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Agreement between Compass Fundus Perimeter New Grid and 10-2 Testing Protocols for Detecting Central Visual Field Defects

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Abstract

Purpose: To evaluate the agreement between Compass New Grid (NG) and 10-2 test protocols for detecting early glaucomatous defects in the central 10 degrees of the visual field (CVFD).

Design: Cross-sectional study.

Subjects and controls: A total of 123 eyes of 14 healthy individuals, 17 glaucoma suspects and 32 glaucoma patients were enrolled.

Methods: Subjects performed NG and 10-2 Compass automated perimetry testing within one week. For both test protocols total deviation (TD) or pattern deviation (PD) plot CVFDs were defined by three contiguous points with probabilities of <5%, <2%, <2% or <5%, <1%, <1%. Cohen's Kappa statistic was used to assess agreement between NG and 10-2 for identifying CVFDs. The Spectralis GMPE Hood Glaucoma Report (investigational software version) macula

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deviation analysis obtained within one year was used for calculating sensitivities and specificities of test protocols.

Main Outcome Measures: Protocols' agreement, sensitivity, and specificity.

Results: Fair to moderate agreement was observed between NG and 10-2 protocols for detecting presence of superior CVFDs on TD (k=0.566) and PD (k=0.256) plots and for detecting inferior CVFDs on TD (0.487) and PD (0.272) plots. Using OCT macula deviation maps, specificity for detecting CVFD was consistently higher with NG than 10-2 tests for TD plots of the superior hemifield (0.82 and 0.65), inferior hemifield (0.92 and 0.84) and for PD plots of the superior hemifield (0.81 and 0.36) and inferior hemifield (0.86 and 0.52). Sensitivity of NG was consistently lower than TD plots of the superior hemifield (0.48 and 0.72), inferior hemifield (0.28 and 0.46) and for PD plots of the superior hemifield (0.48 and 0.78) and inferior hemifield (0.20 and 0.52). Using pattern standard deviation (PSD) criterion, the mean PSD (95% CI) values for 10-2 and NG VF tests were 1.61 (1.26, 1.96) and 1.81 (1.45, 2.17) ($p < 0.001$), respectively.

Conclusion: Although the Compass NG detected fewer CVFDs than the 10-2 test protocol, it did detect CVFDs that were not observed in the Compass 24-2 test in early glaucoma patients, Therefore, NG may be particularly useful in clinical situations for which higher specificity is desired or when PSD criterion is used.

Précis

Compass New Grid and 10-2 had fair to moderate agreement for the detection of central visual field defects. New Grid showed higher specificity and lower sensitivity than 10-2 testing protocol in early glaucoma patients.

Keywords

Glaucoma; visual field; Compass; New Grid; 10-2

Several studies have indicated that central visual field defects may be present in the early stages of glaucoma.[1–4] Thus, it is important to test both the central and peripheral visual field to sensitively detect and manage the disease. Standard automated perimetry (Humphrey Visual Field Analyzer (HFA); Carl Zeiss Meditec, San Leandro, CA)) using the HFA 24-2 testing protocol has become widely adopted for assessing and quantifying visual field (VF) changes in glaucoma, as well as for monitoring the progression of VF defects.[5] However, this test pattern does not adequately sample the macular region, with 12 out of 54 test points in the central 10 degrees and only 4 points falling within the central 8 degrees, the area of the retina that includes approximately 30% of all retinal ganglion cells. It is estimated that 12-34% of early glaucoma patients will have undetected central defects if tested with 24-2 visual field alone.[6,7] This suggests that a more thorough evaluation of the central visual field is necessary to sensitively detect glaucoma.

The HFA program 10-2 that assesses the central VF area is particularly useful because it tests sensitivity at 68 points that are evenly distributed in the central 10 degrees. It has been shown that this test can identify central VF defects that are not detected with program 24-2 in patients with early glaucoma.[6–11] However, program 10-2 test does not examine

peripheral VF points outside the central 10 degrees area. Hence, both 10-2 and 24-2 VF tests often are performed for sensitive detection of glaucoma, which is time-consuming and can be strenuous to patients. However, the relative usefulness of 10-2 testing is controversial as several studies have concluded that 10-2 may not improve the detection of central VF defects and 24-2 test alone is capable of identifying eyes suspected of having glaucoma.[12–17]

Compass (Centervue, Padova, Italy) is an automated perimeter combined with a scanning ophthalmoscope and eye tracker that improves fixation stability and accurate presentation of stimuli at predefined retinal locations.[18] This device evaluates retinal sensitivity using the following test grids: 24-2 (24 degrees tested, 54 locations), 10-2 (10 degrees tested, 68 locations), and New Grid (NG; 24 degrees tested, 65 locations, similar to 24-2, but with additional central points) (Figure 1). A recent study evaluated the threshold sensitivities over the central 24-degree fields of normal subjects and glaucoma patients with Compass compared to HFA 24-2 and found that the sensitivities were similar in 47 of the 54 points tested.[19]

The purpose of the current study was to evaluate the agreement between Compass New Grid (NG) and Compass 10-2 test protocols for detecting glaucomatous defects in the central 10 degrees of the visual field (CVFD) in early glaucoma eyes without CVFDs apparent on 24-2 Compass testing. If the Compass New Grid agrees well with the Compass 10-2 test grid regarding the number of CVFDs detected, then it would provide comparable diagnostic information from a single test.

Methods

Study population

One hundred-twenty-three eyes of 32 (50.8%) early glaucoma, 17 (27.0%) glaucoma suspect, and 14 (22.2%) healthy participants were evaluated in this cross-sectional study. Each individual performed NG and 10-2 automated perimetry measurements within one week of each other and had macular optical coherence tomography (OCT) imaging within 1 year. The study was approved by the Institutional Review Board of the University of California, San Diego and the research protocol adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from all subjects prior to starting the study.

Study participants were enrolled in the Diagnostic Innovations in Glaucoma Study (DIGS).[20] The inclusion criteria were the diagnosis of early glaucoma, which was defined as having at least 2 consecutive, reliable (fixation losses and false negatives ≤ 33% and ≤ 15% false positives) abnormal Compass 24-2 results with a Pattern Standard Deviation (PSD) outside the 95% normal limits and a mean deviation (MD) > −6.0 dB.

Glaucoma suspects and healthy controls also were included. The glaucoma suspect group included eyes with glaucomatous optic neuropathy (pre-perimetric glaucoma) or suspicious appearing optic nerves based on the review of stereoscopic ONH photographs, with or without high IOP (>21 mmHg), and no evidence of repeatable glaucomatous VF damage.[21–23] Optic discs suspicious of glaucoma were defined as discs with excavation, neuroretinal rim narrowing or notching, or either localized or diffuse RNFL defects assessed

using masked fundus stereophotographs.[20] Healthy subjects were defined as having normal-appearing optic discs, neuroretinal rims, and RNFL, IOP ≤ 21 mmHg without history of elevated IOP, and normal 24-2 VF results (PSD within 95% confidence limits in both eyes). If the 24-2 VF test was able to detect central defects, it would not be essential to add additional points to diagnose defects in the central 10 degrees. Therefore, eyes with glaucoma or glaucoma suspects that had defects within the central 10 degrees of the 24-2 test patterns and eyes with MD ≤ −6.0 dB were excluded. The criteria used to determine CVFD in Compass 24-2 tests were either a single point with probability of <0.5%, two contiguous points with probability of ≤ 2% each, or three contiguous points with probabilities of <5%, <2%, <2% or worse. Eighteen eyes from 11 patients with CVFDs on the Compass 24-2 test were excluded from the study based on these criteria. Participant selection was based on a review of visual field results from subjects already enrolled in DIGS to confirm they qualified for this study.

Clinical examination

All subjects underwent a comprehensive ophthalmic examination as part of the DIGS protocol, including best-corrected visual acuity (BCVA), slit-lamp biomicroscopy, IOP using Goldmann applanation tonometry, gonioscopy, pachymetry, dilated fundus examination, stereophotography of the optic disc, SD-OCT, and visual field testing. Initially, subjects underwent visual field testing with Compass in order to learn how this test was performed. The results of this preliminary practice test were not included in the analysis. This practice test was waived if the patient had prior experience with Compass visual field testing. Study Compass NG and 10-2 automated perimetry measurements were then obtained. Central VF defects in the NG and 10-2 test protocols were defined as total deviation (TD) or pattern deviation (PD) plot CVFDs in either superior or inferior hemifields with three contiguous points with probabilities of <5%, <2%, <2% or <5%, <1%, <1%. Both eyes were tested if qualified for the study. Both, the order of eyes tested and the order of perimetry testing were randomized.

A comparative example of the testing grids of the Compass 24-2,10-2, and NG pattern deviation is shown in Figure 1. In this figure, the pattern deviation plot of the 24-2 test showed no central depression in the central 10 degrees (surrounded by the cross) with reduced sensitivity in the periphery. The pattern deviation plot of the 10-2 test shows various clusters of depressed central test points. In the 10-2, no peripheral retinal sensitivity is tested. The New Grid shows depressed test points in the central 10 degrees area (surrounded by the semi-square) and in the peripheral retina.

Macular OCT imaging (6×6mm) using the Spectralis OCT (Heidelberg Engineering GmbH, Heidelberg, Germany) also was obtained as an objective standard for evaluating sensitivity and specificity of Compass test results. For this purpose, macular defects were defined using the Spectralis GMPE Hood Glaucoma Report (investigational software that is not commercially available in the US), which includes regional normative data information and reports regional percentage outside normal limits of the macular ganglion cell inner plexiform layer overlaid on HFA 10-2 grid allowing assessment of defects at or surrounding each VF test point. OCT macular defects were defined as areas of thickness outside normal

limits ($p \leq 0.05$) covering three or more contiguous 10-2 test points in the superior and inferior hemiretina.

Statistical analysis

Cohen's Kappa (k) statistic was used to assess agreement between NG and 10-2 for identifying CVFDs, with confidence intervals determined by clustered bootstrap. Strength of agreement was defined as Kappa values ≤ 0 indicating no agreement, 0.01–0.20 indicating none to slight agreement, 0.21–0.40 indicating fair agreement, 0.41– 0.60 indicating moderate agreement, 0.61–0.80 indicating substantial agreement, and 0.81–1.00 indicating almost perfect agreement.[24] Sensitivity and specificity of NG and 10-2 tests were determined based on true and false positive rates relative to Spectralis macula imaging results as defined above. McNemar test was performed to evaluate the differences in sensitivity and specificity.

The mean central PSD of both visual fields was calculated via mixed model and non-parametric clustered rank-sum tests to compare the 68 points of the Compass 10-2 with the central 24 points of the Compass NG.

We considered p-values less than 0.05 to indicate statistical significance. All statistical analyses were performed using the R statistical software (version 3.5.2).

Results

Patient demographic data and ophthalmic measurement by eye are described in Table 1.

The frequency of CVFDs by hemifield based on total deviation (TD) and pattern deviation (PD) plots for NG and 10-2 test protocols in glaucoma and glaucoma suspect eyes (n= 49) are shown in Table 2. The largest number of CVFDs for either hemifield was observed for the 10-2 followed by the NG test protocol. In particular, the number of eyes with superior CVFD from the NG and 10-2 based on TD plots was 34 (27.6%) and 58 (47.2%) and based on PD plots was 37 (30.1%) and 86 (69.9%), respectively. In contrast, the number of eyes with inferior CVFD from the NG and 10-2 based on TD plots was 20 (16.3%) and 31 (25.2%) and based on PD plots was 19 (15.4%) and 58 (47.2%), respectively. In addition, the number of eyes with any CVFD from the NG and 10-2 based on TD plots was 41 (33.3%) and 62 (50.4%) and based on PD plots was 45 (36.6%) and 89 (72.4%), respectively (Table 2).

Table 3 and Figure 2 show fair to moderate agreement between NG and 10-2 protocols for detecting presence of superior, inferior, or any CVFD, with kappa (k) values ranging between 0.26 and 0.57.

For TD plots, agreement between NG and 10-2 VFs was k=0.57 for detecting superior CVFDs and k=0.49 for detecting inferior CVFDs (k=0.49) with both values indicating moderate agreement. For PD plots, agreement was k=0.26 for detecting superior CVFDs and k=0.27 for detecting inferior CVFDs with both values indicating fair agreement. Agreement between test protocols for detecting any CVFD was k=0.53 and k=0.27 for TD and PD plots, respectively.

Forty-six eyes had macular defects and 62 eyes had no defects on the Hood Glaucoma Report. In the 62 eyes without detectable macula OCT damage, the specificity of NG and 10-2 testing for superior hemifield CVFD was 0.82 and 0.65, respectively, for TD plots and 0.81 and 0.36, respectively, for PD plots. For the inferior hemifield CVFD, the specificity of NG and 10-2 testing was 0.92 and 0.84, respectively, for TD plots and 0.86 and 0.52, respectively, for PD plots. Specificity of NG and 10-2 testing for any defect was 0.87 and 0.74, respectively, for TD plots and 0.83 and 0.44, respectively, for PD plots. In the 46 eyes with detectable OCT macula damage, sensitivity ranged from 0.20 for detecting NG PD plot inferior defects to 0.78 for detecting 10-2 PD plot superior defects (Table 4).

The sensitivities and specificities of superior, inferior, or any CVFD also were calculated based on the VF test order (first vs. second test performed). The test order did not have any impact on sensitivity or specificity ($p>0.22$ for all comparisons; Table 5).

Representative examples of agreement and disagreement among Compass 10-2, Compass NG, and macular damage on the Hood Glaucoma Report are shown in Figure 3. Figure 3A represents a healthy eye with no CVFD on PD plots of Compass 10-2 and NG and no macular damage on the deviation map. Figure 3B shows an example of a pre-perimetric glaucoma eye with no CVFD on Compass 10-2 or NG, but with detectable macular damage on the deviation map. An example of glaucomatous eye is shown is Figure 3C. In this case, CVFD was detected in both VF tests without macular damage on the deviation map. Figures 3D and 3E show disagreement between 10-2 and New Grid. Macular damage on the deviation maps agreed with Compass 10-2 in both cases.

Compass 10-2 protocol measures more points (n=68) than Compass NG (n=24) visual field in the central area, leading to higher probability in finding 3 contiguous points with the cluster criteria. Therefore, a second analysis comparing the 68 points of the Compass 10-2 with the central 24 points of the Compass NG following a different criterion was performed, in which we calculated the central PSD of both visual fields. The mean PSD (95% CI) values for 10-2 and NG VF tests were 1.61 (1.26, 1.96) and 1.81 (1.45, 2.17) (Mixed model p-value <0.001 and Clustered rank-sum test p-value <0.001), respectively. These results suggest that PSD is significantly worse in the eyes measured by the 24 central points of the Compass NG visual field. Figure 4 shows a fair agreement between PSD of the 24 central points of the Compass NG in comparison with the 10-2 VF. However, PSD was normal or low in the Compass 10-2, but elevated in the 24 central points of the Compass NG in a group of eyes. The robust non-parametric clustered rank-sum test p-value was reported due to the skewed distribution observed in PSD in both groups (Figure 4).

The test durations for the 10-2 and NG programs were similar. Mean (± standard deviation) test durations for the 10-2 and NG were 7.60 ± 1.88 and 7.55 ± 1.46 minutes ($p= 0.35$), respectively.

Discussion

The present study showed that the overall agreement between Compass New Grid and Compass 10-2 test protocols for detecting early glaucomatous defects in the central 10

degrees of the visual field was fair to moderate by hemifield for both TD and PD plots. In addition, using macula OCT deviation maps as the gold standard, we found that adding 12 central VF test points using the NG testing protocol was more specific but less sensitive than the Compass 10-2. Although the Compass NG detected fewer central visual field defects than the 10-2, it did detect CVFDs that were not observed in the Compass 24-2 test in early glaucoma patients. The selection of an appropriate testing paradigm thus might depend on whether higher sensitivity or specificity is desired. For early glaucoma detection in a younger patient, Compass 10-2 testing might be preferable to NG because of its higher sensitivity. In contrast, for glaucoma screening of a general population, a clinician might consider the use of NG because of its higher specificity.

Although studies examining the effect of disease severity on the diagnostic performance of Compass are lacking, multiple studies have investigated this effect on the diagnostic ability of standard automated perimetry (SAP).[25,26] Medeiros et al. found a significant effect of disease severity on the diagnostic performance of SAP PSD, which for a specificity of 80%, had a sensitivity of 40% in eyes with early glaucoma.[26] This percentage is lower than the sensitivity of the Compass 10-2 found in the current study. In a study evaluating the validity of HFA (The Swedish interactive threshold algorithm standard and fast) tests as screening tools for glaucoma, they found that HFA specificity was 96% for both algorithms, which is higher than the specificity of Compass NG (81%-92%) calculated in this study.[27]

Specificity for identifying CVFD in eyes without detectable macular damage was consistently higher in the Compass NG test protocol compared to the 10-2 test protocol. The lower specificity observed using the 10-2 test protocol might be due in part to smaller local VF defects detected by a larger number of test points (n= 68 test points) compared to fewer NG test points (n= 24 test points), resulting in fewer NG defects (i.e., some defects could be missed using NG due to increased distance between contiguous test points). Conversely, sensitivity was consistently lower in the Compass NG test compared to the 10-2 test, which likely is due to the fewer central test points in the NG.

Due to the higher probability in finding three contiguous points with the cluster criteria in the 10-2 test protocol, a second analysis comparing the central PSD of both VF tests was performed.[16] The analysis suggests that in some eyes, the PSD in the Compass 10-2 was normal or low, but high in the central points of the Compass NG. Using the PSD criteria, the Compass NG might perform better than the Compass 10-2 in detecting CVFDs.

Although the ability of the Compass 10-2 VF test and central 12 test points of the Compass 24-2 test to detect CVFD in glaucoma has not been studied, several studies have compared the efficacy of HFA 10-2 versus 24-2 VFs in detecting the development and progression of glaucomatous CVFD. These studies have suggested that 10-2 VF tests may improve clinical detection of glaucoma in eyes with normal 24-2 VF results. Specifically, De Moraes et al. found that more than 60% of early glaucomatous eyes and about 40% of glaucoma suspect eyes that had normal cluster criteria on 24-2 VF testing were classified as abnormal on the 10-2 VF.[11] Grillo et al. suggested that the 10-2 VF test is particularly useful to detect glaucomatous macular damage.[7] In contrast, other studies did not find any advantage of 10-2 over 24-2 VF test protocol in detecting early central glaucomatous visual field damage.[12–17]

For instance, Sullivan-Mee et al. found that over 80% of eyes with 10-2 CVFD also had defects in the central 10 degrees of the 24-2 test.[12] Another study by Hood et al. showed that the 10-2 VF test may not be the best measure of early macular damage and impressed the importance of combining structural and functional testing for a more accurate detection of early glaucoma.[13] A recent paper by West and colleagues found that 10-2 test did not add additional benefit of detecting central VF defects in patients with early glaucoma and they suggested reserving this test for patients at a greater risk of central VF progression.[15] These studies did not claim that 10-2 tests were not useful, but emphasized the need for additional studies to determine the potential advantages of performing 10-2 tests and its necessity to be incorporated into glaucoma standard of care.

Several studies have evaluated the relative diagnostic accuracy and test variability of the Compass and HFA 24-2 test grids. Rossetti et al. found that the difference in mean sensitivity between the two devices was smaller than 2dB in normal and glaucoma subjects and claimed that the two perimeters were interchangeable.[18] Montesano et al. concluded that the accuracy of the two perimeters was comparable, but the test-retest variability of mean sensitivity was better for Compass than HFA.[28] Fogagnolo et al. investigated the differences in size of scotomas in glaucoma patients and found that Compass showed larger absolute scotomas than the HFA although the differences in mean sensitivity and global indices were small between the two devices.[19] Overall, the Compass and HFA devices generally provide similar diagnostic accuracy for glaucoma detection for the 24-2 test grid.

The frequency of CVFDs was higher using the PD than the TD plot criteria for both test protocols but most notably for the 10-2 testing protocol in the current study. The PD plot is intended to emphasize localized defects by eliminating generalized VF loss, notably due to cataract. Our results are informative because the PD plot is often used by clinicians to identify glaucomatous damage and its progression.

In the current study, we calculated the number of CVFDs detected using NG testing with a criterion requiring a single point with probability of <0.5% and two contiguous points with probability of ≤ 2% each (data not shown). More CVFDs were identified by the single point and two contiguous points compared to the cluster definition using the NG testing. Regardless of the larger number of CVFDs detected by a single point or two contiguous points, the agreement for detecting superior, inferior, or any CVFD based on the TD and PD plots was still fair to moderate.

A possible limitation of the current study is the use of the OCT macular deviation map as a standard to define CVFD as outside normal limits by the internal OCT database. This may have resulted in false positive or false negative Compass NG or 10-2 results. For example, the larger number of test points included in the 10-2 testing protocol could have contributed to lower specificity (and higher sensitivity) compared to the NG testing protocol due to random abnormal points in noisy VFs. Alternately VF “false positives” could be true positive decreases in VF sensitivity not yet identified by the OCT macula deviation map used as a standard. In addition, the sample size in the current study was relatively small. Further work using the Compass perimeter should include longitudinal studies with

larger sample sizes in order to determine how well the NG compared to the 10-2 (and 24-2) protocols can identify CVFDs over time.

In summary, the two protocols had fair to moderate agreement for the detection of central visual field defects with the Compass New Grid showing higher specificity and lower sensitivity than the Compass 10-2 testing protocol in this study population of early glaucoma patients with no evidence of CVFD on the Compass 24-2 test. This study suggests that the Compass New Grid may be useful in detecting glaucoma CVFD when high specificity is desired or when PSD criterion is used.

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Bibliography

1. Tan O, Chopra V, Lu AT- H, Schuman JS, Ishikawa H, Wollstein G, Varma R, Huang D . Detection of Macular Ganglion Cell Loss in Glaucoma by Fourier-Domain Optical Coherence Tomography. Ophthalmology. 2009;116:2305–2314.e2. [PubMed: 19744726]
2. Wang M, Hood D, Cho JS, Ghadiali Q, De Moraes CG, Zhang X, Ritch R, Liebmann JM. Measurement of Local Retinal Ganglion Cell Layer Thickness in Patients With Glaucoma Using Frequency-Domain Optical Coherence Tomography. Arch Ophthalmol. 2009;127:875–81. [PubMed: 19597108]
3. Sakamoto A, Hangai M, Nukada M, Nakanishi H, Mori S, Kotera Y, Inoue R, Yoshimura N. Three-dimensional imaging of the macular retinal nerve fiber layer in glaucoma with spectral-domain optical coherence tomography. Investig Ophthalmol Vis Sci. 2010;51: 5062–5070. [PubMed: 20463326]
4. Hood DC, Raza AS, de Moraes CG V, Johnson CA, Liebmann JM, Ritch R. The Nature of Macular Damage in Glaucoma as Revealed by Averaging Optical Coherence Tomography Data. Transl Vis Sci Technol. 2012;1:3.
5. Tatham AJ, Medeiros FA, Zangwill LM, Weinreb RN. Strategies to improve early diagnosis in glaucoma. Prog Brain Res. 2015; 221: 103–33. [PubMed: 26518075]
6. Traynis I, De Moraes CG, Raza AS, Liebmann JM, Ritch R, Hood DC. Prevalence and nature of early glaucomatous defects in the central 10 of the visual field. JAMA Ophthalmol. 2014; 132: 291–297. [PubMed: 24407153]
7. Grillo LM, Wang DL, Ramachandran R, Ehrlich AC, De Moraes CG, Ritch R, Hood DC. The 24-2 Visual Field Test Misses Central Macular Damage Confirmed by the 10-2 Visual Field Test and Optical Coherence Tomography. Transl Vis Sci Technol. 2016;5:15.
8. Hood DC, Raza AS, de Moraes CG V, Odel JG , Greenstein VC, Liebmann JM, Ritch R. . Initial arcuate defects within the central 10 degrees in glaucoma. Investig Ophthalmol Vis Sci. 2011; 52: 940–6. [PubMed: 20881293]
9. Park SC, Kung Y, Su D, Simonson JL, Furlanetto RL, Liebmann JM, Ritch R. Parafoveal scotoma progression in glaucoma: Humphrey 10-2 versus 24-2 visual field analysis. Ophthalmology. 2013; 120: 1546–1550. [PubMed: 23697959]
10. Asaoka R Mapping glaucoma patients' 30-2 and 10-2 visual fields reveals clusters of test points damaged in the 10-2 grid that are not sampled in the sparse 30-2 grid. PLoS One. 2014; 9:e98525. [PubMed: 24950300]

11. De Moraes CG, Hood DC, Thenappan A, Girkin CA, Medeiros FA, Weinreb RN, Zangwill LM, Liebmann JM. 24-2 Visual Fields Miss Central Defects Shown on 10-2 Tests in Glaucoma Suspects, Ocular Hypertensives, and Early Glaucoma. Ophthalmology. 2017;124:1449–1456. [PubMed: 28551166]
12. Sullivan-Mee M, Karin Tran MT, Pensyl D, Tsan G, Katiyar S. Prevalence, Features, and Severity of Glaucomatous Visual Field Loss Measured with the 10-2 Achromatic Threshold Visual Field Test. Am J Ophthalmol. 2016;168: 40–51. [PubMed: 27173372]
13. Hood DC, Thenappan AA, Tsamis E, Liebmann JM, De Moraes CG. An Evaluation of a New 24-2 Metric for Detecting Early Central Glaucomatous Damage. Am J Ophthalmol. 2021;223:119–128. [PubMed: 32777374]
14. Wu Z, Medeiros FA, Weinreb RN, Girkin CA, Zangwill LM. Specificity of various cluster criteria used for the detection of glaucomatous visual field abnormalities. Br J Ophthalmol. 2020; 104:822–826. [PubMed: 31530565]
15. West ME, Sharpe GP, Hutchison DM, Rafuse PE, Shuba LM, Nicolela MT, Vianna JR, Chauhan BC. Value of 10-2 Visual Field Testing in Glaucoma Patients with Early 24-2 Visual Field Loss. Ophthalmology. 2020; S0161-6420(20)30852-6.
16. Wu Z, Medeiros FA, Weinreb RN, Zangwill LM. Performance of the 10-2 and 24-2 Visual Field Tests for Detecting Central Visual Field Abnormalities in Glaucoma. Am J Ophthalmol. 2018;196: 10–17. [PubMed: 30099037]
17. Orbach A, Ang GS, Camp AS, Welsbie DS, Medeiros FA, Girkin CA, Fazio MA, Oh WH, Weinreb RN, Zangwill LM, Wu Z. Qualitative Evaluation of the 10-2 and 24-2 Visual Field Tests for Detecting Central Visual Field Abnormalities in Glaucoma. Am J Ophthalmol. 202; S0002-9394: 00080-5.
18. Rossetti L, Digiuni M, Rosso A, Riva R, Barbaro G, Smolek MK, Orzalesi N, De Cilla S, Autelitano A, Fogagnolo P . Compass: Clinical evaluation of a new instrument for the diagnosis of glaucoma. PLoS One. 2015; 10: e0122157. [PubMed: 25807241]
19. Fogagnolo P, Modarelli A, Oddone F, Digiuni M, Montesano G, Orzalesi N, Rossetti L. Comparison of Compass and Humphrey perimeters in detecting glaucomatous defects. Eur J Ophthalmol. 2016; 26:598–606. [PubMed: 27375066]
20. Sample PA, Girkin CA, Zangwill LM, et al. The African descent and glaucoma evaluation study (ADAGES): Design and baseline data. Arch Ophthalmol. 2009; 127:1136–45. [PubMed: 19752422]
21. Cennamo G, Montorio D, Velotti N, Sparnelli F, Reibaldi M, Cennamo G. Optical coherence tomography angiography in pre-perimetric open-angle glaucoma. Graefe's Arch Clin Exp Ophthalmol. 2017; 255:1787–1793. [PubMed: 28631244]
22. Aydogan T, Akçay BS, Kardeş E, Ergin A. Evaluation of spectral domain optical coherence tomography parameters in ocular hypertension, preperimetric, and early glaucoma. Indian J Ophthalmol. 2017;65:1143–1150. [PubMed: 29133640]
23. Cvenkel B, Sustar M, Perovšek D. Ganglion cell loss in early glaucoma, as assessed by photopic negative response, pattern electroretinogram, and spectral-domain optical coherence tomography. Doc Ophthalmol. 2017; 135:17–28. [PubMed: 28567618]
24. Landis JR, Koch GG. The Measurement of Observer Agreement for Categorical Data. Biometrics. 1977; 33: 159–174. [PubMed: 843571]
25. Liu S, Lam S, Weinreb RN, Ye C, Cheung CY, Lai G, Lam DS, Leung CK . Comparison of standard automated perimetry, frequency-doubling technology perimetry, and short-wavelength automated perimetry for detection of glaucoma. Investig Ophthalmol Vis Sci. 2011; 52: 7325–31. [PubMed: 21810975]
26. Medeiros FA, Sample PA, Zangwill LM, Liebmann JM, Girkin CA, Weinreb RN. A Statistical Approach to the Evaluation of Covariate Effects on the Receiver Operating Characteristic Curves of Diagnostic Tests in Glaucoma. Investig Opthalmology Vis Sci. 2006;47:2520–7.
27. Budenz DL, Rhee P, Feuer WJ, McSoley J, Johnson CA, Anderson DR. Sensitivity and specificity of the Swedish interactive threshold algorithm for glaucomatous visual field defects. Ophthalmology. 2002; 109:1052–8. [PubMed: 12045043]

28. Montesano G, Bryan SR, Crabb DP, et al. A Comparison between the Compass Fundus Perimeter and the Humphrey Field Analyzer. Ophthalmology. 2019; 126: 242–251. [PubMed: 30114416]

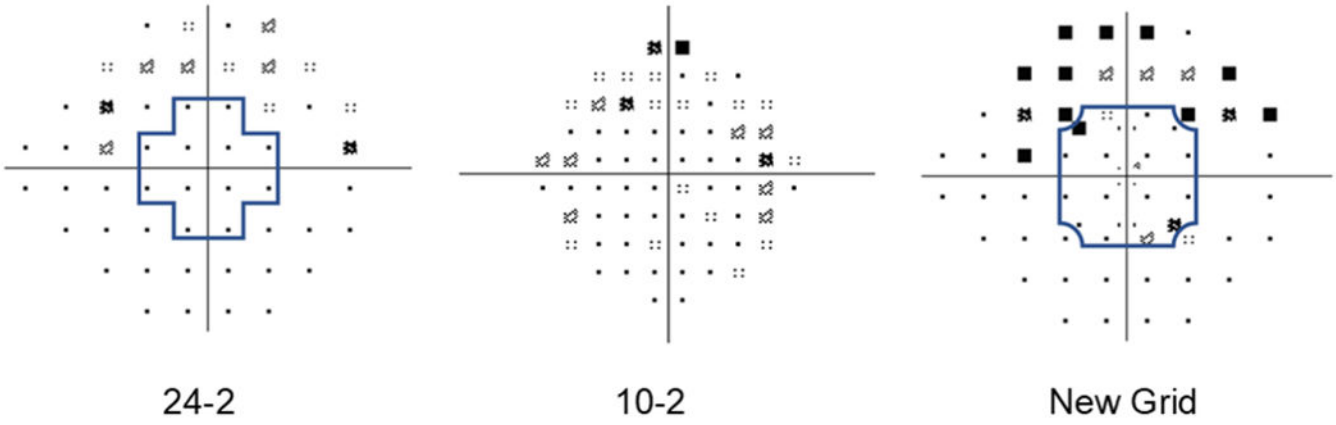

Figure 1.
Pattern deviation plots of Compass 24-2, 10-2, and New Grid of the same early glaucoma eye included in the current study.

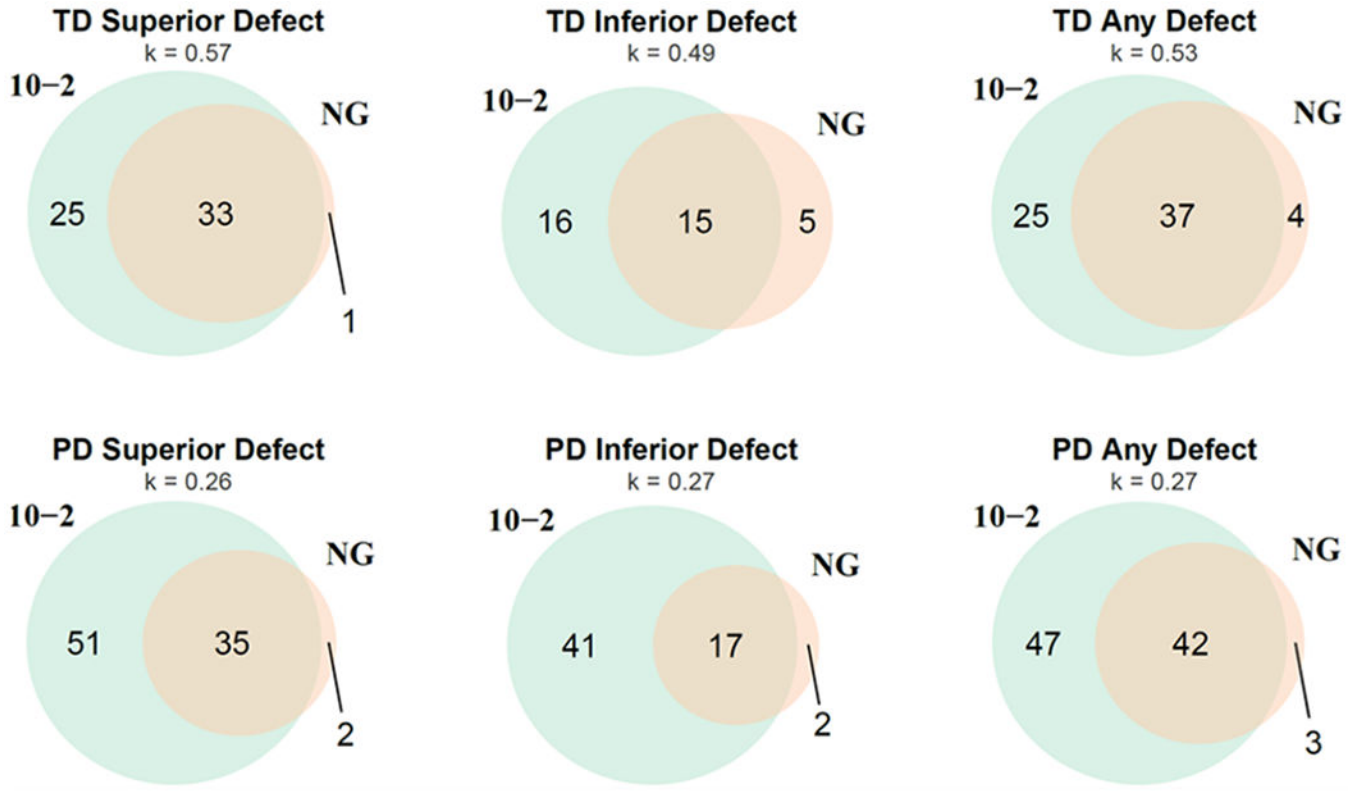

Figure 2.

Venn Diagrams illustrating the fair to moderate agreement for identifying the presence of superior, inferior, or any central visual field defects in glaucoma and glaucoma suspect eyes among the New Grid (NG) and 10-2 testing protocols.

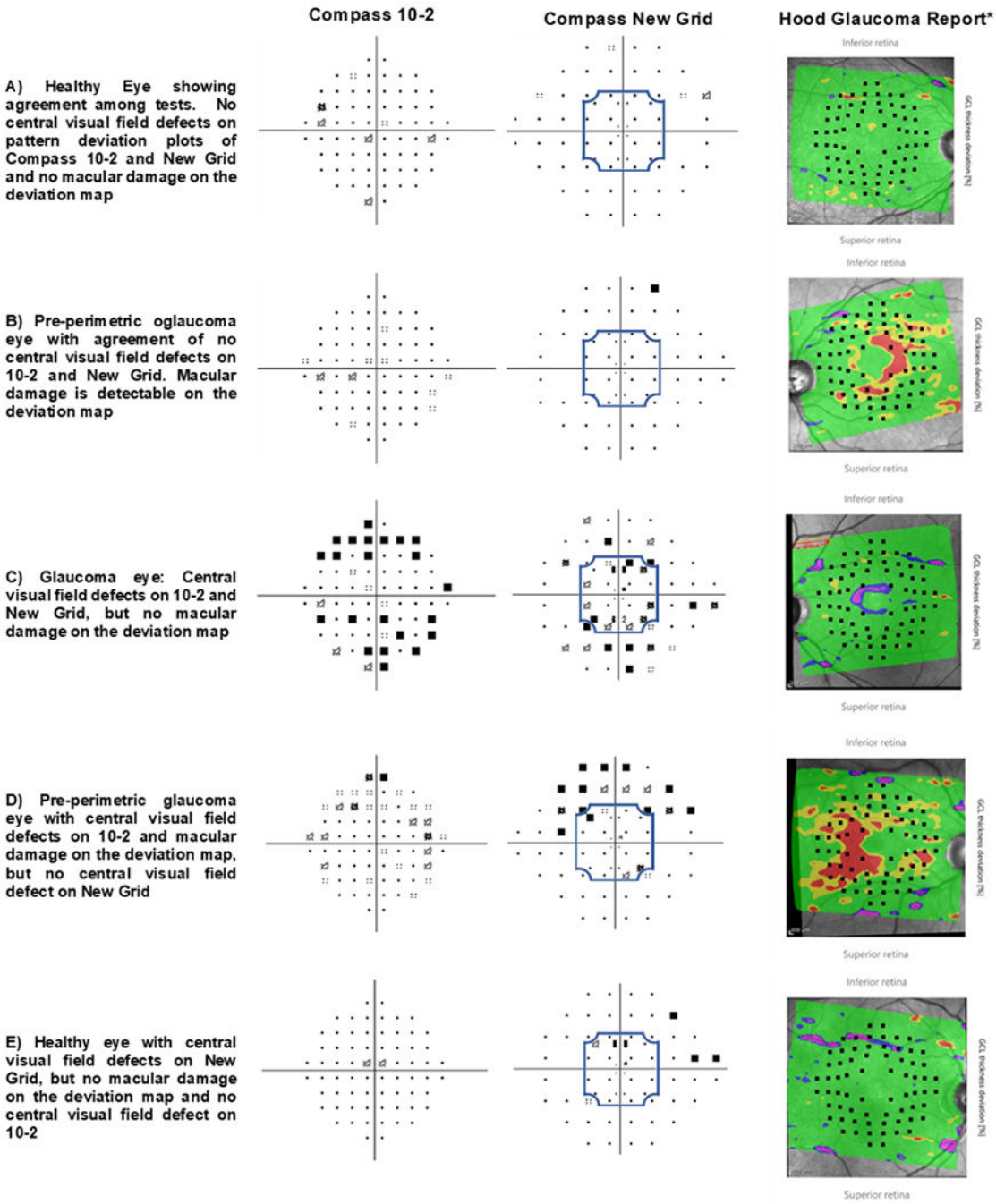

Figure 3.

Representative cases of agreement and disagreement between 10-2, New Grid, and Hood Glaucoma Report.

* Hood Glaucoma Report is an investigational software version; software is not commercially available in the US.

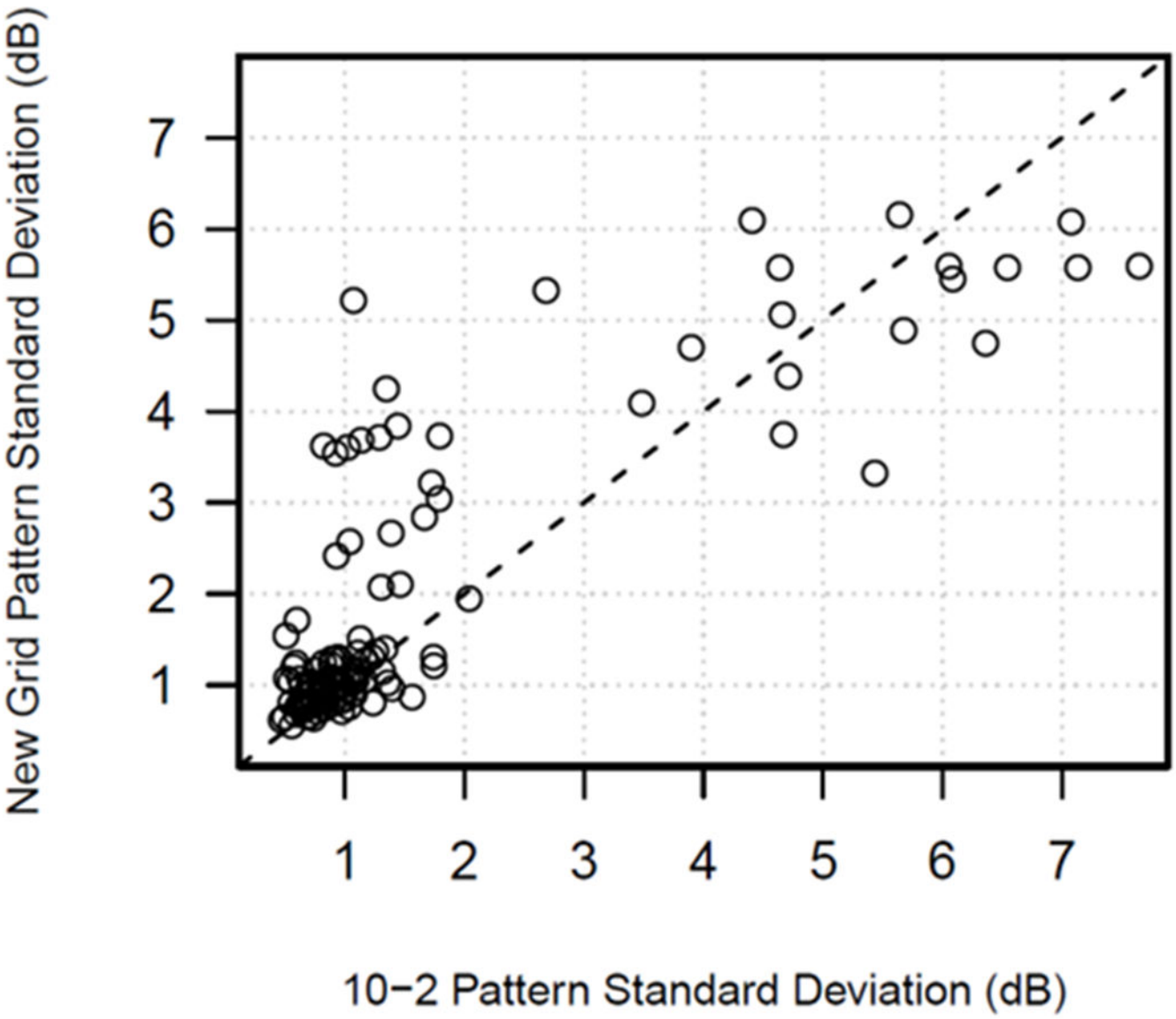

Figure 4.
Scatterplot of the pattern standard deviation (PSD) of the central 24 points of the New Grid visual field test against the PSD of the entire points of 10-2 visual field test. The black line represents the line of equality between these 2 parameters.

Table 1.

Patient demographic and clinical characteristics.

	Healthy (n = 48 eyes, 25 subjects)	Suspect (n = 72 eyes, 39 subjects)	Glaucoma (n = 226 eyes, 142 subjects)	p value
Age (years)	63.4 (59.2 – 67.5)	67.7 (64.4 – 71.1)	68.7 (67.0 – 70.5)	0.067
Gender				
% male	20.0	36.9	55.6	0.001
% female	80.0	64.1	44.4	
Race				
Caucasian (%)	68.0	64.1	62.7	0.458
African Descent (%)	28.0	18.0	26.1	
Others (%)	4.0	17.9	11.2	
Compass 24-2 MD (dB)	0.1 (−0.2 – 0.5)	−1.2 (−2.1 – −0.3)	−5.3 (−6.2 – −4.4)	< 0.001
IOP (mmHg)	14.8 (14.0 – 15.5)	17.5 (16.4 – 18.6)	15.6 (14.8 – 16.4)	0.011

Data is presented as mean (95% confidence interval) and count (%) for continuous and categorical data, respectively.

MD: mean deviation; dB: decibels; IOP: intraocular pressure.

Table 2.

Frequency of superior, inferior and any central visual field defects by three contiguous points with probabilities of <5%, <2%, <2% or <5%, <1%, <1% in total deviation (TD) and pattern deviation (PD) plots in glaucoma suspects and patients.

Compass Test Pattern	Superior Defect		Inferior Defect		Any Defect	
	TD	PD	TD	PD	TD	PD
NG	34 (27.6%)	37 (30.1%)	20 (16.3%)	19 (15.4%)	41 (33.3%)	45 (36.6%)
10-2	58 (47.2%)	86 (69.9%)	31 (25.2%)	58 (47.2%)	62 (50.4%)	89 (72.4%)

Table 3.

Agreement between central visual field defect identified by Compass New Grid (NG) and Compass 10-2 test based on total deviation (TD) and pattern deviation (PD) plots.

	TD: 10-2			PD: 10-2		
	No	**Yes**	**Cohen's κ [mean (95% CI)]**	**No**	**Yes**	**Cohen's κ [mean (95% CI)]**
NG: Superior Defect No	64 (98.5%)	25 (43.1%)	0.57 (0.44, 0.70)	35 (94.6%)	51 (59.3%)	0.26 (0.14, 0.39)
Yes	1 (1.5%)	33 (56.9%)		2 (5.4%)	35 (40.7%)	
NG: Inferior Defect No	87 (94.6%)	16 (51.6%)	0.49 (0.30, 0.66)	63 (96.9%)	41 (70.7%)	0.27 (0.12, 0.44)
Yes	5 (5.4%)	15 (48.4%)		2 (3.1%)	17 (29.3%)	
NG: Any CVFD No	57 (93.4%)	25 (40.3%)	0.53 (0.40, 0.66)	31 (91.2%)	47 (52.8%)	0.27 (0.16, 0.42)
Yes	4 (6.6%)	37 (59.7%)		3 (8.8%)	42 (47.2%)	

CI: Confidence interval.

Table 4.

Specificity and sensitivity of Compass New Grid (NG) and Compass 10-2 testing for superior, inferior, and any central visual field defects (CVFD) in total deviation (TD) and pattern deviation (PD) plots based on assessment of macula damage using the Hood Glaucoma Report. AUC p-values are to compare sensitivity and specificity jointly.

Specificity (62 eyes without macula damage)							**Sensitivity (46 eyes with macula damage)**					
Compass Test Pattern	**Superior Defect**		**Inferior Defect**		**Any Defect**		**Superior Defect**		**Inferior Defect**		**Any Defect**	
	TD	**PD**	**TD**	**PD**	**TD**	**PD**	**TD**	**PD**	**TD**	**PD**	**TD**	**PD**
NG	0.82	0.81	0.92	0.86	0.87	0.83	0.48	0.48	0.28	0.20	0.38	0.34
10-2	0.65	0.36	0.84	0.52	0.74	0.44	0.72	0.78	0.46	0.52	0.59	0.65
McNemar p-value	**0.006**	**<0.001**	0.343	**<0.001**	0.160	**<0.001**	**0.003**	**0.001**	**0.027**	**<0.001**	**0.010**	**<0.001**
AUC p-value	0.460	0.135	0.183	0.900	0.619	0.243						

P<0.05 are statistically significant.

Table 5.

Specificity and sensitivity of the visual field test performed first for superior, inferior, and any central visual field defects (CVFD) in total deviation (TD) and pattern deviation (PD) plots based on assessment of macula damage using the Hood Glaucoma Report. AUC p-values are to compare sensitivity and specificity jointly.

Specificity (62 eyes without macula damage)							Sensitivity (46 eyes with macula damage)					
Compass Test Order	**Superior Defect**		**Inferior Defect**		**Any Defect**		**Superior Defect**		**Inferior Defect**		**Any Defect**	
	TD	**PD**	**TD**	**PD**	**TD**	**PD**	**TD**	**PD**	**TD**	**PD**	**TD**	**PD**
First	0.77	0.56	0.89	0.73	0.77	0.56	0.59	0.65	0.39	0.39	0.60	0.68
Second	0.69	0.60	0.85	0.65	0.68	0.55	0.61	0.61	0.35	0.33	0.58	0.63
McNemar p-value	0.267	0.850	0.752	0.404	0.181	0.999	0.999	0.803	0.752	0.628	0.999	0.646
AUC p-value	0.526	0.927	0.379	0.219	0.220	0.554						