Comparison of a Novel Binocular Refraction System with Standard Digital Phoropter Refraction

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SIGNIFICANCE: New refractive technologies are consistently emerging in the optometry market, necessitating validation against current clinical standards.

PURPOSE: This study aimed to compare the refractive measurements between standard digital phoropter refraction and the Chronos binocular refraction system.

METHODS: Standardized subjective refraction was conducted on 70 adult participants using two separate refraction systems. The final subjective values from both devices were compared for M, J_0, and J_{45}. The time taken to complete refraction and patient's comfort were also evaluated.

RESULTS: Good agreement was found between the standard and Chronos refraction, with narrow mean differences (including 95% confidence intervals) and no significant bias for M (0.03 D, –0.05 to 0.11 D), J_0 (–0.02 D, –0.05 to –0.01 D), and J_{45} (–0.01 D, –0.03 to 0.01 D). The bounds of the limits of agreement of M were –0.62 (lower bound; –0.76 to –0.49) and 0.68 (upper bound; 0.54 to 0.81), those of J_0 were –0.24 (lower bound; –0.29 to –0.19) and 0.19 (upper bound; 0.15 to 0.24), and those of J_{45} were –0.18 (lower bound; –0.21 to –0.14) and 0.16 (upper bound; 0.12 to 0.19). No significant differences were noted between the two techniques for any of the refraction components (M standard = –3.03 ± 2.42 D, M novel = –3.06 ± 2.37 D, $z = 0.07$, $P = .47$; J_0 standard = 0.12 ± 0.40 D, J_0 novel = 0.15 ± 0.41 D, $z = 1.32$, $P = .09$; J_{45} standard = –0.04 ± 0.19 D, J_{45} novel = –0.03 ± 0.19 D, $z = 0.50$, $P = .31$). The Chronos was significantly faster than the standard technique, with an average difference of 19 seconds (standard, 190 ± 44 seconds; novel, 171 ± 38 seconds; $z = 4.91$; $P < .001$).

CONCLUSIONS: The final subjective refraction end points of the standard technique and the Chronos were well aligned in this group of adult participants, and no statistically or clinically significant differences were noted in M, J_0, or J_{45} components. The Chronos offered improved efficiency, meeting the demands of eye care.

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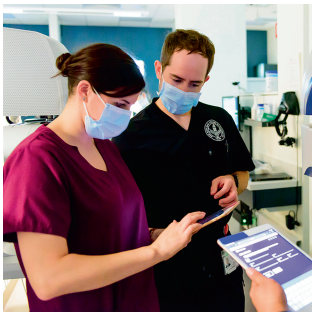

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A key component of the optometric examination is determining the optimal correction for the patient's refractive error.[1,2] Refractive error can be assessed using objective techniques including retinoscopy or autorefraction, subjective techniques such as manual subjective refraction (using trial lenses or a phoropter), or a combination of both. Subjective refraction typically uses an objective starting point to begin the procedure.[3–5] Currently, the most common method used to determine the refractive error of a typical healthy adult is manual distance subjective refraction using a phoropter.[1] This procedure can be time-consuming, and with the ever-increasing demand for access to eye care and examination efficiency, techniques aimed at accurately and efficiently assessing patients' refractive error are continuously being developed.[6–8] To evaluate the accuracy of novel refraction techniques, subjective refraction has previously been used as the standard for comparison.[9–15] The end point value of subjective refraction is often used for validation of new refraction methods, as it provides the best-corrected visual acuity and the value most likely to be accepted by patients for their refractive correction.[16]

The number of diagnostic devices pertinent to delivering effective patient care in clinical practice has increased significantly.[6] As the popularity of automated refractions began to rise in the 1970s, the value of autorefraction has been confirmed as a starting point for subjective refraction.[1,3–5] Another instrument aimed at improving the efficiency of subjective refraction is the digital phoropter. Digital phoropters are manufactured by several different ophthalmic companies with many instruments approved by the U.S. Food and Drug Administration as ophthalmic refractometers, with clinical data that are validated and compare with the manual phoropter.[6] The ability to combine objective testing and subjective testing within the same device may be valuable, as it may increase efficiency and allow practitioners to directly compare subjective reports with objective measurements.

Binocular refraction was first described in the 1940s and became more popular in the 1960s and 1970s in the United States and United Kingdom as a potentially enhanced refractive technique.[17–19] The clinical advantages of binocular refraction include refracting in a more natural state for the patient, not interrupting

fusion, and assisting in identifying patients with fusion issues or visual suppression.[1,20] There are also specific refractive conditions for which binocular refraction is particularly indicated, including hyperopia, pseudomyopia, antimetropia, and latent nystagmus.[20] The most common binocular refraction procedures include the use of monocular fogging (modified Humphriss), Humphriss Immediate Contrast, polaroids, and shutter glasses.[1,8,21] It is important to note that, even though each of these techniques allows the patient to maintain some level of fusion throughout the procedure, most of these methods are not truly "binocular" but rather "biocular" in nature, as they dissociate the images between the two eyes. However, they are typically all categorized as binocular techniques in the literature and clinical practice, and we will therefore refer to them as binocular.

One new instrument developed to assess refractive error is the Chronos binocular refraction system (Topcon Corporation, Tokyo, Japan). The device is a stand-alone instrument that can obtain autorefraction measurements and perform a subjective refraction within the same instrument. The device is available in the United States as an ophthalmic refractometer. It consists of two autorefractors (one for each eye), a phoropter, and two visual acuity charts (one for each eye). The two autorefractors use a super luminous diode light source to illuminate a ring aperture projected through a rotary prism. Like standard autorefractors, it provides interpupillary distance, keratometry values, and automated refraction values for each eye. The device is controlled with a tablet that enables a user interface to manually operate the phoropter within the device.

A special feature of the Chronos device is that it performs refraction under what is traditionally called binocular vision conditions, with both eyes unoccluded. The Chronos uses a stereoscopic view through an independent display that is presented to each eye simultaneously. A system called "binocular lock" is used, which includes targets that are projected to and seen by both eyes simultaneously allowing for fusion as well as separate targets that are only displayed to the eye being tested. This system allows the nontested eye to fixate and maintain some fusion while the other eye is being tested for visual acuity or subjective refraction.

New technologies may differ from existing instrumentation in their setup and subject positioning. Participant physical comfort using new instrumentation may be assessed by ranking instrumentation from most to least comfortable or assessing visual comfort comparison on a numbered scale.[8,22]

Emerging automated refractive technology may assist the optimization of the eye examination workflow; if this technology can also conduct binocular refraction, it would offer additional significant benefits. New instrumentation must be validated by a method of comparison with existing procedures and must show comparable outcomes with such existing procedures before being used in patient care. The Chronos is novel in that it incorporates autorefraction and automated subjective refraction performed within the same instrument and also in that the subjective refraction protocol is performed binocularly, with different targets presented to each eye. Because of these differences, slightly different variations in the refraction procedures are needed, the specifics of which are outlined in the Methods section.

The purpose of this study was to perform a methods comparison to evaluate the agreement in subjective refraction results between a standard digital phoropter and the Chronos refracting system. Areas of interest when assessing this new device include refractive error outcomes, time to conduct refraction, and patient comfort. Therefore, we reported the final refraction values, time taken to complete refraction, and participant comfort within the device.

METHODS

Seventy adult participants between the ages of 18 and 65 years with normal vision and best-corrected visual acuity of 20/25 (+0.10 logMAR equivalent) or better in each eye were recruited for the study between August 12, 2021, and February 28, 2022. Participants were recruited from the New England College of Optometry and its affiliated clinics through email communication. The exclusion criteria were history of double vision, knowledge of a binocular vision problem, amblyopia, strabismus, ocular pathology, previous history of ocular surgery, current treatment with orthokeratology lenses, or concurrent participation in another ocular or vision research study. All participants completed a screening form answering questions on inclusion and exclusion criteria, informed consent, and demographic information. Participant best-corrected visual acuity and ocular alignment (cover test) were assessed before proceeding with the experimental tests of the study to confirm eligibility. This research was reviewed by the New England College of Optometry's independent ethical review board and conforms with the principles and applicable guidelines for the protection of human participants in biomedical research.

Participants were randomized to start testing with one of the two refraction systems: (1) standard automated distance subjective refraction with CV-5000 s digital phoropter (Topcon Corporation; "standard") and (2) novel automated binocular refraction with the Chronos ("novel"). The Chronos device was used as an automated phoropter for the purposes of this study. After the participants completed refraction on one system, they were moved to the following system consecutively with an optional break. The break was offered so that participants could use the restroom or water break; however, no participants elected to have a break between testing.

The two subjective refraction techniques began with autorefraction values as the starting point.[3–5,23] In the (1) standard station, we used the KR-1 autorefractor (Topcon Corporation) objective measures as the starting point, whereas the (2) novel Chronos station used the internal autorefractors within the same instrument. The KR-1 and Chronos autorefractors differ in terms of the light source. The KR-1 uses a light-emitting diode, whereas Chronos uses a super luminous diode, both having a 2-mm-diameter projection ring. Otherwise, the rotary prism and projected rings are the same between devices. In addition, the KR-1 is conducted one eye at a time, whereas the Chronos tests both eyes simultaneously. The subjective refraction protocol was standardized and identical for both subjective refraction techniques. The participants were not cyclopleged during either refraction technique.

The refraction protocol was described in detail hereinafter and in Fig. 1:

1. The objective starting point was entered into the phoropter or Chronos device, and the participant was fit comfortably to the instrument.
2. The left eye was occluded, and the full visual acuity chart encompassing letters from the 20/50 to the 20/20 acuity lines was presented.
   a. When one eye is occluded in the digital phoropter, that eye cannot see anything because there is an opaque occluder within the device blocking its view.

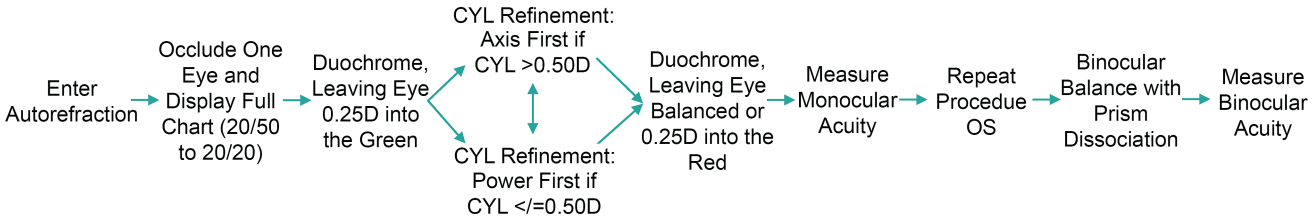

FIGURE 1. Flowchart of refraction protocol used for both the standard digital phoropter refraction and novel binocular refraction. CYL = cylinder; OS = left eye.

b. When one eye is "occluded" in the Chronos, the window for that eye remains open; that eye cannot see the letters displayed to the other eye, but it does see a black box around the letters presented. The fellow eye also sees this black box, allowing fusion during refraction.

3. The red-green filter was displayed over this chart, and the duochrome test was performed asking the participant to compare which letters appeared clearer, those on the red or those on the green side. If the participant reported that the letters on the red side were clearer, 0.25 D of minus sphere power was added. The process continued until the first time the participant reported that the letters on the green side were clearer or that they were equal.
   The lens power when the letters were first reported to be clearer on the green side or equal was chosen as the end point for this initial duochrome test. If the participant initially reported that the letters on the green side were clearer, 0.25 D of plus sphere power was added until the first time the participant reported that the letters on the red side were clearer or equal. In these cases, the end point was the least minus or most plus lens that made the switch from the letters on the green side clearer to the letters on the red side clearer or both equal.
4. Cylinder refinement was then performed using a Jackson cross cylinder.
   The red-green filter was removed, and a target with several black circular dots was displayed. The cylinder axis was refined before the cylinder power if the starting cylinder power was greater than or equal to 0.75 D; the cylinder power was refined before the cylinder axis if the starting cylinder power was less than or equal to 0.50 D.
   Cylinder axis and power were refined asking the participant which of two views made the dots sharper and rounder. The end point of the cylinder refinement for axis and power was when both views presented were of equal clarity, or if they went back and forth for two consecutive responses.

A cylinder check was performed when there was no starting cylinder power from the objective refraction. To perform the cylinder check, 0.50 D of cylinder power was added, and a power refinement was performed at the 180, 45, 90, and 135° meridians. If the participant rejected the added cylinder power at each meridian, the cylinder power was removed. If the cylinder power was accepted at any meridian during the power refinement, a cylinder axis refinement and cylinder power refinement were performed at that meridian as described previously.

5. Once the cylinder refinement was completed, the Jackson cross cylinder was removed, and the full acuity chart with letters from the 20/50 to the 20/20 acuity lines was presented again. The red-green filter was displayed over the chart. The duochrome test was performed again as described previously, except this time the end point was when the participant reported that the letters on both sides of the chart (red and green) were equally clear. If equality was not achieved, the end point was when the participant first reported that the letters on the red side were clearer than the green, to ensure that the participant was not given too much minus spherical power.
6. The red-green filter was then removed, and visual acuity was measured with the full chart with letters from the 20/50 to the 20/20 acuity lines. Participants were asked to read the smallest letters possible, even if they had to guess.
7. Once visual acuity was measured in the right eye, the right eye was occluded, and the same steps 1 through 6 described previously were completed for the left eye.
8. After visual acuity was measured in the left eye, both eyes were unoccluded, and a binocular balance was performed using a method for dissociation that differed slightly for the two techniques:
   a. For the digital phoropter station, a single acuity line larger than the best-corrected visual acuity in the poorer seeing eye was displayed with prisms in front of the participant's eyes to vertically dissociate the line of letters so that one eye saw a line above and the other a line below.
   b. For the Chronos, a single acuity line larger than the best-corrected visual acuity in the poorer seeing eye was displayed separately to each eye. The right eye saw the top line presented, and the left eye saw the bottom line. A black box around both lines and a black line between both lines were presented to each eye to provide fusion cues.

The participant was asked to report which line appeared clearer, and 0.25 D of spherical plus power was added to the eye with the clearer vision.

Once the participant reported that the two lines appeared equal or the clarity reversed from one line to the other, the binocular balance procedure was stopped.

9. The prism was then removed from the phoropter, or the binocular balance views were removed from the Chronos, and visual acuity was measured with the full chart with letters from the 20/50 to the 20/20 acuity lines and both eyes able to see the full chart.

A timer was started once the participant was fit comfortably to the instrument with the objective refraction starting point dialed

into the instrument. The timer was stopped once the visual acuity was measured for both eyes and each eye individually at the conclusion of the subjective refraction procedure described previously.

Refractive data were converted into power vectors using the previously recommended formula to generate spherical lens power equal to mean spherical equivalent (*M*) and two Jackson cross cylinders with one at axis 0 (J_0) and one at axis 45 (J_{45}).[24]

Upon completion of each station, the participants were asked to rank their physical comfort using each instrument for refraction using a 1- to 5-point Likert-style scale, with 1 being very uncomfortable and 5 being very comfortable.

The primary outcome measures included refractive end points with the standard and novel refraction techniques (*M*, J_0, and J_{45}) for the right eye, as well as the time taken to complete each subjective refraction (in seconds). Refraction and time data were assessed for normality using Shapiro-Wilk tests. The confidence intervals for mean differences provided are approximated using standard statistical methods.[25] The limits of agreement (LoAs) between the two subjective refraction techniques, two objective refraction starting points, and objective to subjective refraction results within each technique were generated for the right eye (*M*, J_0, and J_{45}) using Bland-Altman analyses. Limits of agreement were calculated by subtracting the two measurements and multiplying the standard deviations from the mean by 1.96. Intraclass correlation coefficients (ICCs) were computed using a mixed procedure for *M*, J_0, and J_{45} for each measurement pair. The between-participant variance and the within-participant variance were estimated. The ICC for the measurement pair was calculated as the ratio of the between and total variances, where total variance is the sum of the between and within variances. Times were analyzed using Wilcoxon signed rank tests. Statistical significance was set to 95% ($P < .05$) for all tests. A secondary outcome measure was the average participant comfort using each refracting system. The medians and Wilcoxon signed rank tests were used to obtain comfort questionnaire results.

RESULTS

The age of the 70 adult participants ranged from 22 to 62 years (average, 28 ± 8 years). The cohort was 74.7% female and 19.6% male, 4.3% preferred not to say, and 1.4% were nonbinary. Less than half (42.9%) of the participants identified as Asian/Asian American Pacific Islander, 1.4% were Black, 41.4% were White, 5.7% were of mixed race, and 8.6% preferred not to say. The participant's average *M* value for this group of participants' right eye was –2.75 ± 2.42 D, average J_0 was 0.12 ± 0.40 D, and average J_{45} was –0.03 ± 0.18 D.

Comparison analyses demonstrated good agreement between the two subjective refraction techniques (standard subjective vs. novel subjective refraction end points), with LoA calculated by subtracting the Chronos results from the standard phoropter results, with small mean differences including 95% confidence intervals (CIs) between the two for *M* (0.03 D, –0.05 to 0.11 D), J_0 (–0.02 D, –0.05 to –0.01 D), and J_{45} (–0.01 D, –0.03 to 0.01 D). The bounds of the LoAs of *M* were –0.62 (lower bound; –0.76 to –0.49) and 0.68 (upper bound; 0.54 to 0.81), those of J_0 were –0.24 (lower bound; –0.29 to –0.19) and 0.19 (upper bound; 0.15 to 0.24), and those of J_{45} were –0.18 (lower bound; –0.21 to –0.14) and 0.16 (upper bound; 0.12 to 0.19; Fig. 2). No systematic bias was found. There was a small tendency for more

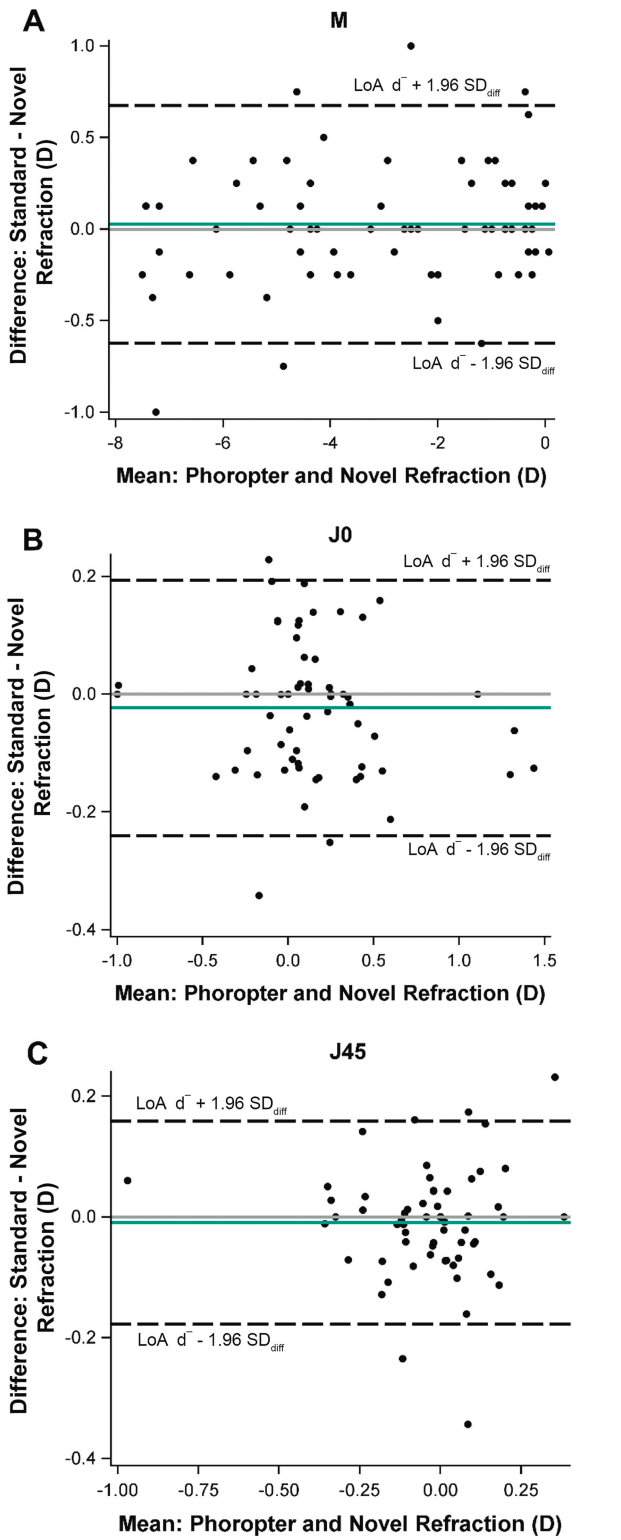

FIGURE 2. Bland-Altman plots comparing the limits of agreement of *M*, J_0, and J_{45} between the standard refraction and novel refraction techniques. The *x* axes represent the mean between the two methods of refraction, and the *y* axes represent the difference between the two (standard – novel) in diopters. The green horizontal line indicates the mean of the differences. The outer black dashed lines indicate the limits of agreement, calculated as 1.96 times the standard deviations from the mean, where the standard deviation is that of the differences.

hyperopic values (mean difference, +0.03 ± 0.33 D) when using the standard phoropter subjective refraction technique compared with the novel Chronos refraction technique.

The ICC was high for the three components (M = 0.99, J_0 = 0.96, J_{45} = 0.90). Wilcoxon signed rank tests showed no significant differences between the two techniques for any of the refraction components (M standard = –3.03 ± 2.42 D, M novel = –3.06 ± 2.37 D, z = 0.07, P = .47; J_0 standard = 0.12 ± 0.40 D, J_0 novel = 0.15 ± 0.41 D, z = 1.32, P = .09; J_{45} standard = –0.04 ± 0.19 D, J_{45} novel = –0.03 ± 0.19 D, z = 0.50, P = .31; Fig. 3).

A comparison of the autorefraction values between the two devices showed a more positive spherical equivalent with the KR-1 compared with the Chronos objective refraction measurements.

The mean differences including 95% CIs between the two were 0.18 D (0.11 to 0.26 D) for M, –0.07 D (–0.12 to –0.03 D) for J_0, and –0.02 D (–0.04 to 0.01 D) for J_{45}, with significant differences for M (standard, –2.75 ± 2.42 D; novel, –2.93 ± 2.47 D; z = 4.87; P < .001) and J_0 (standard, 0.12 ± 0.40 D; novel, 0.19 ± 0.45 D; z = 5.06; P < .001), but not for J_{45} (standard, –0.03 ± 0.18 D; novel, –0.01 ± 0.23 D; z = –0.54; P = .71). The bounds of the LoAs of M were –0.41 (lower bound; –0.53 to –0.28) and 0.78 (upper bound; 0.65 to 0.90), those of J_0 were –0.44 (lower bound; –0.52 to –0.37) and 0.30 (upper bound; 0.22 to 0.38), and those of J_{45} were –0.24 (lower bound; –0.29 to –0.20) and 0.21 (upper bound; 0.17 to 0.26).

Measurements for the KR-1 autorefractor compared with the CV-5000 digital phoropter subjective refraction demonstrated significantly more positive spherical equivalent values (M autorefractor = –2.75 ± 2.42 D, M subjective = –3.03 ± 2.42 D, z = 5.53, P < .001) and changes in oblique astigmatism (J_{45} autorefraction = –0.03 ± 0.18 D, J_{45} subjective = –0.04 ± 0.19 D, z = 1.75, P = .04) with the KR-1 autorefraction measurements, with no differences for J_0 (autorefraction, 0.12 ± 0.40 D; subjective, 0.12 ± 0.40 D; z = 1.07, P = .14). The mean differences including 95% CIs within the standard refraction station (autorefraction minus subjective measurements) were 0.28 D (0.19 to 0.37) D) for M, –0.01 D (–0.04 to 0.03 D) for J_0, and –0.01 D (–0.01 to 0.03 D) for J_{45}, with significant differences for M (z = 5.53, P < .001), J_0 (z = 1.07, P = .01), and J_{45} (z = 1.75, P = .04). The bounds of the LoAs of M were –0.46 (lower bound; –0.62 to –0.31) and 1.02 (upper bound; 0.87 to 1.18), those of J_0 were –0.30 (lower bound; –0.37 to –0.24) and 0.92 (upper bound; 0.23 to 0.36), and those of J_{45} were –0.13 (lower bound; –0.16 to –0.10) and 0.15 (upper bound; 0.12 to 0.18). The Chronos autorefraction measurements were also compared with the Chronos subjective refraction measurements (autorefraction minus subjective measurements), with more positive results in the autorefraction measurements indicating a more positive objective value (M autorefraction = –2.93 ± 2.47 D, M subjective = –3.06 ± 2.37 D, z = 3.03, P = .001), with larger objective J_0 values (J_0 autorefraction = 0.19 ± 0.45 D, J_0 subjective = J_0 = 0.15 ± 0.41 D, z = 2.74, P = .003) and no differences for the oblique astigmatism (J_{45} autorefraction = –0.01 ± 0.23 D, J_{45} subjective = –0.03 ± 0.19 D, z = 0.93, P = .18). The mean differences including 95% CIs within the standard refraction station (autorefraction minus subjective measurements) were 0.12 D (0.05 to 0.20 D) for M, –0.04 D (0.01 to 0.07 D) for J_0, and –0.02 D (–0.01 to 0.04 D) for J_{45}. The bounds of the LoAs of M were –0.49 (lower bound; –0.61 to –0.36) and 0.73 (upper bound; 0.60 to 0.86), those of J_0 were –0.20 (lower bound; –0.25 to –0.15) and 0.29 (upper bound; 0.24 to 0.34), and those of J_{45} were –0.15 (lower bound; –0.19 to –0.12) and 0.18 (upper bound; 0.15 to 0.22).

The novel Chronos refraction technique was significantly faster than the standard digital phoropter technique, with an average difference of 19 seconds (standard, 190 ± 44 seconds; novel, 171 ± 38 seconds; z = 4.91, P < .001; Fig. 4).

The median-assessed comfort using a 1- to 5-point Likert-style scale, with 1 indicating very uncomfortable and 5 indicating very comfortable, was 5 for each technique, and the participants were overall very comfortable with both techniques (Fig. 5). No significant differences were noted in comfort between the two techniques (z = 0.80, P = .21).

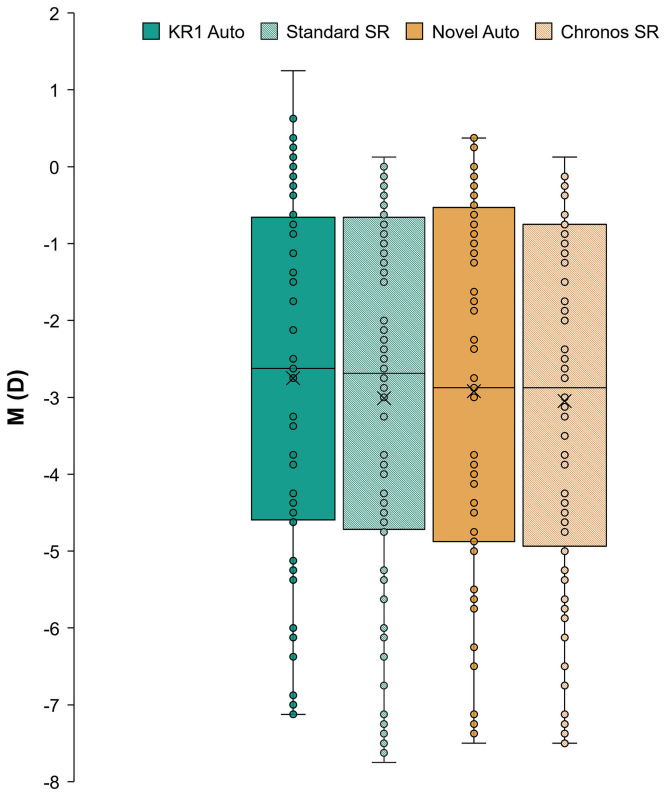

FIGURE 3. Boxplots for the M values for the subjective and objective refraction results from the novel and the standard refraction techniques.

DISCUSSION

New clinical technology must be compared with current standard techniques and demonstrate equivalent performance to be confidently used in clinical practice. This study showed good agreement in the subjective refraction end points between the two subjective refraction techniques using a standard digital phoropter and the novel Chronos system. There was no statistically significant difference between the two refraction techniques on M, J_0, or J_{45}, indicating that these may be used interchangeably in adults. There was also no systematic bias, although a slight trend to more minus spherical power (0.03 D) was found with the novel technique compared with the standard refraction, which is much lower than within examiner variation.[5,13,23] Clinicians can expect equivalent refraction end points whether using the standard

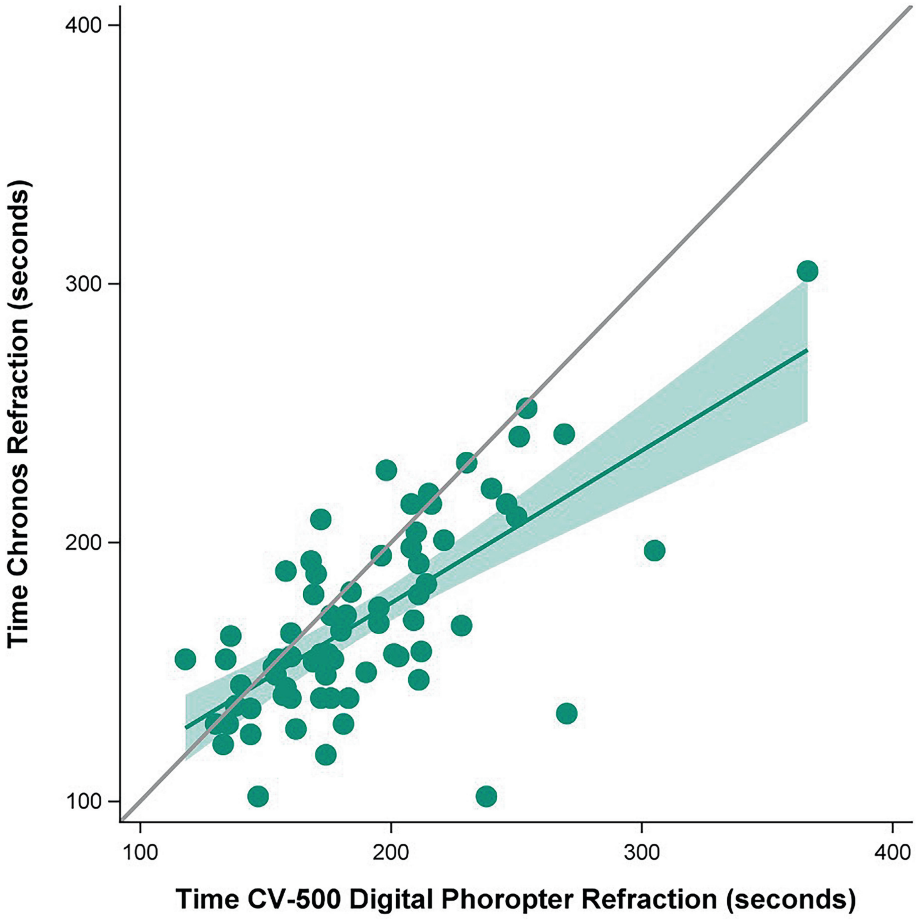

FIGURE 4. Comparison of time (in seconds) that it took to perform the novel refraction technique and standard refraction technique for each subject.

phoropter refraction technique or the novel Chronos binocular refracting system in adult patients.

The autorefraction values, or objective starting points, had slightly more positive spherical values with the KR-1 autorefractor (0.18 D) compared with the novel device's autorefraction, which is consistent with previous research comparing objective measurements between devices.[5,13,26,27] This may be due in part to the two instruments using a slightly different method to acquire the autorefraction results by using different light sources. These differences in starting points (more positive spherical equivalent on both autorefraction measures) did not affect the end points for subjective refraction, as these were not different as outlined previously.

The objective starting point was compared with the subjective refraction result for each technique. There was a trend for more positive spherical equivalent results on the objective measurements versus the subjective measurement for both techniques. The KR-1 was, on average, 0.27 D more positive than the subjective result using the conventional digital phoropter, whereas the novel refraction device's objective measurement was 0.12 D more positive than the subjective result from the same instrument. This may be due to the use of the duochrome technique to determine the starting sphere power before cylinder refinement rather than a fogging technique such as "maximum plus to maximum visual acuity."[2] The use of a more direct fogging technique would likely have resulted in a more positive spherical equivalent subjective refraction end point for both the digital phoropter refraction and the novel subjective refraction.

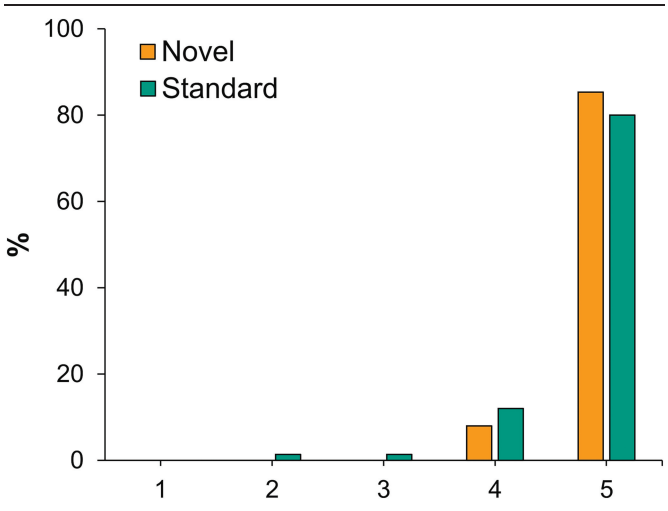

FIGURE 5. Frequency distribution of answers to the comfort question. Shown are percent distribution for 1- to 5-point scale for the standard and the novel subjective refraction techniques.

The novel refraction system was statistically faster with subjective refraction than the standard digital phoropter using the same refraction protocol (19 seconds, on average, which is 10% faster than the standard technique). Considering the increasing demands for examination efficiency in the health care setting, a shorter time spent on refraction could be used to further maximize clinic schedules and examination flow. It is important to note that the timing of the refractions did not include the time taken to obtain the autorefraction measurements and enter this information into each instrument. This would likely add a significant amount of time to the standard refraction compared with the novel refraction technique. As in standard refraction, the autorefraction measurement is typically obtained with a separate instrument, which, in most optometric practices, is also located in a different room. If these additional times—to enter the results of the autorefraction and the patient to travel—had been taken into account, the efficiency of the novel refracting system would have been even greater than the standard technique. In addition, the novel refracting system would also minimize transcription human errors when entering autorefraction information. These results indicate that the use of the novel device could lead to increased examination efficiency, patient volume, and revenue for the adult patient population with normal vision. The Chronos device is not currently recommended for use on individuals with known binocular vision anomalies or amblyopia. Future studies should be performed to further investigate the use of Chronos on individuals with these conditions.

Physical comfort ratings between the two systems were similar, and most participants rated both as "very comfortable." Given the physical differences between the two devices, the goal of this rating was to better understand whether the novel instrument's comfort would be comparable to what patients experience when refracted in a phoropter. The results indicate no differences in comfort between the devices.

The novel refracting system was operated using a tablet that allowed for increased physical distancing between the examiner and the participant. The COVID-19 pandemic introduced a contagious respiratory virus that is transmitted through respiratory droplets and close physical contact.[28,29] Precautions put in place to help stop the spread of the virus included universal masking and physical or social distancing. Other respiratory illnesses may pose a similar threat in the future, and similar precautions may be implemented. Increased physical distancing is challenging in the eye care setting because of frequent close contact required to perform the necessary components of the eye examination.[30,31] The ability to refract from a distance may help reduce the time of close contact with a patient during an eye examination and demonstrates a potential benefit of the novel refracting system.

Because no difference in refraction end points was found with the novel refraction technique and this technique was faster, the findings indicate that it may be appropriate to use this novel refraction system as a refraction option for adult patients with normal vision in the optometric clinical setting.

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