Uptake, Persistence, and Performance of Weekly Home Monitoring of Visual Field in a Large Cohort of Patients With Glaucoma

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• PURPOSE: This study examines the short-term uptake, compliance, and performance of a tablet device used for home monitoring of visual field (VF-Home) by glaucoma patients.

• DESIGN: Single-center, observational, longitudinal, compliance study.

• METHODS: Participants who were glaucoma suspects or had stable glaucoma in at least one eye were recruited during a regular clinic review. Baseline in-clinic visual field (VF) was recorded with the Humphrey Field Analyser (HFA, SITA standard) and repeated at 6 months. Participants were tasked with performing 6 VF examinations from home, at weekly intervals, using a loaned iPad tablet. Uptake was defined as returning at least 1 test from home. Reliability and global indices from VF-Home were compared to in-clinic outcomes. Data are shown as either mean ± [standard deviation] or median [quartile 1-3 range], and group comparisons were achieved with bootstrap.

• RESULTS: We recruited 186 eyes of 101 participants. VF-Home uptake was excellent, with 88% of participants successfully completing ≥1 home examination and 69% completing all 6 examinations. The median duration between tests was 7.0 [7.0-8.0] days. Barriers to uptake and compliance involved information technology (IT) logistical reasons, lack of motivation, or competing life demands. VF-Home gave greater fixation loss but a similar level of False Positives (FP) as the HFA. A high correlation was found for the mean defect between in-clinic and at-home outcomes ($R = 0.85$).

• CONCLUSIONS: VF-Home can return a high level of short-term compliance and results comparable to those found by in-clinic testing. IT logistical reasons and lack of motivation are barriers to uptake and compliance. (Am J Ophthalmol 2021;223:286–295.

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GLAUCOMA IS AN OPTIC NEUROPATHY AFFECTING 66 million people around the world and is characterized by the progressive loss of fibres at the optic nerve with the potential for irreversible blindness.[1] Monitoring glaucoma patients for progression involves a series of clinical tests including periodic assessment of visual field (VF) at 6-monthly[2] or yearly intervals.[3] Frequent hospital reviews place strain on the health care system, which can lead to sight loss or blindness due to inadequate and non-targeted follow up.[4] Even in the presence of frequent reviews, 15.5% of glaucoma patients receiving treatment experience unilateral blindness,[5] with 15.2% progressing in 2 years in the presence of treatment.[6]

One potential solution to ease the health care burden is for patients to undertake self-monitoring of their vision and visual field at home (VF-Home). Portable perimeters, available as tablet devices[7–10] or head mounted displays,[11,12] might provide information on VF progression in between hospital visits leading to early detection of change by patient self-testing. Tablet devices have a small footprint, are relatively inexpensive, and the high rate of smart-device ownership in the population will mean that potential users are familiar with the operation of these devices.

Simulation predicts that weekly home-monitoring of VF can detect progression (–2 dB/y) with 80% sensitivity in 11 months in the presence of moderate test compliance (63%), compared to 2.5 years using standard 6-monthly reviews (100% compliance).[13] Therefore, the high sampling rate associated with weekly home monitoring has the potential to detect early change and provide precision medicine to those who most require intervention. What is not known from simulation, however, is the compliance rate of patients tasked with weekly testing at home and whether such unsupervised testing can return reliable outcomes despite distractions of the home environment.

Melbourne Rapid Fields (MRF; Glance Optical Pty Ltd, Melbourne, Australia) is an iOS application available for the iPad (Apple, Cupertino, CA) that facilitates accurate and reliable thresholding of visual field using an HFA 24-

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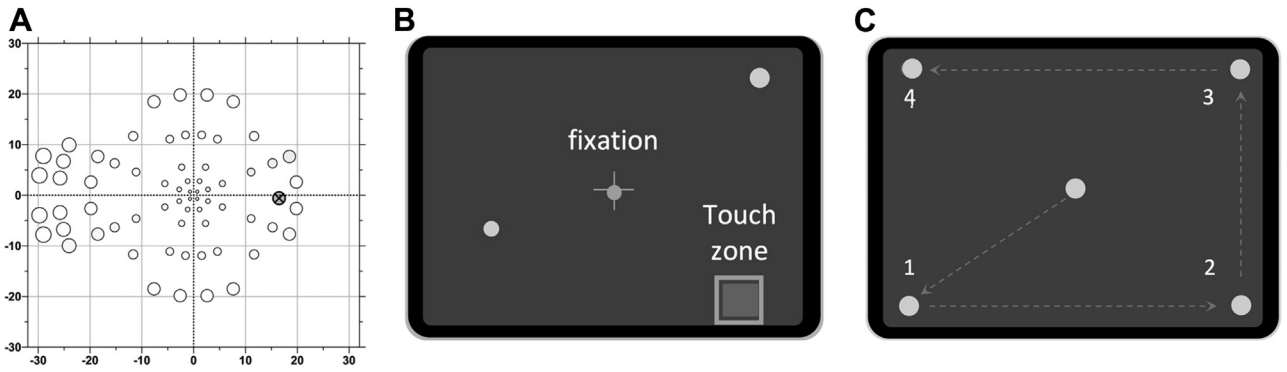

FIGURE 1. Details of the MRF glaucoma test. (A) The test grid has 66 locations. Note how the size of the spot is scaled to return a fixed threshold across the VF (schematic only). (B) VF task. Tablet-generated voice instructions ask patients to fixate centrally and tap the screen in the "touch zone" when they see a spot of light (bright or dim). (C) The test requires 4 changes in fixation achieved with instruction from the "voiceover" to follow the fixation target as it moves serially to the corners of the screen (1-4).

2 test grid.[8,9] The portability of the tablet device allows vision testing at home, and trials have shown that results obtained with the tablet are comparable to those of a Humphrey Field Analyser (HFA) when tablet testing is supervised in-clinic.[9]

The main objective of this study is to determine whether patients with stable, treated glaucoma will comply to the request for weekly testing at home with the MRF (VF-Home). To facilitate compliance, we sent a text message reminder to patients at a mutually agreed time and day. Our secondary objective is to compare perimetry outcomes from home with those obtained from standard in-clinic assays obtained over similar time frames. All participants were provided with a loan iPad loaded with the MRF Glaucoma iOS application, which offered programmed voice guidance for self-testing.

METHODS

ETHICS APPROVAL WAS OBTAINED FOR THIS TRIAL FROM the ethics committee of the Royal Victorian Eye and Ear Hospital (HREC: 12/1220H). All experiments were conducted in accordance with the tenets of the Declaration of Helsinki, with informed consent being obtained from all participants prior to participation.

• **PARTICIPANTS:** Glaucoma participants were recruited from the glaucoma clinic of the Royal Victorian Eye and Ear Hospital. Inclusion criteria were a diagnosis of ocular hypertension (OHT) or stable glaucoma in at least one eye, visual acuity better than 20/40 (6/12), and the ability to understand English instructions as provided by the iPad voice prompt. Note that although multilingual voice prompts are available, we required adequate English capacity for this trial. Stable glaucoma was defined as any form of glaucoma, controlled by IOP-lowering medication and/or previous ocular surgery, with no signs of progression on dilated fundus examination, structural scanning, or VF analysis (HFA 24-2 SITA standard) as confirmed by a glaucoma specialist. Participants used their normal glaucoma medications during the trial and were excluded if they had undergone ocular surgery or changed glaucoma medication in the preceding 6 months. All participants had performed at least 2 visual field tests using the HFA 24-2 SITA standard test before inclusion in the trial.

• **MELBOURNE RAPID FIELDS APP:** The MRF Glaucoma app has been previously described.[8] In brief, it comprises a 66-point radial grid with spot-size increasing in the periphery to maintain constant threshold and variability (Figure 1, A and B). To achieve an eccentricity of 30° in the horizontal meridian on a standard 9.7-inch iPad, the app requires 4 changes in fixation to test peripheral locations (Figure 1, C). Participants are guided through the test and instructed when to change fixation by tablet-generated voice commands. Reliability indices were determined throughout the test using a false-positive check and a blind-spot monitor (≤25% taken as reliable).

• **TESTING PROCEDURES:** Participants were loaned an iPad (9.7-inch, 4th-generation or newer) and were provided with cellular broadband connection for the duration of the study. The timeline of the study is given in Figure 2. On recruitment, a baseline HFA test (24-2 SITA-standard) was performed. A clinical assistant set up an MRF account for the participant and provided a tutorial on how to perform the tablet perimetry examination, save data, and submit results online. Participants were instructed to maintain the correct viewing distance (33 cm) and perform the

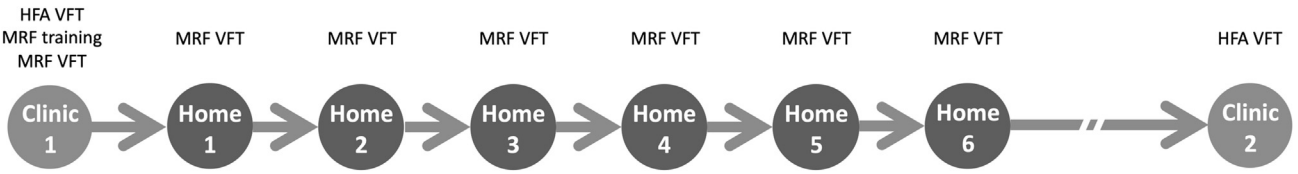

FIGURE 2. Test protocol. Participants attended a baseline clinic session (Clinic 1) where they were tested with the Humphrey Field Analyser (24-2, SITA standard, see text for details) and received an in-clinic training session on how to perform iPad test and save results with a clinical assistant. An iPad test was performed with voiceover guidance, and any issues relating to operating the device or doing the test were clarified. Participants were then asked to perform weekly testing for 6 weeks in the presence of voiceover instructions. The second clinic visit (clinic 2) was a routine review (6 months), and 24-2 on the Humphrey Field Analyser was repeated.

test in a darkened room to avoid reflections off the screen. The viewing distance technique required placing an elbow of the arm contralateral to the test eye, at the edge of the iPad keyboard. They were shown how to orient the arm in a vertical plane and use the palm of that hand to occlude the nontested eye. This positioning has been measured to achieve a viewing distance of 32-35 cm. The participant was then requested to perform a test by themselves following voice prompts and had any questions clarified by the clinical assistant. These early MRF tests (Clinic 1) were not analyzed and were used as learning or familiarization trials. Participants were then tasked with performing 6 VF examinations from home on both eyes at weekly intervals: 15 participants returned VF examinations from one eye only. The clinical assistant sent a weekly reminder text message to each participant on their nominated day and time for testing. If a test result was not received within 24 hours, the participant was contacted via text message or phone call and assistance provided, as required. A second clinical visit was scheduled in 6 months' time (regular review) where a second HFA examination was performed, and the loan iPad returned.

• **UPTAKE AND COMPLIANCE:** Because some of our patients did not own an iPad, we used a successful return from the very first test as establishing the patient's ability to perform the test and data-saving procedures. Uptake was, therefore, the successful completion and submission of the first VF examination from home. Assistance was provided by phone if this did not occur within 24 hours of the first reminder message. Compliance was considered with 2 goals in mind: the request to return 6 home examinations (over the 6-month window) and the request to perform weekly testing. At the end of the 6-month trial, we surveyed participants who did not achieve uptake, or who were noncompliant to testing, to choose from one of the following options as the main cause for their behavior:

- MRF device too difficult to use
- Participation in the trial too much effort
- Information technology (IT) logistical reasons
- Deterioration in health
- Not interested/lack of motivation
- Competing life demands

• **DATA ANALYSIS:** The average test time, reliability, and VF indices were established on a subgroup of participants who completed at least 2 tests from home; this allowed determination of test–retest variability. VF indices returned by at-home self-testing with the MRF (mean deviation [MD], pattern deviation [PD], and visual capacity [VC]) were compared with in-clinic measures obtained from the HFA (mean deviation [MD], pattern standard deviation [PSD], and visual field index [VFI]) using the 2.5 and 97.5 percentile values determined by bootstrap sampling (1000 samples) using Excel spreadsheets.[14,15] VF results were considered reliable if the false positive (FP) and fixation loss (FL) rates were both ≤25%.

RESULTS

ONE HUNDRED EIGHTY-SIX EYES OF 101 PARTICIPANTS MET the inclusion criteria and were enrolled in the study. The average age was 64.6 (range 21-89, median 66.5) years, with 32% being female (Table 1). Majority of participants suffered from primary open angle glaucoma (POAG), although there were 25 eyes that were glaucoma suspect and 9 normal eyes. Nineteen participants (38 eyes) were not included in the analysis because they did not return any tests (12 participants) or only a single test result (7 participants). A further 18 participants (21 eyes) had incomplete clinical data. Of these people, 14 had full data sets for one eye and have been included in our analysis as single-eye data sets. The remaining 78 people (127 eyes) returned more than 2 tests from home and were included in our analysis. Participants who returned exactly 1 test from home could not be included in this analysis because estimates of weekly compliance cannot be returned from a single result.

We find uptake of 88% (Figure 3). The average number of examinations submitted from home was 4.4 [2.3], and 69% of our initial cohort complied to the request for 6 home examinations (Table 2). When we consider the timeliness of the examinations, we find that 72% (of the 69%

TABLE 1. Patient Demographics

Demographics	
Test subjects	101
Eyes	186
Age, y, mean (min-max)	64.6 (21-89)
Sex (% female)	32
Diagnosis	
POAG	86
Other glaucoma[b]	66
GS	25
Normal	9
Total	186
Severity[a]	
Normal (>0 dB)	11
Mild (0 to –6 dB)	60
Moderate (–6 to –12 dB)	21
Severe (<–12 dB)	37
Total	127

GS = glaucoma suspect, HFA = Humphrey Field Analyser, POAG = primary open-angle glaucoma.

[a]Data reported as number of eyes in the analyzed group of 127 eyes.

[b]Other glaucoma includes uveitic glaucoma, normal tension glaucoma, traumatic glaucoma, primary angle closure glaucoma, pseudo-exfoliative glaucoma, and pigment dispersion glaucoma, and inflammatory glaucoma.

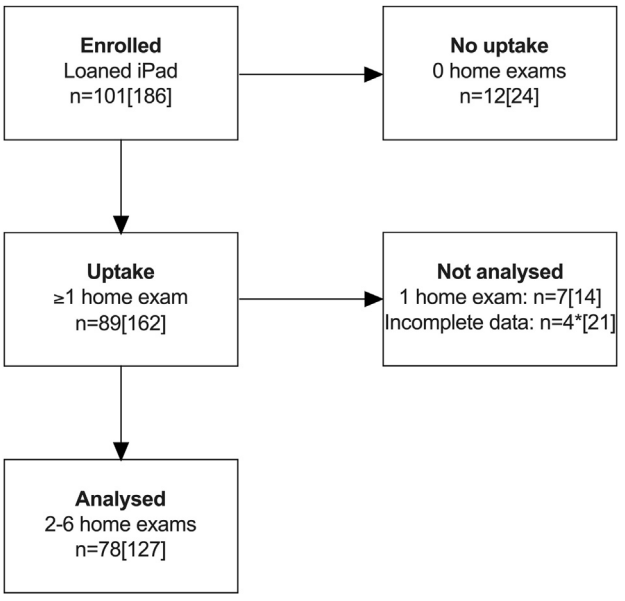

FIGURE 3. CONSORT diagram for short-term VF-Home trial shows the number of patients (and eyes) detailed in the text. Uptake was established when one test was returned from home indicating that the patient understood the testing procedure, the saving of results, and could comply with these procedures. Weekly testing was expected thereafter. *An additional 14 participants had full data sets for one eye and have been included in our analysis as single eye data sets.

above) returned an examination on a weekly basis in the presence of our text message reminder (Table 3). In cases where a test was not returned after a week, the text message prompt sent the following week(s) improved compliance (Table 3). Overall, 87.3% of our cohort returned a test within 3 weeks of the due date (day 7), and 100% returned a test after longer periods. The median [q1-q3] intertrial duration was 7.0 [7.0-8.0] days, confirming that most patients were timely with their return. Seven participants had their typical weekly testing schedule disrupted by holidays or other causes that they had advised; their compliance was adjusted to omit such occurrences. Representative VF results from 2 glaucoma participants are shown in Figure 4.

A total of 36 participants failed to submit 6 MRF examinations and either had no uptake (12 people, 0 examinations submitted) or were noncompliant to the request for 6 examinations (24 participants, submitted 1-5 examinations). IT logistic reasons (26%; Figure 5, A) and lack of interest (26%; Figure 5, A) were the main reasons for lack of uptake in 12 cases. In the 24 participants in the noncompliant group, IT logistic reasons (59%, Figure 5B) was the main cause preventing the requested number of examinations from being performed and submitted. In those who returned 6 tests (Figure 5, C), factors that limited compliance to a weekly schedule were IT reasons (20%) or competing life demands (20%).

The average test time for the HFA SITA-standard thresholding protocol in-clinic was 6.4 ± 1.2 minutes per eye (Figure 6). The 66-point MRF glaucoma test performed at home was significantly faster at 5.2 ±1.2 minutes per eye (Figure 6).

We examined whether undertaking vision testing at home under the direction of voice prompts and in the absence of a clinical assistant may affect the reliability of results because of the distractions of daily life. Of the 679 tests returned, 16 were excluded from analysis because of an iPad keyboard failure (2.4%) that prevented responses from being captured; this was identified post hoc using a median test. A higher rate of FPs, FNs, and FLs was found with at-home testing (Table 4). The blind spot was not identified in 26.2% of examinations (BS; Table 4), limiting the blind spot monitor from recording fixation loss. We find that a large proportion of tests returned by VF-Home were classified as unreliable based on standard criteria (44.3%) compared with the HFA in-clinic (18.4%), with the greatest cause being fixation loss (96% of unreliable tests at home were due to high FL; see Table 4). False positive and false negative rates of VF-Home were on average 13.9% and 12.0%, respectively. Next, we considered how the outcomes from home compared with the in-clinic and supervised testing returned from the Humphrey Field Analyser given the limited reliability of test outcomes.

No significant difference was observed for MD ($P > .05$; Figure 7, A), PSD vs PD ($P > .05$; Figure 7, B), and VFI vs

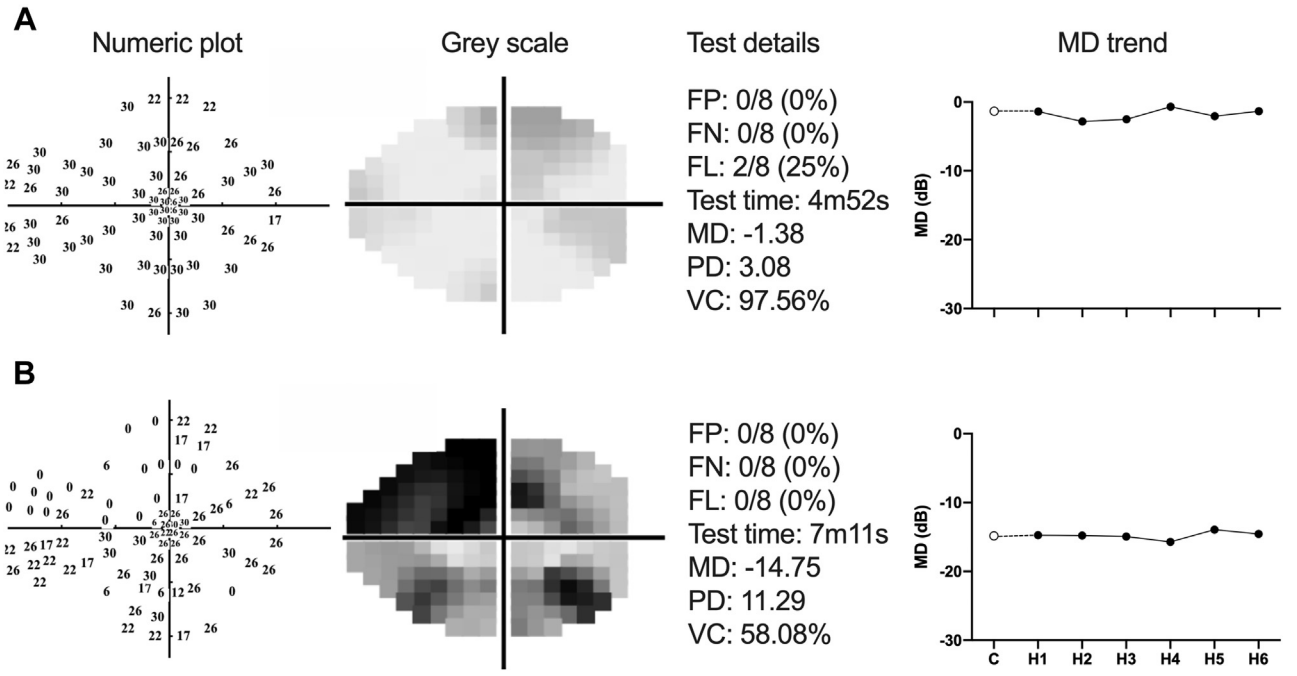

FIGURE 4. Typical outcomes for 2 participants returned by at-home testing (VF results [on left] show the outcome for test 6 at home). Right panels show mean sensitivity for clinic test and each week over the study period. X-axis labels indicate MD for clinic MRF (C) and MD for home MRF (H1-H6). A. Data for a 77-year-old woman with a mild VF defect. (B) Data for a 78-year-old man with a severe defect. FP = false positive rate, FN = false negative rate, FL = fixation loss, MD = mean deviation, PD = pattern deviation, VC = visual capacity.

TABLE 2. Number of Home Tests Performed and Analyzed

No. of Tests	n, People (Eyes)	%, People (Eyes)
2	3 (4)	3.4 (2.5)
3	5 (8)	5.6 (4.9)
4	1 (2)	1.1 (1.2)
5	8 (13)	9.0 (7.7)
6	61 (100)	69 (62)
Total	78 (127)	

Number and of VF-Home tests returned by glaucoma participants. Those who performed 1 home examination were considered to have uptake but were not analyzed, as test frequency could not be established from 1 result. Participants who returned 6 VF-Home tests were compliant and those who returned between 2 and 5 tests were noncompliant. % = percentage of the uptake group (n = 89 [162]).

TABLE 3. Intertrial Durations When Testing at Home

Next Test (Days)	Test 2 (%)	Test 3 (%)	Test 4 (%)	Test 5 (%)	Test 6 (%)	All (%)	Cumulative (%)
0-8	80.5	78.0	69.5	72.0	61.0	72.2	72.2
9-14	7.3	8.5	13.4	7.3	9.8	9.3	81.5
15-21	9.8	6.1	1.2	2.4	3.7	4.6	86.1
22-28	0.0	1.2	2.4	1.2	1.2	1.2	87.3
>28	2.4	6.1	13.4	17.1	24.4	12.7	100

Frequency of VF-Home reports the percentage of participants performing examinations after specific periods. Test 2 refers to the next test after the first baseline from home.

VC ($P > .05$; Figure 7, C). In fact, despite the number of tests with higher fixation loss, a strong correlation is found between the MD ($R = 0.85$; Figure 7, E) of the in-clinic HFA results and the at-home MRF outcomes. The spread of data seen in the Bland-Altman analysis (Figure 7, D) is consistent with a high concordance between test outcomes (95% limits of agreement, –6.2 to 8.8 dB). Of note, the coefficient of repeatability is better for the MRF (4.3; Table 5) than it is for the HFA (6.2; Table 5), indicating that the larger number of home tests reduces between-test variability.

DISCUSSION

HOME TESTING OF VISION ALLOWS PATIENTS TO TAKE AN active role in monitoring their condition and reducing the burden of unnecessary reviews on the hospital system. To our knowledge, this is the biggest study as of this writing

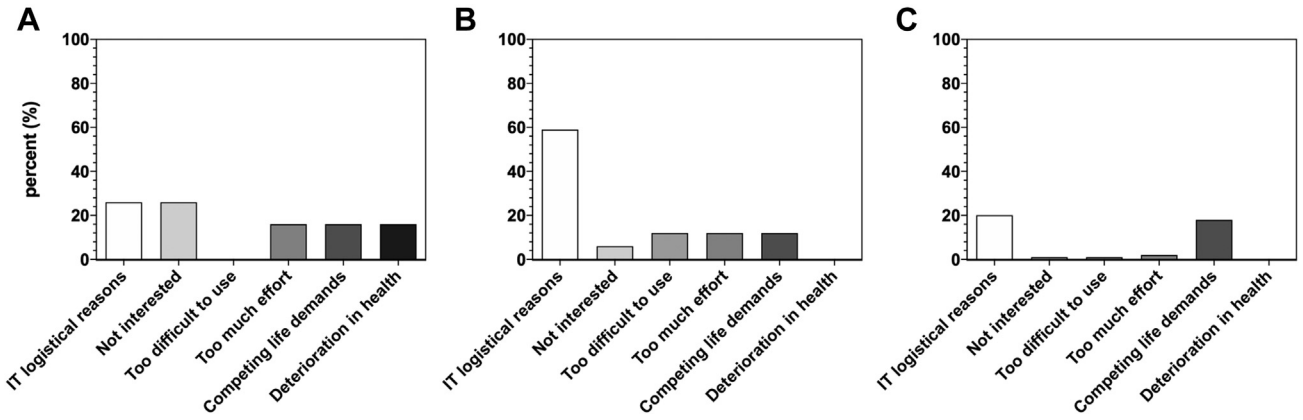

FIGURE 5. Reasons for withdrawal and noncompliance given by 36 participants. (A) Reasons for no uptake (n = 24 eyes, 12 participants). (B) Reasons for noncompliance to 6 home examinations (n = 21 eyes, 18 participants). (C) Reasons for noncompliance to weekly testing (n = 42 eyes, 42 participants).

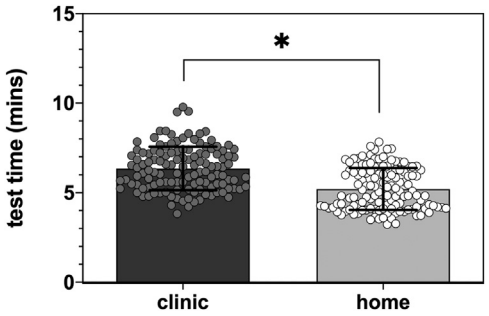

FIGURE 6. Time needed to complete the VF tests per eye in the clinic (HFA) and at home (MRF glaucoma). *Significant with Bootstrap (95% Confidence limit).

examining the use of portable technology to enable visual field testing at home in glaucoma patients. In this study, we determine the uptake and compliance to our request for home monitoring and identify factors limiting self-testing. We also compare results from home to those obtained from standard in-clinic assays made with the HFA.

Given the test environment in home, our compliance rate of 69% is high. We believe that the provision of a text prompt to remind patients to do the test on the day facilitated this level of compliance. This is evident from our median intertrial duration of exactly 7 days (coincident with the prompts) with a very small interquartile range (7-8 days). The effect of the prompt is also evident from the fact that compliance increased to 87% after 3 further (weekly) reminders were sent, confirming that patients were sensitized to respond to the prompts. These findings indicate that most patients (87%) returned a result within 1 month of the due date with the majority (75%; third quartile) within 8 days. This level of compliance is very high for long-term trials and indicates good potential for home monitoring to not only reduce clinical loads but to also be used for remote vision testing as part of telehealth. It also justifies the 63% compliance rate adopted in our simulation study.[13]

However, despite our positive findings, lower compliance has been reported by Adams et al[16] in a group of 38 participants having age-related maculopathy and who were home-monitoring. That group reported that 48%-52% of their participants were "active" at the end of the 2-month trial. In our group, we find 87% active within a month of the due date and 100% active if we allow a much longer time for response, indicating much greater involvement than for the Adams trial.[16] This improved activity might arise from the fact that we loaned our participants an iPad and broadband, whereas the Adams trial required patients to use their own devices. In doing so, we posit that our patients felt some compulsion to remain active to retain these items. Participants are known to respond positively by being rewarded for healthy behaviors,[17] and in this case the tablet and broadband would be seen as an incentive for participation.

In a recent trial that recruited 20 glaucoma patients to monthly self-testing for a period of 6 months, the authors report a compliance rate of 95%.[18] In that study, participants were recruited by advertisement and were also loaned a tablet with broadband, so their levels of motivation and participation could be expected to be high. Similar to our study, participants received e-mail reminders on a monthly basis for testing, promoting timely participation, although the timeliness of test returns was not reported by the authors.[18] The high compliance of glaucoma participants achieved in our shorter intervention (87%) appears to flow through to longer-term 6-monthly trials and suggests that high compliance can be achieved in the long term in the presence of incentives. This will be the topic of a future article reporting 12 months of clinical follow-up of glaucoma patients.

In the presence of weekly testing, missed tests have less impact in identifying those patients who are progressing

TABLE 4. Average Reliability of Results Obtained From VF-Home by Glaucoma Patients

	Test	1	2	3	4	5	6	All
Rate								
FP (%)	MRF	11.9	18.1	12.3	10.4	16.0	15.0	13.9
	HFA	1.6	1.6	—	—	—	—	1.6
FN (%)	MRF	7.9	11.4	12.3	13.2	15.1	12.0	12.0
	HFA	1.6	1.6	—	—	—	—	1.6
FL (%)	MRF	42.5	44.4	37.5	38.7	48.0	44.6	42.6
	HFA	18.9	18.9	—	—	—	—	18.9
BS (%)	MRF	22.5	25.6	26.8	27.8	28.6	26.0	26.2
Reliability								
Unreliable (%)	MRF	42.5	46.9	38.8	41.3	48.0	48.6	44.3
	HFA	18.9	17.9	—	—	—	—	18.4

FN = false negative, FP = false positive.

%FP and %FN were calculated by dividing the respective number of FPs and FNs by the total number of tests returned. Indication of reliability: ≤25% FP and ≤25% FL. A test was deemed unreliable if one or both reliability indices were >25%.

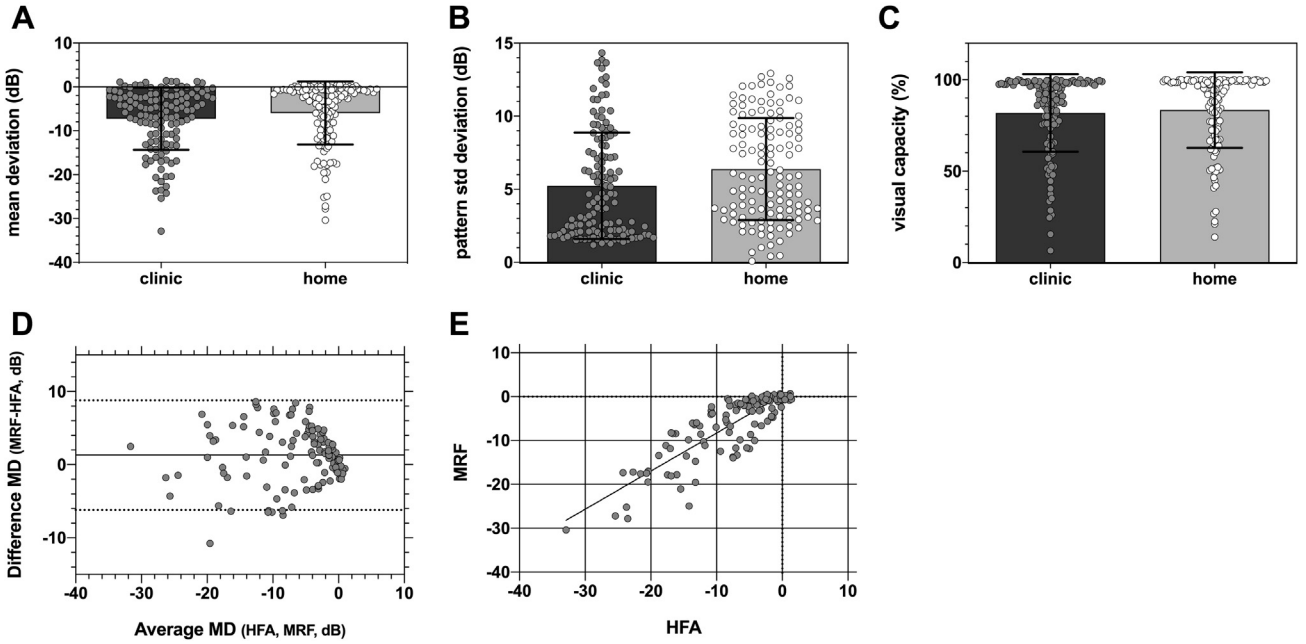

FIGURE 7. Comparison of VF global indices in-clinic (HFA) vs at-home (MRF) for glaucoma cases (n = 127 eyes). Clinic mean represents the average of 2 examinations. Home mean represents the average of 6 examinations. (A) Mean deviation (HFA vs MRF, dB). (B) Pattern standard deviation (HFA, dB) vs pattern deviation (MRF, dB). (C) VF index (HFA, %) vs visual capacity (MRF, %). (D) Bland and Altman plot for mean deviation of MRF (average of 2-6 tests) and HFA (average of 2 tests). (E) Correlation of average mean deviation for HFA and MRF (R = 0.85). The differences between home and clinic were not statistically significant ($P > 0.05$).

rapidly. Collecting a lot of data reduces the between-test variability. To demonstrate this point, Figure 8 plots the between-test variability from our home monitoring trial as the mean absolute error (MAE) in the patient's mean deviation (MD). This shows MAE decreases with increasing numbers of tests. If the frequency of testing is weekly, such change requires 6 weeks to reach the asymptote contrasted to monthly testing, which will require 6 months for a similar outcome. The data in Figure 8 was taken from our glaucoma participants. The shaded zone identifies the MAE returned from 2 tests conducted on the HFA 6 months apart. What is evident is the MAE for MRF at home falls within the 95% percentile of the HFA error zone on the first test done at home. But as further tests are completed (3-6), the between-test variability (MAE) reduces by 80%.

TABLE 5. Repeatability for VF testing in Glaucoma

Test	Index	Mean (SD)	Bias (vs HFA)	CoR (dB)
HFA	MD	−7.3 (7.1)		6.2*
MRF	MD	−6.0 (7.2)	1.3	4.3*
HFA	PSD	5.2 (3.6)		3.4
MRF	PD	6.4 (3.5)	1.2	3.1
HFA	VFI	82 (21)		18
MRF	VC	83 (21)	1.5	18

CoR = coefficient of repeatability, MD = mean deviation, PD = pattern deviation of MRF examination, PSD = pattern standard deviation of HFA examination, VC = visual capacity of MRF examination, VFI = visual field index of HFA examination.

Bland-Altman bias = MRF-HFA (dB). CoR is derived from 6 MRF tests and 2 HFA tests.

*$P < 0.05$.

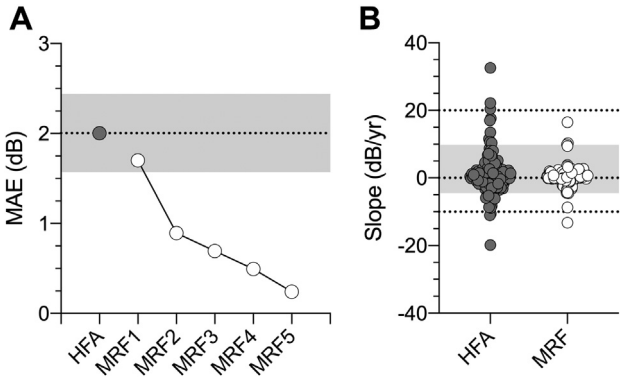

FIGURE 8. (A) Mean absolute error (MAE, dB) calculated from our data for 2 HFA tests performed in clinic (grey filled circle) and 1-5 MRF tests performed at home (unfilled circles). Gray-shaded area represents the 95% confidence interval for the HFA data. (B) Slope (dB/y) for n = 127 glaucoma patients tested on the HFA (2 tests, gray-filled circles) and n = 87 MRF (6 tests, unfilled circles). Gray-shaded area represents the 95% confidence interval for the MRF. Black dotted lines are the 95% confidence intervals for the HFA. The greater frequency of weekly testing with the MRF returns greater precision in the slope estimate.

The benefit of this reduction becomes evident when progression is plotted as a slope (linear regression) of the time-related change in MD in the right panel (Figure 8, B). After 6 home tests, the 95% confidence limit for the slope in our data spans 3.5 dB/y (–1.3 to 2.2 dB/y). This approach will identify progression >–1.3 db/y after 6 weeks of testing. In comparison, the 95% limit for the HFA after 2 tests spans 19.7 dB/y (–8.1 to 11.6 dB/y). These ranges are significantly different (F test, $P < .05$) with the 6 home tests returning greater precision than the 2 in-clinic reviews. Obviously, the more tests that we accumulate, the greater the precision in our trend; for example, 6 months of weekly testing will return 26 tests compared with 6 tests from monthly testing. It should be self-evident that weekly testing will identify a significant change more rapidly than does monthly testing. Although daily testing would yield the fastest and most precise baseline, we do not believe that such high frequency of testing is needed for slowly progressing diseases like glaucoma.

There are other benefits to undertaking weekly home monitoring in contrast to monthly or 4-monthly schedules. A study from the United Kingdom identified that approximately 20 patients a month suffer severe avoidable sight loss because of a lack of timely monitoring.[4] On every patient presentation, we have no prior idea if they will show slow or fast progression even though fast progressors are less likely in well-treated glaucoma. For this reason, we propose that good clinical care should define the nature of the progression of a particular patient, using weekly testing in the initial phase of monitoring. Once the rate of progression is established, the review frequency could be adjusted relative to the patient's progress, presuming that they will not show a sudden or catastrophic loss.

Twelve participants had no uptake of home monitoring (12%) and performed zero examinations from home even though they were loaned a tablet. The most common reasons cited by these people (Figure 5, A) were a lack of motivation, deterioration in health, or IT logistic reasons, where the individual experienced difficulties logging in, performing the test, or saving the test. Lack of familiarity with tablet operation and the IT interface can be expected in trials where tablets are loaned to participants, as they were in our case, as the participant may not be familiar with such devices and would require education on use and troubleshooting and close monitoring initially to reduce operational difficulties. A further 24 participants did not perform the requested 6 examinations from home and 42 were not compliant to weekly VF-Home (Figure 5, B and C). Again, the main barrier for both groups was IT logistic reasons. This suggests that making improvements to the education and familiarity aspects involved in testing, and providing continued education programs might motivate and minimize dropout, increasing test compliance.

Test reliability is an important aspect for home-monitoring outcomes to yield data comparable to the HFA and that clinicians can trust. The rate of FP and FN was greater at home than in-clinic (average 12%-13%), which we feel primarily arises from the different test methods used to obtain these indices; however, they might also reflect the greater distractions and the absence of the clinical assistant at home. Nevertheless, both were in the acceptable range (≤25%), and Table 3 indicates that reliable FP and FN outcomes were returned in some 98% of tests with the HFA as well as at home (note: home reliability can be exposed by subtracting the FL category from the total unreliable in Table 3). However, FL was commonly found (44% of tests) when tested at home

compared with the HFA (18%). This is perhaps not a surprising finding given that the MRF uses "free space" viewing, and our trial could not enforce the correct viewing distance (33 cm). In the absence of viewing distance control, the blind-spot monitor could become corrupted by either not being able to establish the blind-spot (26%, Table 3) or by recording artifactual eye movements secondary to changes in viewing distance. Adopting the front-facing camera of the iPad to monitor head, face, and eye movement are presently being considered.

Despite the high FL recorded in our study, half of all tests were reliable. This argues for a high frequency of testing to yield an adequate frequency of reliable outcomes to anchor any trends. This prospect is demonstrated in the data of Figure 8. However, studies of large urban glaucoma populations (n > 750), FL (>20%) has been found to affect 40%-48% of test outcomes.[19,20] A recent study that considered gaze tracking during the SITA faster test algorithm found that 20% of participants made >6° eye movement errors >20% of the time.[21] Thus, the concern is not so much whether FLs occur during the test but what effect it has on visual field outcomes. Three groups have considered this issue and all show that high FLs have no to little association with field outcomes and minor impact on test reliability.[22–24]

The high concordance that we find between the MD of MRF at-home and the HFA in-clinic result (0.85) suggests that VF-Home can produce clinically useful outcomes. The high correlation indicates that the high number of FLs that our blind-spot monitor recorded at home, in patients using free space viewing, produced minor effects on outcomes obtained from home. This indicates that the role of fixation loss in "free space" viewing needs clarity for better definition of the effects that it can have on perimetry outcomes. The high correlation also indicates that clinicians can have confidence that the MD returned by the MRF is a good approximation of that found in the clinic by the HFA. Of note, Jones et al made use of free space viewing when testing a limited 20° region of the central visual field, and they also find a high correlation (0.94) between their tablet-based outcomes and repeat HFA 24-2 SITA-fast test results.[18] This high concordance is also evident in our Bland-Altman plots (Figure 7, D) and in the Coefficient of Repeatability (CoR) listed in Table 5. The CoR defines the limits that should contain 95% of data on retest, and Table 5 shows that the CoR is smaller for the home testing environment derived from 6 tests (4.3 dB) than for the HFA derived from 2 tests (6.2 dB). So, despite the noisy test outcomes for any individual test, the repeated test data and sheer volume of tests over time cleans up the average indices in a home monitoring application.

One potential limitation of this study is that the correct viewing distance of 33 cm could not be enforced. Although our participants were informed on how to adopt the correct viewing distance in their training session, and the voiceover instructed them to maintain 33 cm, the test was performed in free space. This limitation can be reduced by supplying a viewing hood with a forehead or chin rest at the appropriate viewing distance, for individuals who cannot produce reliable outcomes but who need self-monitoring or where greater reliability is required (eg, clinical trials).

We find that many individuals with glaucoma are willing to undertake regular VF-Home and can successfully perform VF testing under the guidance of tablet-generated voice prompts. Compliance to weekly testing was high in the presence of a text-message reminder. Although we find that just over half of our outcomes meet conventional reliability criteria, they returned high concordance with in-clinic HFA test outcomes. This means that weekly VF-Home with a tablet device can provide useful VF information in between clinical visits, and that can be used to supplement clinical decision treatment.

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