Frequency-Doubling Technology Perimetry for Detection of the Development of Visual Field Defects in Glaucoma Suspect Eyes
A Prospective Study

Shu Liu, PhD; Marco Yu, BSc; Robert N. Weinreb, MD; Gilda Lai, BSc; Dennis Shun-Chiu Lam, MD; Christopher Kai-Shun Leung, MD

IMPORTANCE While standard automated perimetry (SAP) remains the reference standard for evaluation of visual field (VF) defects in glaucoma, this study demonstrates that frequency-doubling technology (FDT) perimetry is effective in monitoring visual field progression and may detect the onset of visual field defects earlier than SAP.

OBJECTIVES To compare detection of the development of VF defects, rate of change of VF loss, and risk factors for progression between SAP and matrix FDT perimetry in glaucoma suspect and ocular hypertensive eyes.

DESIGN, SETTING, AND PARTICIPANTS A total of 113 glaucoma suspect and ocular hypertensive eyes from 76 patients with normal SAP and FDT perimetry results at baseline were prospectively followed up for SAP and FDT perimetry testing at approximately 4-month intervals for 30 months or longer. Patients were consecutively enrolled and followed up from January 2, 2008, to February 28, 2012, at the Hong Kong Eye Hospital, Chinese University of Hong Kong. Visual field progression was defined by the development of VF defects confirmed by 3 or more consecutive examinations at a cluster of 3 or more (less conservative) or 4 or more (more conservative) locations. The rates of change of mean deviation and pattern standard deviation were evaluated with linear mixed models and the risk factors for VF progression were computed with Cox proportional hazard models.

RESULTS During a median study period of 3.4 years, 8.0% of eyes developed VF defects detected by FDT perimetry, 6.2% by SAP, and 4.4% by both using the less-conservative criteria. The detection dropped to 6.2%, 4.4%, and 2.7%, respectively, when the more-conservative criteria were applied. The rate of change of pattern standard deviation was significantly faster for FDT perimetry than SAP \( (P < .001) \). Baseline average retinal nerve fiber layer thickness and the number of clock hours of abnormal retinal nerve fiber layer measurement were associated with increased risk for VF progression for both SAP and FDT perimetry.

CONCLUSIONS AND RELEVANCE Frequency-doubling technology perimetry would be useful to monitor the onset of VF defects in glaucoma and may detect VF defects not evident in SAP.
Perimetry is indispensable for assessment of visual function in glaucoma management. While white-on-white standard automated perimetry (SAP) remains the reference standard for evaluation of visual field (VF) in glaucoma, there is evidence supporting that frequency-doubling technology (FDT) perimetry performs as well as, if not better than, SAP for detection of glaucomatous VF defects. However, less is known about the role of FDT perimetry in monitoring the development of glaucoma defects and their progression. Longitudinal studies investigating VF progression detected by FDT perimetry have been largely based on the first generation of FDT perimetry examining 17 (C-20 program) to 19 (N-30 program) locations within the central 20° to 30°. The second generation of FDT perimetry, the Matrix FDT Perimeter (Carl Zeiss Meditec Inc), has a spatial resolution similar to the 24-2 testing pattern in SAP. With larger-sized stimuli, the Matrix FDT perimetry has been shown to provide a more uniform test-retest variability at different levels of visual sensitivity compared with the SAP. Thus, Matrix FDT perimetry may outperform SAP to detect progressive VF loss. Determining the role of Matrix FDT perimetry in monitoring disease progression is an unmet need in glaucoma management.

In this prospective study, we performed Matrix FDT perimetry and SAP examinations at the same visits approximately every 4 months for at least 30 months in eyes with a diagnosis of glaucoma suspect or ocular hypertension. We compared their performance for detection of the development of VF defects, calculated the rates of change of mean deviation (MD) and pattern standard deviation (PSD) derived from these 2 perimetry, and evaluated their risk factors for development of VF defects. The results of the study would be informative to address the roles of FDT perimetry in monitoring the onset of glaucomatous damage.

Methods

Participants
One hundred thirteen glaucoma suspect and ocular hypertensive eyes from 76 patients were consecutively enrolled and followed up from January 2, 2008, to February 28, 2012, at the Hong Kong Eye Hospital, Chinese University of Hong Kong. Glaucoma suspect was defined as (1) eyes with definite or suspected glaucomatous optic disc changes, including loss of neuroretinal rim with/without thinning of the retinal nerve fiber layer (RNFL) but without evidence of VF defects in SAP and FDT perimetry, or (2) the fellow perimetrically normal eyes (ie, no VF defects in SAP and FDT perimetry) of a patient with glaucoma (patients with glaucoma had glaucomatous VF defects in SAP in at least 1 eye). Ocular hypertensive eyes had a record of intraocular pressure (IOP) of 22 mm Hg or greater measured by Goldmann applanation tonometry in 3 follow-up visits without evidence of glaucomatous optic disc damage (ie, ocular hypertension). All included eyes had no VF defects in SAP and Matrix FDT perimetry in the baseline visit.

This study was conducted in accordance with the ethical standards stated in the Declaration of Helsinki and approved by the local research ethics committee, with written informed consent obtained.

All patients underwent a full ophthalmic examination including measurement of visual acuity, refraction and IOP, gonioscopy, and fundus examination. Patients were included if they had visual acuity of at least 20/40. Patients were excluded if they had clinical evidence of macular disease, refractive or retinal surgery, neurological disease, or diabetes mellitus. Each patient underwent SAP (Humphrey Field Analyzer II, Carl Zeiss Meditec Inc) and FDT perimetry (Matrix Frequency-Doubling Perimeter, Carl Zeiss Meditec Inc) testing, as well as RNFL imaging with a spectral-domain optical coherence tomographer (OCT) (Cirrus HD-OCT, Carl Zeiss Meditec Inc), in a random order with at least a 10-minute break in between during the same visit (described here) by a team of experienced technicians in the baseline visit, and then in 4-month intervals for at least 30 months. During the follow-up, patients were observed or treated at the discretion of the attending physicians taking the target IOP and the risk for progression into consideration.

VF Testing
Static automated white-on-white threshold perimetry (SAP) was performed with the 24-2 SITA standard program version 4.1 of the Humphrey Field Analyzer II. Each of the achromatic Goldman size III targets was presented for 200 milliseconds on a background illumination of 10 cd/m². The principle of FDT perimetry has been described. Frequency-doubling technology perimetry was performed with the Matrix FDT Perimeter. Also, 0.5 cycles/degree sinusoidal gratings undergoing counter phase flickering at 18 Hz were sequentially displayed over 54.5° × 5° squares using the 24-2 zippy estimation by sequential testing thresholding algorithm. For SAP, the patients’ appropriate near correction was corrected with a trial lens inserted in the lens holder. For Matrix FDT perimetry, the patients used their habitual correction. Only reliable VFs (fixation losses and false-negative errors and false-positive errors ≤20% for both SAP and FDT perimetry) were analyzed. To minimize potential selection bias in the comparison between the perimetric tests, we only included VFs that had concurrent FDT perimetry and SAP results in the same visits. With an approximate 4-month follow-up schedule, a total of 1173 visits were included for analysis throughout the study for all patients. Eighteen eyes missed 18 FDT examinations and 1 eye missed 1 SAP examination. Three FDT perimetry and 2 SAP examinations were considered unreliable. When a patient missed a follow-up appointment, we would call back the patient and arrange another appointment within about 2 weeks. When aVF was unreliable, we would ask the patient to retake the test after rest. For this reason, the dropout rate was low and the number of unreliable VFs was small. Finally, 1149 FDT perimetry and 1149 SAP examinations were available for analysis.

Criteria to Define the Development of VF Defects
Two sets of criteria were used to define the development of VF defects:
1. More conservative: At least a cluster of 4 monedge locations (except for the 2 nasal locations 30° away from the central fixation) indicated at a probability level of 5% or less with
at least 1 of 1% or less on the same side of the horizontal meridian in the pattern deviation plot, and detected at the same locations by at least 3 consecutive examinations by the same types of perimetry.

2. Less conservative: At least a cluster of 3 nonedge locations (except for the 2 nasal locations 30° away from the central fixation) indicated at a probability level of 5% or less with at least 1 of 1% or less on the same side of the horizontal meridian in the pattern deviation plot, and detected at the same locations by at least 3 consecutive examinations by the same types of perimetry.

The same sets of criteria were applied for both SAP and FDT perimetry.

Cirrus HD-OCT RNFL Imaging
Spectral-domain OCT imaging was performed with the Cirrus HD-OCT software version 5.0. An optic disc cube scan protocol was used to measure the RNFL thickness in a 6 × 6 mm² area consisting of 200 × 200 axial scans (pixels) at the optic disc region. The RNFL thickness at each pixel was measured and an RNFL thickness map was generated. A calculation circle of 3.46-mm diameter consisting of 256 A scans was then automatically positioned with the center overlapped with that of the optic disc. Clock-hour, quadrant, and total average RNFL thicknesses were reported and color coded in green, yellow, or red, representing within normal limits (within 95% normal distribution), borderline (within 1%-5% of normal distribution), or outside normal limits (below the lower 0%-1% of normal distribution), respectively, with reference to the normative database. All the OCT scans included in the study had a signal strength of at least 7. Saccadic eye movement was detected with line-scanning ophthalmoscopy overlaid with the OCT en-face images. Images with motion artifact were rescanned at the same visit.

Statistical Analyses
Statistical analyses were performed using Stata version 10.0 (StataCorp). Optical coherence tomography average RNFL thickness and VF MD and PSD measurements between the baseline and final follow-up visits were compared with linear mixed models after adjustment of correlation between fellow eyes. The proportion of progressing eyes detected by FDT perimetry and SAP was compared with Fisher exact test. The agreement of progression detection between SAP and FDT perimetry was calculated with Kappa statistics. A value from 0.0 to 0.2 indicated slight agreement, 0.21 to 0.40 was fair, 0.41 to 0.60 was moderate, 0.61 to 0.80 was substantial, and 0.81 to 1.0 was almost perfect agreement. The rates of change of PSD and MD were calculated with linear mixed modeling using all the longitudinal VF data (1149 FDT perimetry and 1149 SAP results) collected from all eyes. The model comprised 2 components: (1) fixed effects and (2) random effects. The fixed-effects model included the overall/global regression line from all the data weighted according to the duration and number of examinations in each eye. The random-effects model included the deviation from the overall/global regression line after accounting for subject- and eye-specific variations. Comparison of the rates of change of MD and PSD between FDT perimetry and SAP was evaluated with likelihood ratio test between the goodness of fit of the linear mixed models. The sample size required for the linear mixed models was calculated based on the estimates of random intercept variance, random slope variance, residual variance, the covariance between random slope and random intercept, and the working correlation matrix derived from the linear mixed models, and assuming that all longitudinal measurements were collected at regular time intervals (every 4 months for 30 months).

Sample size calculation revealed that at least 78 eyes would be required to detect a rate of change of MD of −0.5 dB/y or less and a rate of change of PSD of 0.1 dB/y or more (these rates were arbitrary cutoffs considered as clinically relevant) at a statistical power of 80%. Risk factors for development of VF defects were analyzed with Cox proportional hazard models after adjusting for treatment effect (1 = with IOP lowering therapy, 0 = without IOP lowering therapy; among the 113 eyes, 62 eyes [54.9%] had received IOP lowering therapy) with reference to the results derived from the less-conservative criteria. A shared frailty model was used to adjust for the correlation between fellow eyes. P < .05 was considered statistically significant.

Results
A total of 113 glaucoma suspect and ocular hypertensive eyes with normal SAP and Matrix FDT perimetry results at the baseline visit were followed up for at least 30 months. The demographics are shown in Table 1. There were significant differences in the MD between the baseline and final visits for both perimeties (P < .02). Likewise, a significant difference in the average RNFL thickness was found between the baseline and final visits (P < .001). The PSD was significantly greater in the final visit for Matrix FDT perimetry (P = .001), but not for SAP (P = .08).

Using the more-conservative criteria (a cluster of 4 nonedge locations detected at the same locations in at least 3 consecutive examinations), 6.2% (7 eyes, 6 patients) and 4.4% (5 eyes, 4 patients) of eyes developed VF defects detected by FDT perimetry and SAP, respectively, over a median study period of 3.4 years (range, 2.5-4.1 years) (Figure, A). A total of 2.7% (3 eyes) had progression detected by both perimetries (2 eyes had progression detected by FDT perimetry 4.8-9.8 months earlier than SAP, 1 was detected by both at the same visits).

Using the less-conservative criteria (a cluster of 3 nonedge locations detected at the same locations in at least 3 consecutive examinations), the proportions increased to 8.0% (9 eyes, 8 patients), 6.2% (7 eyes, 6 patients), and 4.4% (5 eyes, 4 patients), respectively (Figure, B). Among the 5 progressing eyes detected by both perimetries, 2 had progression detected by FDT perimetry 9.8 to 13.0 months earlier than SAP, 2 were detected at the same follow-up visits, and 1 had progression detected by SAP 4 months earlier than FDT perimetry.

The agreement for detection of VF progression was fair to moderate (kappa = 0.47-0.60), and there were no significant differences in the proportions of progressing eyes between the perimetry using the less- or the more-conservative criteria (P = .77, Fisher exact test).
Taking all eyes into consideration, the rate of change of PSD was 0.04 dB/y (95% CI, 0.01 to 0.08) for SAP and 0.10 dB/y (95% CI, 0.06 to 0.14) for FDT perimetry. The rates of change for MD were −0.24 dB/y (95% CI, −0.32 to −0.15) and −0.22 dB/y (95% CI, −0.39 to −0.06), respectively, after adjusting correlation between fellow eyes in the linear mixed models. The rate of change of PSD was faster in FDT perimetry than in SAP (P < .001), whereas the rates of change of MD were similar between the perimetries (P = .08).

A thinner baseline average RNFL thickness and an increase in the number of clock hours of abnormal RNFL measurement (clock hour indicated in yellow or red in the OCT analysis printout) were associated with an increased risk for development of VF defects for both SAP and FDT perimetry (Table 2). The hazard ratios were 0.864 (95% CI, 0.756-0.986) and 0.849 (95% CI, 0.738-0.975) for each micrometer increase in average RNFL thickness for SAP and FDT perimetry, respectively, and 1.623 (95% CI, 0.968-2.722) and 1.956 (95% CI, 1.228-3.148), respectively, for each unit increase in clock hour of abnormal RNFL measurement. Age, central cornea thickness, and baseline IOP were not associated with the development of VF defects in SAP and FDT perimetry.

### Discussion

To our knowledge, this is the first prospective, longitudinal study comparing the rates of change of VF loss and risk factors for glaucoma progression between Matrix FDT perimetry and SAP. Following 113 glaucoma suspect and ocular hypertensive eyes with no SAP and FDT perimetry abnormality at baseline, we showed that most eyes that developed VF defects in FDT perimetry were detected either prior to or simultaneously with SAP (72.7% [8 of 11 eyes] for the less-conservative criteria and 77.8% [7 of 9 eyes] for the more-conservative criteria), and that PSD progressed faster in FDT perimetry compared with SAP. These findings suggest that Matrix FDT perimetry may detect VF defects not evident in SAP and would be useful to monitor the onset of development of VF defects in glaucoma.

While it has been shown that an abnormal baseline FDT VF is predictive of subsequent VF loss in SAP, longitudinal data comparing SAP and FDT perimetry are sparse and most were obtained with the first generation of FDT perimetry. Haymes and colleagues followed up 65 patients with glaucoma for a median of 3.5 years (range, 2.0-4.5 years) and showed that less than 6% of patients had progression detected by SAP and/or FDT perimetry if 3 or more deteriorating test locations were required in FDT perimetry and 7 or more were required in SAP, confirming in 2 of 3 examinations. Using less-conservative criteria with 1 deteriorating test location for FDT perimetry and 2 deteriorating locations for SAP detected in 2 of 3 examinations, 49% progressed with detection by FDT perimetry and 49% progressed with detection by SAP, in which 25% were detected by both. In another study with FDT perimetry progression defined by having 1 deteriorating test location (out of 17) within the same hemifield (not necessarily the same test location) verified on 2 of 3 VF’s within 1 month and 2 of 3 visual fields performed 3 months later, Bayer and Erb followed up 65 patients with glaucoma for a median of 3.5 years (range, 2.0-4.5 years) and showed that less than 6% of patients had progression detected by SAP and/or FDT perimetry if 3 or more deteriorating test locations were required in FDT perimetry and 7 or more were required in SAP, confirming in 2 of 3 examinations. Using less-conservative criteria with 1 deteriorating test location for FDT perimetry and 2 deteriorating locations for SAP detected in 2 of 3 examinations, 49% progressed with detection by FDT perimetry and 49% progressed with detection by SAP, in which 25% were detected by both. In another study with FDT perimetry progression defined by having 1 deteriorating test location (out of 17) within the same hemifield (not necessarily the same test location) verified on 2 of 3 VF’s within 1 month and 2 of 3 visual fields performed 3 months later, Bayer and Erb followed up 65 patients with glaucoma for a median of 3.5 years (range, 2.0-4.5 years) and showed that less than 6% of patients had progression detected by SAP and/or FDT perimetry if 3 or more deteriorating test locations were required in FDT perimetry and 7 or more were required in SAP, confirming in 2 of 3 examinations. Using less-conservative criteria with 1 deteriorating test location for FDT perimetry and 2 deteriorating locations for SAP detected in 2 of 3 examinations, 49% progressed with detection by FDT perimetry and 49% progressed with detection by SAP, in which 25% were detected by both. In another study with FDT perimetry progression defined by having 1 deteriorating test location (out of 17) within the same hemifield (not necessarily the same test location) verified on 2 of 3 VF’s within 1 month and 2 of 3 visual fields performed 3 months later, Bayer and Erb followed up 65 patients with glaucoma for a median of 3.5 years (range, 2.0-4.5 years) and showed that less than 6% of patients had progression detected by SAP and/or FDT perimetry if 3 or more deteriorating test locations were required in FDT perimetry and 7 or more were...
showed that 74.1% of eyes progressed in the group that showed SAP progression, and 35.7% of eyes progressed in the group that did not show SAP progression over 30 months (SAP progression was determined by the criteria of the Collaborative Normal Tension Glaucoma Study). Not unexpectedly, the different criteria to define VF progression in FDT perimetry in previous studies would result in different levels of agreement between SAP and FDT perimetry. Of note, that the number of test locations was fewer in FDT perimetry (17 for FDT perimetry C-20 vs 54 for SAP 24-2) has rendered the first generation of FDT perimetry difficult to compare with SAP in progression analysis.

The advent of Matrix FDT perimetry has permitted a more direct comparison with SAP because of point-to-point correspondence in the respective VFs. Following up 33 patients with glaucoma for a mean (SD) of 21.1 (1.8) months (range, 18-26 months) and defining progression as a change in MD greater than the test-retest variability, Xin and colleagues detected 14.5% of eyes progressed with detection by SAP, 23.6% by Matrix FDT perimetry, and 9% by both methods. However, as only 3 follow-up VF examinations at 6-month intervals were obtained, the rate of change of VF loss was not evaluated. Performing VF examinations approximately every 4 months for at least 30 months in this study, at least 8 VF measurements were available for calculation of the rate of VF loss. An important finding was that while the rate of change of MD was comparable between FDT perimetry (−0.22 dB/y; 95% CI, −0.39 to −0.06) and SAP (−0.24 dB/y; 95% CI, −0.32 to −0.15) (P = .08), the rate of change of PSD was significantly faster for FDT perimetry (0.10 dB/y; 95% CI, 0.06 to 0.14, vs 0.04 dB/y; 95% CI, 0.01 to 0.08) (P = .001). Pattern standard deviation is calculated from the pattern deviation plot after adjusting the general reduction in visual sensitivity and therefore a more sensitive parameter to detect and quantify localized defects than MD. The faster rate of change of PSD corroborated the observation that among the eyes showing progression defined with reference to the pattern deviation plot, 72.7% to 77.8% developed repeatable VF defects in FDT perimetry either prior to or simultaneously with SAP. Frequency-doubling technology perimetry may detect the development of VF defects earlier than SAP. However, it is worth noting that although the dynamic ranges of SAP (0-38 dB) and Matrix FDT perimetry (0-41 dB) were similar, the rates of change of MD and PSD may not be directly comparable because the thresholding algorithms between the instruments are different. In addition, because the rate of change of PSD/MD represented a group mean (ie, a rate estimate of all eyes) and the sample only contained glaucoma suspects and ocular hypertensives, the relatively small rates of change of PSD may reflect the fact that only a small portion of eyes progressed (approximately 90% of eyes did not develop VF defects for approximately 3.4 years in this study). The magnitude of the difference in the rates of change of PSD between the perimetry would depend on the sample composition, and its clinical significance remains to be determined.

While central corneal thickness and baseline IOP are known risk factors for VF progression in SAP in patients with ocular hypertension, they lack a significant impact on the progression analysis in this study. Such disparity can be attributed to the fact that patients followed up in this study comprised ocular hypertensives and glaucoma suspects and that some patients were under treatment at the discretion of attending physicians with reference to the target IOP and other risk factors for glaucoma progression. As shown in some studies, the association of baseline IOP measurement and central corneal thickness with VF progression may not always be significant in patients with glaucoma. In fact, only average RNFL thickness and number of clock hours of abnormal RNFL measurements obtained at the baseline were accountable for SAP and FDT perimetry progression. We showed that for each micrometer reduction in average RNFL thickness, there was a 14% increase in risk for progression in SAP, and 15% increase in risk for progression in FDT perimetry. For each clock-hour increase of abnormal RNFL measurement, the respective increases in risk were 62% and 96%. Our finding not only supports the notion that structural change precedes detectable functional change in SAP (measured in decibel scale), but also provides new information indicating that RNFL thinning would be evident before detectable change in Matrix FDT perimetry. Measurement of RNFL thickness would be relevant and important for risk assessment of VF progression. The similar risk pro-

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hazard Ratio (95% CI)a</th>
<th>Matrix FDT Perimetry</th>
<th>SAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average RNFL thickness, μm</td>
<td>0.849 (0.738-0.975)</td>
<td>0.864 (0.756-0.986)</td>
<td></td>
</tr>
<tr>
<td>Clock hour of abnormal RNFL measurementb</td>
<td>1.956 (1.228-3.118)</td>
<td>1.623 (0.968-2.722)</td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>0.984 (0.932-1.038)</td>
<td>0.993 (0.938-1.052)</td>
<td></td>
</tr>
<tr>
<td>Central corneal thickness, μm</td>
<td>0.997 (0.966-1.030)</td>
<td>1.017 (0.984-1.050)</td>
<td></td>
</tr>
<tr>
<td>Baseline IOP, mm Hg</td>
<td>0.904 (0.702-1.164)</td>
<td>0.908 (0.710-1.161)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: FDT, frequency-doubling technology; IOP, intraocular pressure; RNFL, retinal nerve fiber layer; SAP, standard automated perimetry.

a Hazard ratios were calculated in the multivariate models after adjusting for treatment effect (1 = with IOP lowering therapy; 0 = without IOP lowering therapy).

b Clock hour of RNFL measurement indicated in yellow or red in the optical coherence tomography analysis printout.
files and hazard ratios of SAP and FDT perimetry affirm the use of FDT perimetry for detection of glaucomatous VF progression. In this study, we only included eyes with no VF defects in both FDT perimetry and SAP at baseline. The rationale was to provide a similar baseline to facilitate comparison of development of VF defects and the rate of VF loss between the perimtries. Yet, it is notable that the FDT PSD (mean [SD], 3.07 [0.65] dB) was greater than the SAP PSD (mean [SD], 1.75 [0.85] dB). In contrast to SAP, applying patients’ habitual corrections (ie, patients’ spectacles) is recommended by the manufacturer in Matrix FDT perimetry. The use of progressive and bifocal correction may introduce different degrees of refractive blur in different parts of the field of view, resulting in a higher PSD on FDT perimetry. Nonetheless, the difference in baseline PSD would not pose bias in the comparison of the rates of change of PSD between the perimetry because the baseline PSD had been adjusted in the random effects of the linear mixed model. In agreement with the previous study by Haymes et al using the first generation of FDT perimetry, the concordance of progression detection was fair to moderate, indicating SAP and FDT perimetry likely detect different spectra of VF progression and would be complementary to each other to monitor glaucoma progression. One unavoidable drawback in studies evaluating glaucoma progression is the lack of reference standard, rendering the determination of sensitivity and specificity difficult. For this reason, we adopted 2 criteria to define progression. Although the more-conservative criteria may reduce the sensitivity to detect change, high specificity would be desirable in the evaluation of subjective functional tests to detect new defects. Notably, there is no consensus regarding how VF defects should be defined in Matrix FDT perimetry. With the same number of test locations and similar dynamic range of visual sensitivity measurements between SAP and Matrix FDT perimetry, it seems reasonable to apply the same definitions for both SAP and FDT perimetry. The present study only investigated the development of VF defects in eyes with normal VFs at baseline, the relative performance between the perimtries for progression detection in the later stages of glaucoma requires further evaluation. While a number of algorithms have been devised for analysis of VF progression in SAP (eg, Advanced Glaucoma Intervention Study and Collaborative Initial Glaucoma Treatment Study visual field scoring systems, the Pointwise Linear Analysis, and the Guided Progression Analysis), optimal strategies for progression analysis in Matrix FDT perimetry remain to be established.

To summarize, our data suggest that Matrix FDT perimetry would be useful to monitor glaucoma progression. With a faster rate of change of PSD in FDT perimetry, FDT perimetry may facilitate early detection of development of VF defects. A longer-term longitudinal investigation with a larger sample size would be needed to validate the findings of the present study.