Original Article

Comparison of Two Different Contrast Sensitivity Testing Methods in Patients with Low Vision

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Abstract

Purpose: To assess the agreement between two different contrast testing modalities using the index of contrast sensitivity (ICS) in patients with low vision.

Methods: Thirty-eight patients with low vision were included in the study. Contrast sensitivity (CS) was measured binocularly with both the Vector vision-standardized CS test (CSV-1000E, Vector Vision Co, Greenville, Ohio, USA) and the MonPack 3 (Metrovision, France) after refractive correction for each participant. Based on the data from the two tests, the ICS was calculated. The Bland–Altman technique was used to evaluate the agreement between ICSs obtained from different test methods.

Results: Range of best corrected visual acuity was 0.50–1.00 logMAR. According to the median logCS values, CS values were highest at 3 cycles per degree (cpd) for the CSV-1000E test and at 1.5 cpd for the Metrovision MonPack 3 test. The median ICS for CSV-1000E was −0.22 (95th percentile 4.75), and the median ICS for Metrovision MonPack 3 was 0.08 (95th percentile 1.65). The mean difference was 0.655 (between −3.82 and 5.13) within limits of agreement (LoA). The difference and mean values between the two CS test measurements were found to be within LoA range.

Conclusions: An agreement was found between the Metrovision MonPack 3 test and the standard CSV-1000E test results in patients with visual impairment. However, the agreement range was within very wide limits. Therefore, it was thought that they may not be used interchangeability in clinical practice.

Keywords: Contrast sensitivity, Index of contrast sensitivity, Low vision

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Introduction

Contrast sensitivity (CS) is tested by detecting the lowest illumination difference identified by a subject in a static image with a target object and background.[1] The CS test is the most sensitive among the various tests used to determine visual functions and the acuity of visual perception.[2,3] Although it is not widely used in routine eye examinations, the use of CS testing is increasing in our clinical practice.

There are various methods for testing CS, from simple cards to complex devices, and these methods are still being developed.[4] The aim of the developed tests is to measure CS with a reliable, simple, and fast method.[5] The Vector vision-standardized CS test (CSV-1000E) is frequently utilized for CS assessment; however, the reliability of the recommended test protocol is low in children and adults.[6] Further, despite the detection of increased consistency when performed by the same examiner, it has been shown that retest reliability cannot be ensured.[6] Metrovision MonPack 3 is the electrophysiological CS test. The advantages of this test include its practicality and speed, automatic generation of the CS curve, and the individual display of vertical sinusoidal gratings.[7]

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A decrease in CS has been reported in patients with low vision due to macular dystrophy, age-related macular degeneration (AMD), neurophthalmological diseases, cataract, diabetic retinopathy, and glaucoma.[8,9] The loss of CS can seriously affect the quality of life of people with low vision by causing difficulties in daily activities such as reading.[10] Measuring CS values have a special importance for this population, and this test should be used more frequently in this group. Therefore, it is preferred that the CS test measurement be accurate, reliable, and practical. The CSV-1000E standard test can be used in the assessment of CS in low vision group but in this test, multiple images are shown at the same time, and the patient is asked to make a compulsory choice between two images. Young children may have difficulty understanding which image is being tested when there are many images, while low vision patients with central scotoma may be affected by the "crowding phenomenon".[11] In addition, patients with low vision may have difficulty performing this test at the standard test distance of the device, 2.50 m.

In order to ensure the accuracy, reliability, and comparability of these tests, it is necessary to evaluate the agreement between the results obtained from the devices and to show that the measurements taken from the same patient are similar.[12] However, it is difficult to compare different CS tests, interpret CS curves, and statistically analyze CS values at each spatial frequency separately.[7,13-15] Wachler and Krueger[15] stated that the obtained CS values may have a factor according to the population average at each test frequency and form the basis of the CS index (ICS) concept. ICS scores are clinically valuable in determining the effect and role of each spatial frequency on visual performance in a selected population.[16] Haughom and Strand[14] stated that calculating ICS in a selected population (young, healthy eye) could facilitate these comparisons.

In this study, the agreement between two different contrast testing methodologies (CSV-1000E Standard, Vector Vision Co, Greenville, Ohio, USA, and MonPack 3, Metrovision, France) was evaluated using ICS, and the low vision population was selected as the study group. Our aim is to investigate whether there is an agreement between the standard CSV-1000E test, which we still use in our clinic, and the Metrovision MonPack 3 test results we have just started to use, and whether they can be used interchangeably.

Methods

This is a prospective observational case series study. The local ethics committee approved the study (10.09.2020/İ8-504-20), and all procedures were in accordance with the principles of the Declaration of Helsinki. Informed consent forms were obtained from all individuals (from parents or legal guardians of the children) participating in the study.

The two different CS tests (Standard CSV-1000E and Metrovision MonPack 3) were applied to low-vision patients who applied to the Department of Ophthalmology, Low Vision Rehabilitation of our hospital. Individuals with best corrected visual acuity (BCVA) of 20/400≤ BCVA ≤20/63 were defined as "low vision." Thirty-eight low vision individuals between the ages of 8–89 who could complete the CS tests properly were included in the study. Individuals with cognitive problems that would not allow them to perform CS tests were excluded from the study. A comprehensive eye examination was performed, and the BCVA, fundus examination, near visual acuity, slit-lamp biomicroscopy, applanation tonometry, and low vision examination were recorded. CS was measured binocularly by both Standard CSV-1000E and Metrovision MonPack 3 with best refractive correction. Patients had not experienced any of the tests before. There were 10-min breaks between the two tests, and all measurements were performed by the same clinician between 9 AM and 12 PM in a dark room. All tests were asked to the participants in the same order. No time limits were imposed upon the participants during the tests. The examiner asked the participants to answer the questions on the test but did not insist on having an answer and did not want them to make predictions.

The standard CSV-1000E test is a psychophysical CS test that consists of vertical sine-wave gratings at four spatial frequencies (3, 6, 12, 18 cycles per degree [cpd]). There is a separate row for each spatial frequency (A, B, C, D). Each row has 17 shapes, with 8 pairs of circular patches and a sample patch at the highest contrast at the beginning of the row. In each pair, one of the patches contains sine-wave grids, while the other is blank. There are eight different degrees of contrast at each of the four spatial frequencies. The contrast of the gratings decreases from left to right throughout the row. For two alternative patches at four spatial frequencies, patients are asked if either of them has grating and, if so, whether the grating is on the upper or lower side. The last correct response in each line is defined as the contrast threshold for each frequency. Vector vision guidelines can be used to convert the responses given by patients to CSV values (3 cpd [CS range, 5–120], 6 cpd [CS range, 8–193], 12 cpd [CS range, 4–99], and 18 cpd [CS range, 1.5–36]), and to logCS values (3 cpd [logCS range, 0.70–2.08], 6 cpd [logCS range, 0.91–2.29], 12 cpd [logCS range, 0.61–1.99], and 18 cpd [logCS range, 0.17–1.55]) (http://www.vectorvision.com/csv1000-norms/). In this test, 1.5 cpd and 3 cpd are accepted as low spatial frequencies and 6 cpd and 9 cpd as medium spatial frequencies. The test consists of a backlit transparent graphic with an automatically adjustable light level of 85 cd/m2 and is performed at a distance of 2.5 m[17] (normal values for photopic and mesopic CS - VectorVision, https://www.vectorvision.com/csv1000-norms/).

All participants in our study had visual impairment. For this reason, measurements could not be made at high spatial frequencies. In addition, due to low vision, the CSV-1000 E test was performed at a distance of 1.25 m by reducing the standard test distance by half. The results obtained from the test were recorded in the data form as corrected values by decreasing the cpd values of the tested spatial frequency by half. For example, the CS and logCS values obtained for 3 cpd were recorded assuming that they were obtained for 1.5 cpd since the test distance was reduced by half.

The Metrovision MonPack 3, another psychophysical CS test, uses vertical sine-wave gratings at various spatial frequencies. Each black and white bar is presented with very low contrast first, followed by an automatic gradual increase in contrast. During the test, the patient presses a button to indicate that they were able to detect black and white bars on the flat screen. But does not verbally indicate. The device automatically presents the CS test results in graphic form. This test is practical and fast. However, the disadvantage is that the response is delayed because the subject does not have enough time to identify changes in vertical black and white lines, or the contrast increases automatically.[7] On the graph, spatial frequencies of 0.5, 1, 2, 5, 10, 20, and 50 cpd on the horizontal axis and 0–30 dB on the vertical axis are available. In this test, 0.5 and 1.5 cpd are accepted as low, 3.0 and 6.0 cpd as medium, and values between 12.0 and 24.0 cpd are defined as high spatial frequencies.[18]

In this study, ICS values were used to compare the measurement results obtained from two different contrast tests.[14] ICS is a simple linear weighting function and is defined as the sum of residual differences (positive or negative) from the median CS value for each frequency. These differences are weighted based on clinical importance as factor 3, factor 2, and factor 1. It is important to note that the weights and ICS scores change based on the CS performance of each population. Haughom and Strand[14] stated that for a young and normal vision population, the CS of the eye peaked at 6 cpd and the results obtained at 6 cpd were clinically most important. For the assessment of CS in a young population with normal visual acuity, the 6 cpd frequency is factored by a weight of 3 (since this frequency carries the greatest importance), the 3 and 12 cpd values are weighted by 2, while the remaining values are weighted by 1.[14]

Dynamic CS function (dCSF): CSF (f) − median CSF (f)

ICS: 1.dCSF (1.5 cpd) +2.dCSF (3 cpd) +3.dCSF (6 cpd) +2.dCSF (12 cpd) +1d.CSF (18 cpd)

(The dCSF value indicates the deviation of the CS value measured at any frequency from the median value at that spatial frequency for that population, f: spatial frequency).[13]

Statistical analysis

All data were transferred to SPSS v20 (IBM Corp., Armonk, NY, USA). The Shapiro–Wilk test was used for the normality check. In order to perform the consistency analysis between the two methods, Bland–Altman scatter plot was used. The limits of agreement (LoA) were calculated as ±1.96 standard deviation (SD) of the differences of the mean. The Wilcoxon Signed-Rank test was performed to compare the mean differences. The $P = 0.05$ was considered statistically significant level.

Results

The study group consists of 20 males and 18 females with a mean age of 54.2 ± 31.0 (range, 8–89) years. Males had a mean age of 56.7 ± 29.4 years (12–86 years), while females had a mean age of 51.4 ± 33.3 years (8–89 years). The mean age of male and female patients was similar ($P = 0.612$). Diagnoses were as follows: 25 (65.8%) had AMD, 7 (18.4%) had oculocutaneous albinism (OCA), and 6 (15.8%) had cone dystrophy. Distant BCVA (according to logMAR) mean value was 0.69 ± 0.19 (range, 0.50–1.00). According to the diagnoses, mean BCVA was 0.65 ± 0.18 in AMD, 0.86 ± 0.15 in OCA, and 0.62 ± 0.15 in cone dystrophy. Considering the median logCS values, it was found that 3 cpd in the CSV-1000E test (low spatial frequency for CSV-1000E) and 1.5 cpd in the Metrovision MonPack 3 test (low spatial frequency for Metrovision MonPack 3) were clinically important. The median values in both tests are shown in Table 1.

When looking at the maximum, median, and minimum logCS values at 1.5, 3, 6, and 9 cpd spatial frequencies for the CSV-1000E test, the peak for the CSV-1000E test was observed at 3 cpd [Figure 1].

When looking at the maximum, median, and minimum logCS values at 0.5, 1.5, 3, 6, and 9 cpd spatial frequencies for the Metrovision MonPack 3 CS test, the peak for the Metrovision MonPack 3 CS test was observed at 1.5 cpd [Figure 2].

When the sum of the residual differences from the median (in each frequency) was weighted according to clinical significance, it was observed that 3 cpd for CSV-1000E and 1.5 cpd for Metrovision MonPack 3 CS had the highest power (factor 3). The 1.5 and 6 cpd frequencies in CSV-1000E and the 0.5 and 3 cpd frequencies in the Metrovision MonPack 3 test received factor 2. The remaining test frequencies were weighted as factor 1. The differences of the best values obtained (3 cpd in CSV-1000E and 1.5 cpd in Metrovision MonPack 3) were multiplied by three, the differences of the values at 1.5 and 6 cpd (in CSV-1000E) and 0.5 and 3 cpd (in Metrovision MonPack 3) were multiplied by two. Finally, the

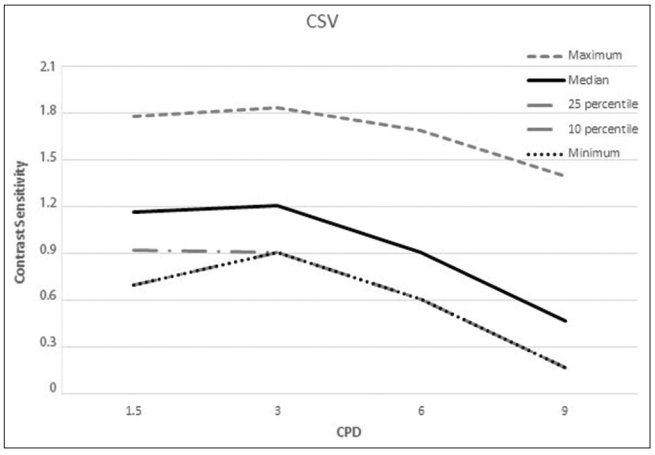

Figure 1: Maximum, median, and minimum logCS values obtained from the Vector vision-standardized contrast sensitivity (CSV-1000E) test. The maximum, median, and minimum logCS units values at 1.5, 3, 6, and 9 cycles per degree (cpd) spatial frequencies for the CSV-1000E test. The peak for the CSV-1000E test was observed at 3 cpd

differences of the values at 9 cpd (in CSV-1000E) and 6 cpd (in Metrovision MonPack 3) were multiplied by one. The ICS scores were calculated by summing the resultant values. The distribution of ICS scores in the tested frequencies are shown in Figure 3 (for CSV-1000 test) and Figure 4 (for Metrovision MonPack 3). The ICS scores in percentiles for the two tests are shown in Table 2.

When the ICS scores at each frequency were calculated for each participant, there was no difference between the ICS scores of the CSV-1000E and Metrovision MonPack 3 tests ($P = 0.109$). This result was confirmed in the Bland–Altman scatter plot. The median ICS for CSV-1000E was −0.22 (95th percentile 4.75) and the median ICS for Metrovision MonPack 3 was −0.08 (95th percentile 1.65). The mean difference was 0.655 (between -3.82 and 5.13) within LoA. The difference and mean values between the two different CS test measurements were within LoA range [Figure 5].

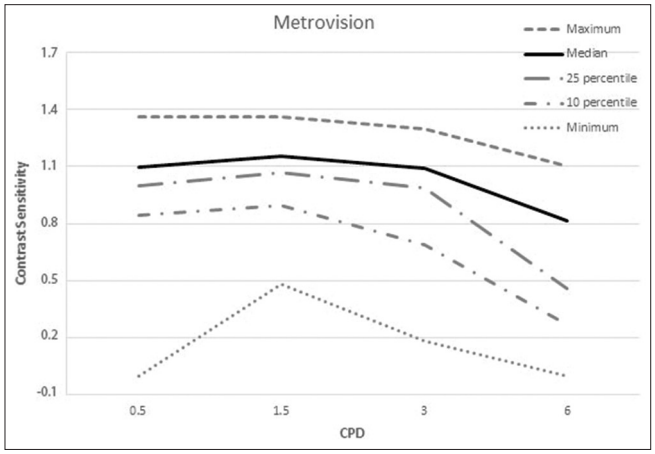

Figure 2: Maximum, median, and minimum logCS values obtained from the Metrovision Monpack 3 test. The maximum, median, and minimum logCS values at 0.5, 1.5, 3, and 6 cycles per degree (cpd) spatial frequencies for the Metrovision Monpack 3 test. The peak for the Metrovision Monpack 3 test was observed at 1.5 cpd

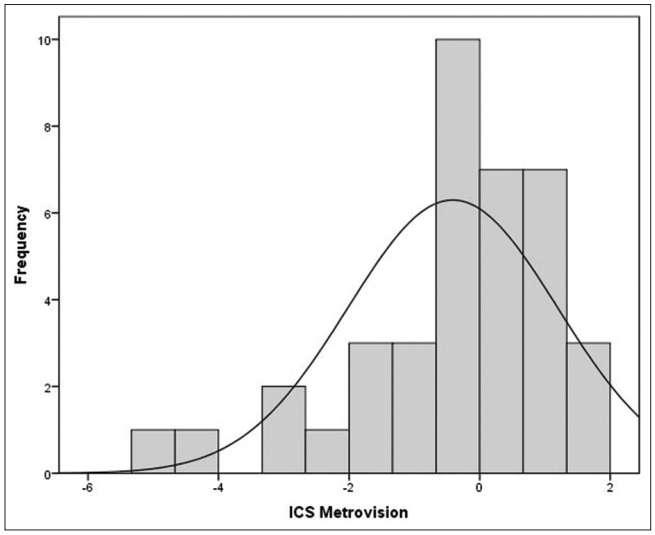

Figure 4: The index of contrast sensitivity (ICS) score distribution in Metrovision Monpack 3 test. The distribution of ICS scores in the tested frequencies are shown for Metrovision Monpack 3. ICS is defined as the sum of residual differences (positive or negative) from the median contrast sensitivity value for each frequency.

Discussion

In our study, two different CS tests were performed on 38 low-vision patients by using the CSV-1000E and Metrovision

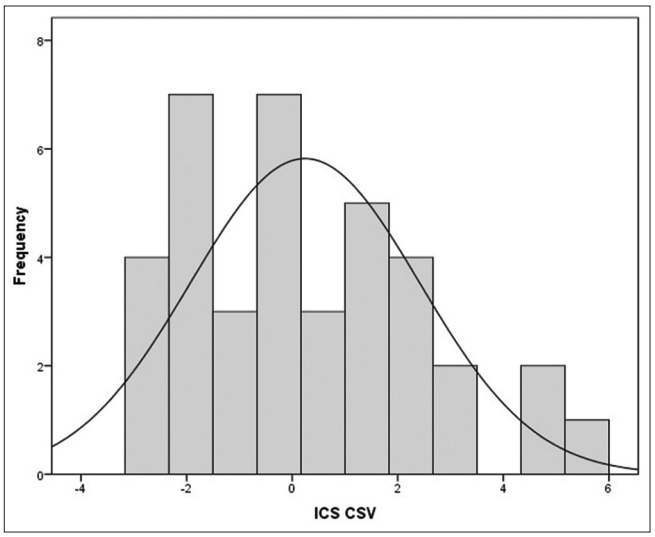

Figure 3: The index of contrast sensitivity (ICS) score distribution in Vector vision-standardized contrast sensitivity (CSV-1000E) test. The distribution of ICS scores in the tested frequencies are shown for CSV-1000E test. ICS is defined as the sum of residual differences (positive or negative) from the median contrast sensitivity value for each frequency.

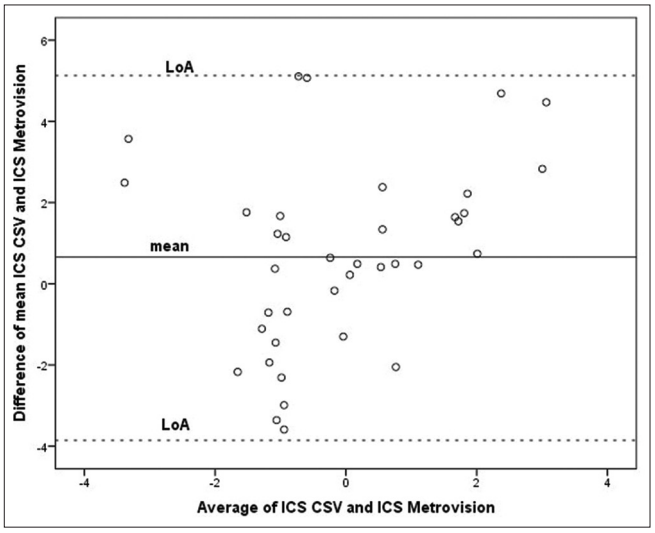

Figure 5: The index of contrast sensitivity (ICS) score averages and differences of Vector vision-standardized contrast sensitivity (CSV-1000E) and Metrovision Monpack 3 tests in the Bland–Altman scatter plot. The mean values and differences between the two contrast sensitivity test measurements were found to be within the values that could be considered compatible for limits of agreement

Table 1: Median values of logCS for Vector vision-standardized contrast sensitivity test (CSV-1000E) and Metrovision Monpack 3 contrast sensitivity test

Spatial frequency (cpd)	CSV-1000E				Spatial frequency (cpd)	Metrovision Monpack 3			
	Median logCS values	Mode	95% percentile	Range results		Median logCS values	Mode	95% percentile	Range results
1.5	1.17	0.70	1.78	1.08	0.5	1.10	1.08	1.30	1.36
3	1.21	0.91	1.84	0.93	1.5	1.16	1.18	1.35	0.88
6	0.91	0.61	1.55	1.08	3	1.09	1.00	1.28	1.12
9	0.47	0.17	1.40	1.23	6	0.82	1.08	1.08	1.10

Cpd: Cycles per degree, CSV-1000E: Vector vision-standardized contrast sensitivity test

Table 2: Index of contrast sensitivity scores in percentiles for Vector vision-standardized contrast sensitivity (CSV-1000E) and Metrovision Monpack 3 contrast sensitivity tests

	CSV-1000E (ICS scores)	Metrovision Monpack 3 (ICS scores)
Median	−0.22	−0.08
Mean	0.24	−0.41
Standard deviation	2.17	1.60
Percentiles		
10	−2.47	−3.15
25	−1.61	−0.94
50	−0.22	−0.08
75	1.86	0.77
90	3.12	1.01
95	4.75	1.65

ICS: Index of contrast sensitivity, CSV-1000E: Vector vision-standardized contrast sensitivity test

MonPack 3 testing methods. CS values were highest at 3 cpd for the CSV-1000E test and at 1.5 cpd for the Metrovision MonPack 3 test. It was observed that the highest CS values were reached at low spatial frequencies with both tests. When the measurement results were compared using the ICS, it was seen that there was some agreement between these two different CS tests.

Different stimulus or lighting conditions used in CS tests make it difficult to compare the results of different contrast tests.[19] This problem is observed rather frequently, even in studies investigating normative CS values in individuals with normal visual acuity. For example, Wachler and Krueger[15] performed CS tests in a monocular photopic conditions, while Haughom and Strand[14] performed the tests in a binocular mesopic and photopic conditions. Even if the same device and the same CS test method were used in the studies, the differences in the inclusion criteria in the studies are another factor that prevents direct comparison of the results obtained.[16] Therefore, studies comparing test methods and devices should be conducted in selected populations. In our study, two different devices using vertical sine-wave grating were tested in a low-vision population to ensure that the results were comparable. Haughom and Strand[14] stated that calculating ICS in a selected population (young, healthy eye) could facilitate these comparisons. In addition, they introduced the ICS as a "possible collective descriptor of the CS curve" and accepted it as a simple linear weighting function that assumed that the CS peaked at 6 cpd in this population. In our study, the CS value reached a peak at 3 cpd in the CSV-1000E test and 1.5 cpd in the Metrovision MonPack 3 test. This result can be explained by the decrease in the CS levels of patients with low vision.[8,9] In both devices, CS testing could not be performed at high spatial frequencies.

The reproducibility of CS tests is another parameter that is examined in studies comparing CS testing methods. It has been reported in the literature that reproducibility is generally low.[6,20] In our study, reliability testing could not be performed. Kelly *et al*.[6] reported no significant difference between the results of the tests performed by different clinicians and did not consider inter-observer variation as an important problem. Even so, it is important to note that repeatability coefficient estimates should be established by expanding studies using this type of ICS calculation.

It is possible to compare the results of two different CS tests with ICS calculation.[14] Koefoed *et al*.[16] suggested that CS test methods could be compared with ICS, and Bunce[12] reported that Bland–Altman analysis was useful in such comparisons.[12,16] In a study evaluating 180 military personnel with normal visual acuity (18–25 years), the Optec 6500/FACT photopic test, the Optec 6500/FACT mesopic test, and the CSV-1000E photopic tests were compared according to the ICS, and there was agreement on photopic tests. It has been stated that they can be used interchangeably and that there is very little agreement in mesopic and photopic tests.[12,16]

Eppig *et al*.[13] evaluated mesopic and photopic CS in pseudophakic eyes with differently designed intraocular lenses in the Optec 6500/FACT system and reported that the ICS was indeed an overall useful index for CS evaluation. In our study, the ICS scores at each frequency were calculated for each participant and compared statistically to evaluate the compatibility, which demonstrated reasonable agreement between the two methods.

The, ICS was defined by Haughom and Strand[14] in the young and normal sighted population. In our study, the "low vision" group was used as the population, and ICS was used to compare two different contrast test methods. Chung and Legge[21] reported that the CS parabolic curves of those with low

vision and normal vision had a similar shape, but stated that although the results were comparable, the spatial frequency and CS values were different. In the mentioned study, low-vision patients with a BCVA worse than 0.14 (20/125 Snellen) who had been diagnosed with AMD, Stargardt macular dystrophy, glaucoma, or optic neuritis, were all found to have decreased CS values.

In our study, ICS score was used in a group with a high range of age distribution, including elderly subjects (mean age, 54.2 ± 31.0); however, it has been previously shown that ICS can be utilized in subjects with advanced age in the study by Eppig *et al*. (mean age, 73.1 ± 7.86).[13]

In our study, a separate power factor was used for each cpd, as determined according to median values for each frequency in the CS tests. The median ICS value was found to be −0.22 (95th percentile 4.75) for the CSV-1000E test and −0.08 (95th percentile 1.65) for the Metrovision MonPack 3 test. In the statistical analysis, there was no difference between the two test methods in terms of ICS values. This result was confirmed by the histogram plot and the Bland–Altman scatter plot. Therefore, it was seen that there was agreement between the two CS tests. However, it was observed that the agreement range (LoA range, −3.82 to –5.13) between the two tests was quite wide. The Bland-Altman method calculates the mean difference between two different methods of measurement (the "bias") and 95% LoA as the mean difference (2 SD). This limit shows how well the agreement is between the two different measurement methods - the smaller this range, the better the agreement between the two methods.[22] Similarly, Koefoed *et al*.[16] found that the two CS tests were compatible and stated that the LoA range (−2.20 to –1.34) was wide, which should trigger investigations to assess the clinical importance of this characteristic. Contrary to these studies, Hong *et al*.[23] compared the VCTS-6500 (Vision Contrast Test System 6500) and the Optec 6500 devices in normal eyes and patients with cataract. They found very little agreement between them. Franco *et al*.[24] compared the CSV-1000E and the VCTS-6500 devices in 105 healthy eyes (in patients aged 19–26), and found that there were excessive differences between results.

The difficulties in comparing different CS tests and interpreting CS curves have been frequently reported in the literature.[7,13-15] ICS is not widely used clinically. It was not used in the mentioned studies either. In studies investigating the agreement between contrast test methods, it was thought that if there is agreement between different CS tests, perhaps it can be demonstrated using ICS.

In the present study, the effect of factors such as age, diagnosis, pupil diameter, BCVA, refractive error, and the presence of intraocular lens (due to previous the cataract surgery) on CS values could not be investigated due to the limited number of cases. The CSV-1000LV test could not be used because it was not available in our clinic. All participants were tested first with CSV-1000E and then with Metrovision MonPack 3. This situation may have created a learning/sequence bias effect. This is also part of the limitations. In addition, in the CSV-1000E test, evaluation is done manually by an experimenter and automatically in Metrovision MonPack 3. There may have been experimenter bias in the CSV-1000E. This situation may have affected the results. The advantage of our study is that two different CS test methods, which are difficult to compare, could be compared with ICS. Another advantage is that it provides a reference to CS values in individuals with low vision. Our study contributes to the literature in terms of comparing two different CS tests using ICS and making this comparison in low vision population.

In conclusion, when the ICS values were calculated for each test method according to the frequency data, there was some agreement between the Metrovision Monpack 3 and the CSV-1000E tests. It might not be appropriate to use these tests interchangeably in patients with low vision. However, further studies are needed to compare CS tests with subgroup analyses in patients with different diagnoses and the inclusion of a greater number of participants.

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Conflicts of interest

There are no conflicts of interest.

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