Harnessing the Power of Automation with the Chronos Binocular Refraction System

The combination of binocular autorefraction and automated subjective refraction in a single instrument makes Chronos an efficient tool for optimising the process of refraction.

By Prof. Mehdi Shajari

Despite the giant strides that have been made to improve patient outcomes in the field of ophthalmology, uncorrected refractive error remains one of most pressing causes of poor vision globally. In 2020, around 86 million people and 2.3 million people were estimated to be suffering from moderate to severe vision impairment and blindness, respectively, due to uncorrected refractive error (1). These numbers illustrate how the burden of an ageing population is impacting the ability of healthcare systems around the globe to deliver even the most basic of ophthalmic services: timely refraction and accurate glass prescription. A shortage of trained personnel and inefficient screening represent major areas of improvement in the detection of untreated refractive errors (2,3). Tackling this challenge requires the process of refraction to be optimised, so that a large volume of patients can be tested, while still ensuring that each patient receives the correct optical correction. This calls for looking beyond the traditional methods of refractive error detection and developing new technologies with improved speed and accuracy, that can be operated by clinical support staff for greater outreach.

The current paradigms in refraction

Refractive errors can be measured using objective or subjective methods. Objective refraction is based on the optical properties of the eye, while subjective refraction is determined by neurological factors, such as depth of focus and blur sensitivity, in addition to optical factors (4, 5).

Retinoscopy is considered the gold standard for objective refraction; however, it relies on examiners being proficient in a skill that can take years to master, and patients can find the bright light uncomfortable. In the 1970s, the advent of autorefractometers brought about a paradigm shift in objective refraction due to their speed and ease of use. Furthermore, autorefractors showed good reliability and repeatability, and were validated as a start point for subjective refraction (6-8). This led to autorefractors replacing retinoscopy for most clinical scenarios. Over the years, autorefractors have undergone several refinements in working principle and optical design. Modern autorefractors are based on various measurement principles, including photorefraction, Scheiner disc principle, and wavefront analysis, that show good agreement with subjective refraction (5). Additional design features, such as inbuilt fogging and an open-field view, can further increase accuracy and repeatability.

Blur minimisation, performed using a trial frame or phoropter and presenting a variety of lenses, is the most widely used method of subjective refraction. Since subjective refraction is based on patient input, the resulting spherocylindrical correction provides optimal visual acuity and maximum comfort. For this reason, subjective refraction is considered the gold standard for the measurement and correction of refractive errors. However, the inherent subjectiveness of patient responses and the possibility of examiner bias imparts higher variability to subjective refraction when compared with objective methods (9). Advances in subjective refraction aim to decrease variability, while maintaining accuracy and reducing test times. Various novel technologies, such as algorithm-based methods and self-refraction devices, are being investigated, although the current iterations of these technologies show less precision when compared with standard manual subjective refraction (10, 11).

Optimising refraction with the Chronos automated binocular refraction system

The Topcon BV-1000 was the first hybrid device that combined objective and subjective refraction in a single instrument. It performed binocular refraction using automated testing algorithms based on patient responses (12). The same core concepts have been refined for the development of Topcon's next-generation automated binocular refraction system – the Chronos.

Improved testing efficiency

Featuring two autorefractors (one for each eye), one phoropter, and two visual acuity charts (one for each eye), the Chronos binocular refraction system (Topcon Healthcare, Tokyo, Japan) enables clinicians to perform objective refraction, subjective refraction, visual acuity testing, and keratometry, using a single device (Figure 1). Since patients do not need to move from one device to another, testing with Chronos improves patient convenience, especially for those with mobility issues, and reduces time wasted travelling between various instruments. In initial studies, testing with Chronos resulted in statistically faster subjective refraction, with test durations reduced by approximately 10%, on average (13).

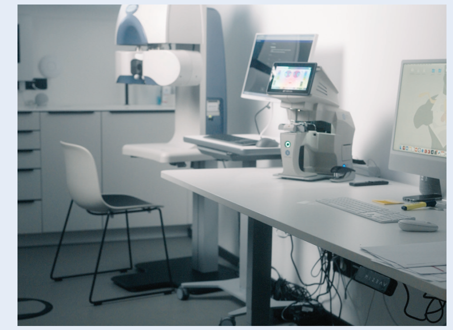

Figure 1. The Chronos automated binocular refraction system.

Additionally, the Chronos features two modes for conducting subjective refraction: a standard mode, where the device is operated as a conventional digital phoropter, and a fully-automated mode, utilising the proprietary SightPilot™ Guided Refraction System. SightPilot™ is a unique testing algorithm that guides operators through the steps of subjective refraction based on patients' responses (Figure 2). This streamlines workflows for refractive error assessment, further reducing testing durations, and enables refraction to be partially delegated to clinical support staff, allowing ophthalmologists to devote more time to detailed clinical examination and thorough patient counselling.

Enhanced reliability with binocular refraction

While automated and all-in-one testing is designed to reduce the time spent on refraction, the binocular refraction system of the Chronos ensures that increased testing speed does not compromise measurement accuracy and precision.

Traditionally, refraction is performed monocularly by testing one eye at a time, while occluding the non-tested eye; this breaks binocular fusion and stimulates accommodation, leading to possible inaccuracies in refractive error estimation due to over-minusing (14). Binocular refraction offers advantages over monocular refraction by presenting a more natural viewing state that minimises the interruption of fusion and reduces the influence of accommodation on refractive error measurements. This prevents overcorrection or under-correction of ametropia, especially in eyes with higher refractive errors (15). However, the conventional binocular refraction procedures involve the dissociation of images between tested and non-tested eyes, making them more bi-ocular than binocular (14).

The Chronos improves upon these limitations with a unique 'binocular lock' mechanism. A target image is displayed to both the tested and non-tested eye simultaneously, which preserves binocular fusion, while a separate image of the visual acuity chart is presented only to the tested eye. With both eyes unoccluded and fixating, refraction can be performed under truly binocular conditions reflective of patients' daily vision. Auto-fogging with a 'rotary prism technology' is utilized to control accommodation, further increasing the accuracy of refractive error assessment. Predictably, the Chronos has been found to have good agreement with standard methods of objective and subjective refraction in previous studies (4, 13).

Clinical experience with the Chronos

Intrigued by the possibility of offering an enhanced testing experience to my patients, I conducted a retrospective study on outcomes with Chronos in patients reporting for routine clinical check-up at my practice in Frankfurt, Germany. Refraction with a standard method (objective refraction with the Nidek AR-1s

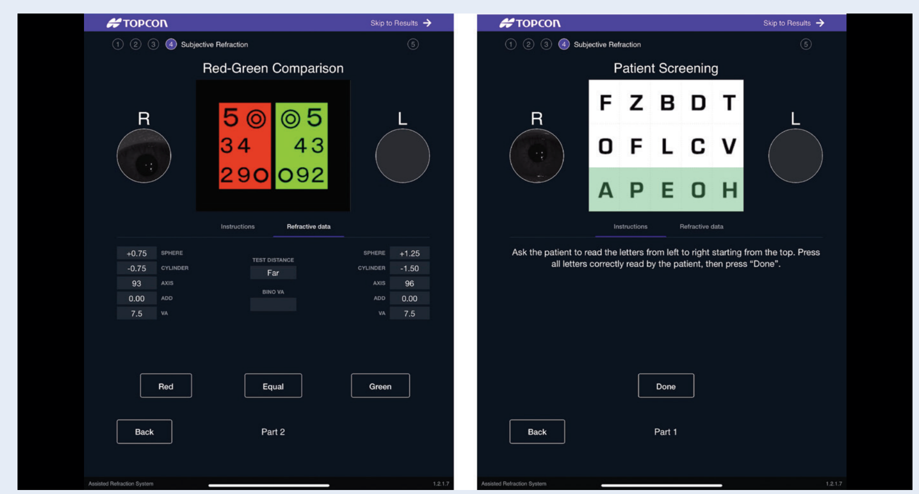

Figure 2. Guided refraction with the Chronos SightPilot™ algorithm.

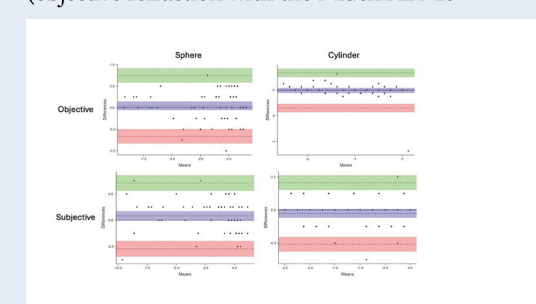

Figure 3. Bland-Altman plots comparing measurements between standard and Chronos methods.

autorefractor and manual subjective refraction with digital phoropter) was compared to binocular objective and subjective refraction with the Chronos method. A total of 60 eyes of 30 patients (mean age 38.0±15.4 years; range: 19–80 years) were included. Noncycloplegic testing was performed, first with the standard method then with the Chronos method, with the autorefraction values serving as starting points for subjective refraction. All tests were performed by a single examiner to reduce bias.

We observed that objective and subjective measurements with Chronos showed no statistically significant differences when compared to those obtained by the standard method (Table 1). Horizontal and oblique cylinder vector values (J0 and J45, respectively) also showed no statistically significant differences between Chronos and standard methods for objective (J0: 0.097±0.47 versus 0.086±0.41, respectively, p=0.94; J45: 0.033±0.48 versus 0.064±0.47, respectively, p=0.21) and subjective (J0: 0.031±0.42 versus -0.034±0.44, respectively, p=0.54; J45: 0.040±0.49 versus -0.082±0.49, respectively, p=0.47) measurements. Mean absolute difference between spherical equivalent (SE) values obtained by Chronos and standard methods showed no statistically significant differences between eyes grouped by manual subjective cylinder power (≤ -0.50 D or > -0.50 D) or by patient age (≤ 40 years or > 40 years).

Measurements obtained with Chronos were slightly more myopic than those obtained by standard method for sphere and SE (Table 1); more myopic SE values with Chronos have also been observed in previous studies (4,13). This is likely due to the closed-view autorefractor used in the Chronos, as closed-view devices show tendency towards more myopic values when compared to open-view autorefractors (16). However, Chronos' binocular refraction system evidently counteracts the proximal accommodation stimulated by the closed-view autorefractor, ensuring that measurement differences are not statistically significant (Table 1). Previous studies on the Chronos also reported no statistically significant differences in SE, J0, and J45 values obtained by Chronos and standard methods (13).

Table 1. Objective and subjective measurements (mean±SD) obtained with standard method (Dr Vision clinic method) and Chronos method. P values calculated using Wilcoxon signed-rank test.

OBJECTIVE					Confidence Interval		Mean Absolute Difference
	n	Dr Vision	Chronos	p value	Lower	Upper	
Sphere	60	-1.90±3.0	-1.94±3.0	0.358	-7.56E-05	0.25	0.28
Cylinder	60	-1.05±0.7	-1.01±0.9	0.639	-0.125	0.25	0.3
SE	60	-2.42±3.1	-2.45±3.2	0.171	-0.06	0.25	0.34
SUBJECTIVE					**Confidence Interval**		**Mean Absolute Difference**
	n	Dr Vision	Chronos	p value	Lower	Upper	
Sphere	58	-2.19±3.0	-2.27±3.1	0.055	-4.67E-05	0.25	0.27
Cylinder	58	-1.08±0.8	-1.03±0.8	0.118	-0.25	6.08E-06	0.16
SE	58	-2.73±3.2	-2.79±3.2	0.161	-5.96E-05	0.185	0.29

Table 2. Distribution of eyes by degree of concordance between standard method (Dr Vision clinic method) and Chronos method.

Difference between Dr Vision and Chronos values	Sphere		Cylinder		SE	
	Objective n=60	Subjective n=58	Objective n=60	Subjective n=58	Objective n=60	Subjective n=58
High concordance (difference ≤0.25D)	41 (68.3%)	46 (79.3%)	48 (80.0%)	52 (89.7%)	34 (56.7%)	36 (62.1%)
Medium concordance (difference >0.25 and ≤0.5 D)	16 (26.7%)	9 (15.5%)	8 (13.3%)	5 (8.6%)	17 (28.3%)	18 (31.0%)
Weak concordance (difference >0.5 and ≤0.75 D)	2 (3.3%)	3 (5.2%%)	2 (3.3%)	1 (1.7%)	5 (8.3%)	4 (6.9%)
No concordance (difference >0.75D)	1 (1.7%)	0 (0%)	2 (3.3%)	0 (0%)	4 (6.7%)	0 (0%)

The concordance between Chronos and standard methods was assessed as high, medium, weak, and no concordance for measurement differences of ≤ 0.25D, > 0.25 and ≤ 0.50 D, > 0.50 and ≤ 0.75 D, and > 0.75 D, respectively. In the majority of eyes, differences between both methods were ≤ 0.25 D for both objective and subjective measurements (Table 2). Rates of high concordance were lesser for objective measurements than for subjective measurements; this could be attributed to differences in the measurement principle and optical design of Chronos and the Nidek AR-1s autorefractor. However, greater rates of high concordance in subjective end points obtained by Chronos and standard methods suggests that optical correction measured by the Chronos has good accuracy for use in routine clinical practice.

Bland-Altman analyses showed good agreement between both methods (Figure 3). Objective measurements showed near zero systematic bias, while subjective measurements showed small but statistically and clinically insignificant systematic bias. No proportional bias was observed. This is consistent with previous studies on the Chronos that also reported good agreement between Chronos and standard refraction techniques, with minimal systematic bias and no proportional bias (4, 13). In the current study, limits of agreement for subjective measurements and for objective sphere measurements were similar to those observed between other refractive methods (17), while limits of agreement were wider for objective cylinder measurements.

Measurements with Chronos and standard methods were also strongly correlated with each other for objective sphere (r = 0.993, p<0.001) and for subjective sphere (r = 0.995, p<0.001) and cylinder (r = 0.951, p<0.001). Objective cylinder values obtained by both methods were moderately correlated (r = 0.648, p<0.001). Coupled with the wider limits of agreement for objective cylinder noted on Bland-Altman analysis, this seems to suggest that agreement between Chronos and standard autorefractor may be lesser for objective cylinder measurements.

On intra-method comparison of outcomes, subjective sphere, cylinder and SE were slightly more myopic than objective values with the standard method (p<0.001, p=0.203, p<0.001, respectively), as well as the Chronos method (p<0.001, p=0.270, p<0.001, respectively). With both methods, differences between objective and subjective measurements were ≤ 0.25 D (high concordance) in the majority of eyes. Greater rates of high concordance were observed with the standard method than with the Chronos method (sphere: 74.1% versus 63.8%, respectively; cylinder: 94.8% versus 89.7%, respectively; SE: 62.1% versus 56.9%, respectively). Objective and subjective values were strongly correlated with each other with the standard method (sphere: r=0.994, p<0.001; cylinder r=0.942, p<0.001) as well as the Chronos method (sphere: r=0.995, p<0.001; cylinder: r=0.694, p<0.001).

Conclusion

Binocular automated objective and subjective refraction with the Chronos showed good agreement with standard methods. Although observations were derived from a small cohort, these findings are consistent with available literature on the Chronos. Due to a relatively worse agreement with standard method for objective cylinder values, it may be prudent, for now, to employ the Chronos as a supplement to, and not a substitute for, standard refraction techniques. However, further studies in larger cohorts are needed to arrive at a conclusive opinion on its clinical utility.

At present, the evidence points towards Chronos being a reliable and efficient tool for refractive error estimation that can be critical in the management of the global burden of refractive errors. Binocular refraction with an automated approach can streamline practice workflows without compromising accuracy, thereby empowering clinicians to maximise patient outcomes and satisfaction.

References

1. *GBD 2019 Blindness and Vision Impairment Collaborators, Vision Loss Expert Group of the Global Burden of Disease Study. Causes of blindness and vision impairment in 2020 and trends over 30 years, and prevalence of avoidable blindness in relation to VISION 2020: the Right to Sight: an analysis for the Global Burden of Disease Study. Lancet Glob Health. 2021;9(2):e144–e160. doi:10.1016/S2214-109X(20)30489-7*
2. *Murthy GV. Vision testing for refractive errors in schools: "screening" programmes in schools. Community Eye Health. 2000;13(33):3–5.*
3. *Naidoo K, Jaggernath J. Uncorrected refractive errors. Indian J Ophthalmol. 2012;60(5):432. doi:10.4103/0301-4738.100543*
4. *Fukushima M, Hirota M, Yukimori T, et al. Evaluation of objective and subjective binocular ocular refraction with looking in type. BMC Ophthalmol. 2024;24(1):170. doi:10.1186/s12886-024-03449-y*
5. *Venkataraman AP, Brautaset R, Domínguez-Vicent A. Effect of six different autorefractor designs on the precision and accuracy of refractive error measurement. PLoS One. 2022;17(11):e0278269. doi:10.1371/journal.pone.0278269*
6. *Goss DA, Grosvenor T. Reliability of refraction--a literature review. J Am Optom Assoc. 1996;67(10):619–630.*
7. *Zadnik K, Mutti DO, Adams AJ. The repeatability of measurement of the ocular components. Invest Ophthalmol Vis Sci. 1992;33(7):2325–2333.*
8. *Kinge B, Midelfart A, Jacobsen G. Clinical evaluation of the Allergan Humphrey 500 autorefractor and the Nidek AR-1000 autorefractor. British Journal of Ophthalmology. 1996;80(1):35–39. doi:10.1136/bjo.80.1.35*
9. *Bullimore MA, Fusaro RE, Adams CW. The Repeatability of Automated and Clinician Refraction. Optometry and Vision Science. 1998;75(8):617–622. doi:10.1097/00006324-199808000-00028*
10. *Venkataraman AP, Sirak D, Brautaset R, Dominguez-Vicent A. Evaluation of the Performance of Algorithm-Based Methods for Subjective Refraction. J Clin Med. 2020;9(10):3144. doi:10.3390/jcm9103144*
11. *Tousignant B, Garceau M, Bouffard-saint-pierre N, Bellemare M, Hanssens J. Comparing the Netra smartphone refractor to subjective refraction. Clin Exp Optom. 2020;103(4):501–506. doi:10.1111/cxo.13003*
12. *Dave T, Fukuma Y. Clinical Evaluation of the Topcon BV-1000 Automated Subjective Refraction System. Optometry and Vision Science. 2004;81(5):323–333. doi:10.1097/01.opx.0000134906.98403.c3*
13. *Bossie T, Reilly J, Vera-Diaz FA. Comparison of a Novel Binocular Refraction System with Standard Digital Phoropter Refraction. Optometry and Vision Science. 2023;100(7):451–458. doi:10.1097/OPX.0000000000002037*
14. *Momeni-moghaddam H, Goss DA. Comparison of four different binocular balancing techniques. Clin Exp Optom. 2014;97(5):422–425. doi:10.1111/cxo.12198*
15. *Kobashi H, Kamiya K, Handa T, et al. Comparison of Subjective Refraction under Binocular and Monocular Conditions in Myopic Subjects. Sci Rep. 2015;5(1):12606. doi:10.1038/srep12606*
16. *Nagra M, Akhtar A, Huntjens B, Campbell P. Open versus closed view autorefraction in young adults. J Optom. 2021;14(1):86–91. doi:10.1016/j.optom.2020.06.007*
17. *Paudel N, Adhikari S, Thakur A, Shrestha B, Loughman J. Clinical Accuracy of the Nidek ARK-1 Autorefractor. Optometry and Vision Science. 2019;96(6):407–413. doi:10.1097/OPX.0000000000001386*