of subjective refraction. Therefore, the subjective refraction was performed with the clinician masked to autorefraction but not masked toward previous spectacles. Therefore, if there were any bias, the subjective refraction would have been biased toward the previous spectacles.

Subjective refraction was performed using a trial frame, in which loose lenses could be inserted so the lens with the highest refraction was apposed to the eye, separated by a vertex distance of 12 mm. Careful subjective refraction was undertaken by determination of best vision sphere and the Jackson's cross-cylinder technique. Changes in cylinder power were compensated for by adjustment of sphere power, but all such compensations were double checked subjectively. The final cylinder power was defined as the highest cylinder power for which an increase was requested. Each eye was refracted monocularly, followed by binocular balancing. The final spherical power was defined as the highest plus value or the lowest minus value that gave the best visual acuity. All refractive measurements were done without cycloplegia. Manifest refraction was recorded to the nearest 0.25 DS, 0.25 DC, and 2.5°.

The Nidek ARK-700A autorefractor works according to Scheiner's double pinhole principle. Two infrared light sources illuminate the retina through a small aperture and reflect image onto a photodetector. Moving the position of the aperture varies the image focus, and its position for the sharpest image gives the measure of refractive error. The different meridians are measured by a coupled rotation of the illumination and the electronic detection system. This device has an autofogging mechanism to relax accommodation.[9] The autorefractor has a measurement range from −18.0 to +23.0 D in sphere and up to ±8.0 D in cylinder and can measure through pupils as small as 2.0 mm. Measurements were taken according to the manufacturer's instructions using the autotracking and autoshot functions, with accuracy set to 0.12 D for power and 1° for axis.[10] Five measurements of an eye were taken, and the values were automatically averaged.

The Topcon KR-8000 autorefractor also works according to the Scheiner double pinhole principle. In this case, two light sources are imaged in the plane of the pupil to simulate the Scheiner pinhole apertures. A photodetector observes the degree of coincidence between the two images on the fundus. The focus is adjusted by axial displacement of the illumination and detection systems. First, the Badal system is focused in one meridian, and then continuous measurements are taken through 180° using a rotating prism system. A "fogging" target is also used to relax accommodation. The autorefractor has a measurement range from −25.0 to +22.0 D in sphere and up to ±8.0 D in cylinder. Measurements were taken according to the manufacturer's instructions using the automeasurement functions, with accuracy set to 0.12 D for power and 1° for axis.

A record of previous spectacle correction was also made, when available (N = 134), for comparison to subjective refraction. This was to determine whether autorefraction or previous spectacles made a better starting point for subjective refraction (i.e., which was closer to the subjective refraction endpoint). Subjective and autorefraction and previous spectacle correction data were stored in a spreadsheet and converted into spherical equivalents (sphere + 1/2 cylinder) for calculation of differences. The differences are shown as positive if the subjective refraction was more hyperopic (less myopic) than the autorefraction and negative if the subjective refraction was more myopic (less hyperopic) than the autorefraction. Bland-Altman limits of agreement (mean difference between the two methods ± 1.96 SD of the differences)[11] were used to compare spherical equivalent agreement as in previous studies of autorefraction agreement with subjective refraction.[2, 4, 6, 12]

Similarly, recent studies have established that astigmatism should be compared with Fourier or vector analysis of differences because this considers the magnitude and the direction of two cylinders when calculating their difference.[2, 5, 13–17] Several approaches have been described, but they are all based on the trigonometric difference between two vectors.[17] However, the results may be expressed in a number of ways. In this study, we report the power (length) and axis of a vector that connects vectors representing the subjective refraction and autorefraction astigmatism (difference vector). The Bland-Altman limits of agreement method is not appropriate for vector differences because these data are not normally distributed. The median vector differences and 95th percentile are presented as an alternative. The success of matching the

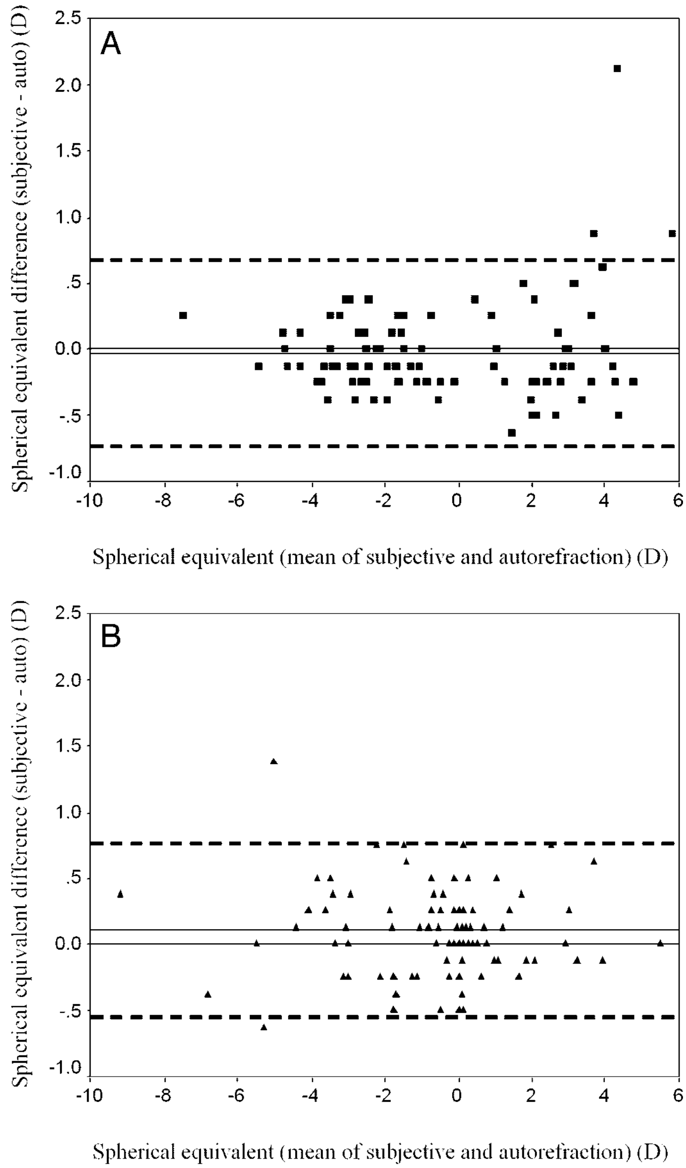

FIGURE 1.

The agreement between subjective and autorefraction spherical equivalent (D) for A: the Nidek ARK-700A (■), the lines indicate mean agreement (solid line at −0.03 D) and the 95% limits of agreement (dashed lines at −0.74 and +0.68 D), and B: the Topcon KR-8000 (▲), the lines indicate mean agreement (solid line at +0.11 D) and the 95% limits of agreement (dashed lines at −0.55 and +0.77 D).

groups and any differences in means between groups were assessed using analysis of variance with the SPSS statistical analysis program (SPSS software, version 10.1, Chicago, IL).

RESULTS

The total sample consisted of 190 subjects (mean ± SD; age, 38.9 ± 14.3 years; gender, 52% female; manifest spherical equivalent refractive error, −0.53 ± 2.62 D; and manifest cylinder power, 0.59 ± 0.67 D), who formed two groups: the Nidek ARK-700A (N = 95; age, 39.0 ± 13.2 years; gender, 52% female; spherical equivalent, −0.49 ± 2.96 D; and cylinder power, 0.58 ± 0.63 D) and the Topcon KR-8000 (N = 95; age, 38.9 ± 15.4 years; gender, 52% female; spherical equivalent, −0.58 ± 2.25 D; and cylinder power, 0.61 ± 0.70 D). The groups were similar for age (analysis of variance; $F_{1,189} = 0.04$, $p > 0.05$), gender ($\chi^2 = 0.19$, $p > 0.05$), spherical equivalent refractive error (analysis of variance; $F_{1,189} = 0.05$, $p > 0.05$), and cylinder power (analysis of variance; $F_{1,189} = 0.09$, $p > 0.05$).

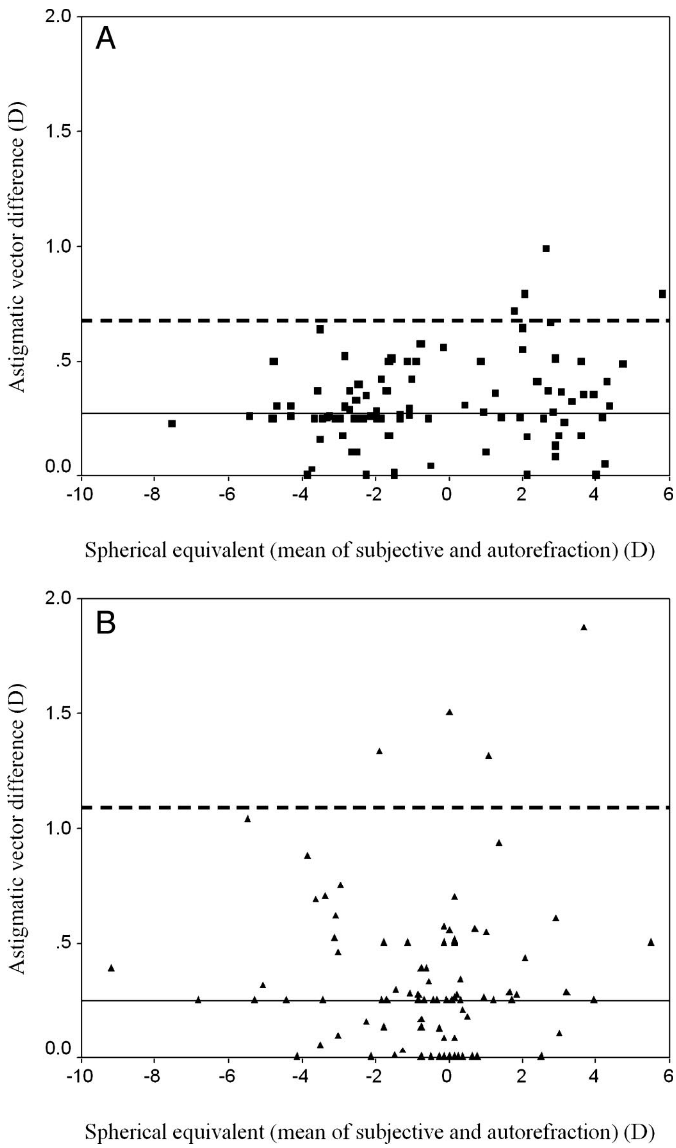

FIGURE 2.

The agreement in astigmatism of subjective and autorefraction as a function of spherical equivalent (average of subjective and autorefraction; D) for A: the Nidek ARK-700A (■), the lines indicate median vector difference (solid line at +0.27 D) and the 95th percentile (dashed line at +0.67 D), and B: the Topcon KR-8000 (▲), the lines indicate median vector difference (solid line at +0.25 D) and the 95th percentile (dashed line at +1.09 D).

Spherical Equivalent Analysis

The Nidek ARK-700A group had a mean (± SD) difference between subjective and autorefraction in spherical equivalent of −0.03 ± 0.36 D, which gave 95% limits of agreement of −0.74 to +0.68 D (Fig. 1A). The Topcon KR-8000 group had a mean difference of +0.11 ± 0.34 and 95% limits of agreement of −0.55 to +0.77 D (Fig. 1B). These means were significantly different (analysis of variance; $F_{1,189} = 7.84$, $p < 0.01$). The difference in spherical equivalent between subjective refraction and previous spectacles was 0.03 ± 0.50 D, giving 95% limits of agreement of −0.96 to +1.02 D.

Astigmatic Vector Analysis

The Nidek ARK-700A group had a median astigmatic vector difference between subjective and autorefraction of 0.27 D, with a 95th percentile of 0.67 D (Fig. 2A). The Topcon KR-8000 group had a median astigmatic vector difference of 0.25 D, with a 95th percentile of 1.09 D (Fig. 2B). The median astigmatic vector difference between subjective refraction and previous spectacles was 0.25 D, with a 95th percentile of 0.98 D. The difference vectors are displayed in Fig. 3. All difference vectors start at the origin, but for clarity only the endpoints are shown. Most vector differences were <1.00 D, and the distributions of response appear random, suggesting no directional error bias.

Outlier Analysis

The frequency of clinically significant discrepancies between subjective refraction and autorefraction was calculated. The cases with >0.50 D difference from subjective refraction for spherical equivalent were (number and percentage) 5 and 5.3% for Nidek ARK-700A and 9 and 9.5% for Topcon KR-8000 (see Fig. 1).

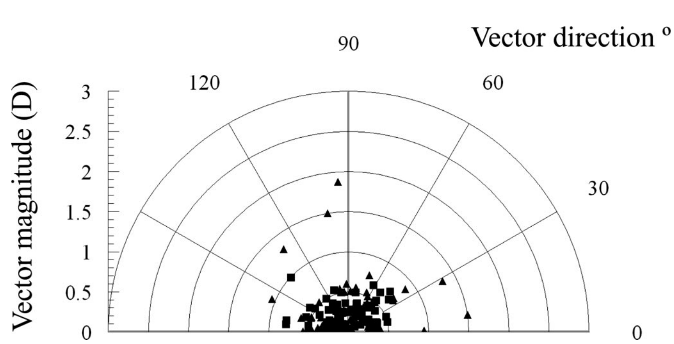

FIGURE 3.

Vectorial display of the difference in astigmatism between subjective refraction and autorefraction for Nidek ARK-700A (■) and the Topcon KR-8000 (▲). The distance of each marker from the origin indicates the magnitude (D) with the position (°) indicating the direction of the difference vector. No directional bias is evident for either autorefractor.

This was not significantly different (χ^2, 1.14, $p > 0.05$). There were two cases with spherical equivalent disagreement >1 D, one (1.1%) with each autorefractor. The cases with >0.50 D astigmatic vector difference were (number and percentage) 13 and 14% for Nidek ARK-700A and 20 and 21% for Topcon KR-8000 (see Fig. 2). This was not significantly different (χ^2, 1.48, $p > 0.05$). There were five cases with astigmatic vector difference >1 D, all with the Topcon KR-8000 (5.3%). This was significantly different (χ^2, 12.5, $p < 0.05$).

DISCUSSION

Subjective refraction and autorefraction gave similar results for spherical equivalent refractive error. Although the mean difference in spherical equivalent was significantly different between autorefractors, the magnitude of the difference was only 0.14 D; therefore, this significance reflects the large sample rather than a clinically important difference. The two autorefractors had almost identical 95% limits of agreement, with the Topcon KR-8000 having 0.10-D tighter agreement. In a clinical setting, this could also not be considered a significant difference. For ease of comparison with previous studies, the limits of agreement of Nidek ARK 700A (−0.74 to +0.68 D) and Topcon KR-8000 (0.55 to +0.77 D) could be reported as Nidek ARK 700A ±0.71 D and Topcon KR-8000 ±0.67 D. These results are similar to previous studies for Nidek[6, 7, 18, 20] (e.g., AR-1000, ±0.55 D[6]) and Topcon (e.g., RM-A6000, ±0.71 D).[19]

No directional astigmatic error bias was evident for either autorefractor. The Nidek and Topcon median astigmatic vector difference was similar. The Nidek ARK-700A autorefractor had a smaller 95th percentile for astigmatism than the Topcon KR-8000 autorefractor by 0.42 D. This is probably clinically important but only in terms of outliers. The Nidek ARK-700A performed better than in a report of an earlier version (ARK-2000)[21] and similarly to the current version (ARK-600A).[18]

An important issue for autorefractor performance is the frequency of major discrepancies because such results may have adverse consequences whatever uses the autorefractor is put to. For 0.50 D magnitude errors, there were slightly but not significantly more errors with the Topcon for spherical equivalent (see Fig. 1) and vector differences (see Fig. 2). Although both instruments had discrepancy rates of <10% for spherical equivalent, the rates were 14% for Nidek and 21% for Topcon for astigmatic vector difference. This suggests that autorefraction astigmatism results must be interpreted with some caution. There was a low rate of large discrepancies with only two cases of >1-D difference in spherical equivalent, one with each machine (see Fig. 1). However, for astigmatic vector difference, there were clearly more large errors with the Topcon machine, which was also reflected in the larger 95th percentile (see Fig. 2).[5] This suggests a clinical advantage for the Nidek ARK-700A over the Topcon KR-8000 but only in terms of a lower rate (0% vs. 5.3%) of 1 D astigmatism errors. Although neither autorefractor produced a high rate of large errors, a reduction in the rate of astigmatic vector differences >0.50 D is probably the most useful potential improvement in autorefraction performance.

The overall similar performance of the Topcon and Nidek autorefractors is not surprising given they both work according to Scheiner's double pinhole principle. The significant mean difference in spherical equivalent probably simply reflects a small difference in calibration. The only other difference was in the frequency of large astigmatic errors. This is a difficult to explain with confidence; it may be caused by the different measurement technique for astigmatism or perhaps by a measurement quality control issue with the Topcon.

Previous spectacles had no mean difference from subjective refraction spherical equivalent, but the 95% limits of agreement were much poorer than with autorefraction (0.56 to 0.66 D broader). This was despite the previous clinician not being masked to the previous spectacles but masked to the autorefraction. Similarly, for the astigmatic differences, both autorefractors and previous spectacles had the same median value; the Nidek had a smaller 95th percentile (0.67 D), but the Topcon (1.09D) was similar to worse than previous spectacles (0.98 D). Therefore, autorefractors provide a starting point more predictive for subjective refraction, especially in terms of spherical equivalent, than previous spectacles.

The limits of agreement between subjective refraction and autorefraction are comparable with previously reported test-retest repeatability of subjective refraction (95% limits of agreement, ±0.63 D,[12] ±0.78 D,[2] and ±0.51 D[15]). Notably, the test-retest repeatability of autorefraction (95% limits of agreement, ±0.38 D[2] and ±0.32 D, under cycloplegia[12]) is significantly better.[14] It may be difficult to improve on these limits of agreement because subjective refraction is not an ideal gold standard. In one study comparing subjective refraction with autorefraction, VA was better with autorefraction than subjective refraction in 15% of cases.[22] Although this was probably largely the result of test-retest variation in VA, it might illustrate that flawed results can occur with subjective refraction. A previous study looking at reliability of subjective refraction found a median vector difference of 0.20 D with a 95th percentile of 0.62 D.[15] Because the agreement between autorefraction (at least with the Nidek) and subjective refraction is as good as between two clinicians and the repeatability of autorefraction is superior to subjective refraction, autorefraction should be suitable for tasks such as screening for refractive error,[4, 5] pretesting to provide a starting point for subjective refraction,[1, 2] and as an outcome measure for myopia progression studies.[2]

It is generally agreed that autorefraction is not suitable to substitute for subjective refraction for the purposes of prescribing spectacles.[1] Human testing has advantages over autorefraction because additional procedures, like binocular balancing and measurement of oculomotor coordination, improve on refraction toward information necessary for prescribing. Certainly, refraction and prescribing are different concepts; the latter involves a thought process that considers the previous prescription, the likelihood of the new prescription being tolerated, the needs of the patient, and so on.[23, 24] For all these reasons, refraction alone, whether it is subjective or automated, cannot substitute for prescribing. However, our results suggest that the autorefractors assessed in this study serve as excellent tools to approximate a patient's refractive error.

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Konrad Pesudovs
College of Optometry
University of Houston
505 J. Davis Armisted Building
Houston, TX 77204-2020
e-mail: konrad@pesudovs.com