Evaluation of threshold estimation and learning effect of two perimetric strategies, SITA Fast and CLIP, in damaged visual fields

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PURPOSE. *The threshold estimation, learning effect, and between-algorithm differences of the Fast Swedish Interactive Thresholding Algorithm (SITA Fast), of the Humphrey Field Analyzer (HFA), and the Continuous Light Increment Perimetry (CLIP) strategy of the Oculus Twinfield perimeter were evaluated in damaged visual fields.*
METHODS. *Twenty-one glaucomatous patients with damaged visual fields (MD worse than –8 dB) underwent Oculus Full Threshold (FT), Humphrey FT, SITA Fast, and CLIP 30-2 perimetric examinations. All the tests were repeated in a second session at least 3 days later. The point-wise differences in absolute sensitivity and of the total deviation plot values between FT and fast algorithms, between fast algorithms and the learning effect were evaluated (Wilcoxon test and Bland-Altman analysis).*
RESULTS. *The average point-wise sensitivity difference between SITA Fast and HFA FT strategy (0.84 dB) was significantly lower than that found between CLIP and Oculus FT strategy (1.71 dB). Between-algorithm point-wise differences of the total deviation plot values of the fast strategies were not significantly different. Learning effect for SITA Fast (0.67 dB) was higher than that found for CLIP (0.39 dB). Test time for SITA (367±71 sec) and CLIP (453±98 sec) were about 55% and 35%, respectively, shorter ($p<0.001$) than those found with FT algorithms. The acceptance for fast algorithms and particularly for CLIP was significantly better.*
CONCLUSIONS. *The two fast strategies, even though using very different algorithms, showed good threshold estimation compared to FT strategies with a consistent time saving in damaged visual fields. (Eur J Ophthalmol 2008; 18: 182-90)*

KEY WORDS. *CLIP, Fast threshold strategies, Continuous light increment perimetry, Automated static perimetry, SITA Fast, Glaucoma*

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INTRODUCTION

Differential light threshold topographic estimation in automatic perimetry is usually done using a sequence of static stimuli of defined circular shape presented in all the explored test locations with short exposure times (100–200 ms) modifying their light luminance according to different strategies. The fast perimetric strategies have been designed to obtain visual fields (VF) examination in shorter time than full threshold (FT) strategies. Many new rapid algorithms obtain the shortening of test duration, reducing the number of stimuli exposures. Time saving and good precision was obtained with algorithms like SITA Standard (1-3) (Humphrey) and Dynamic Strategy (4) (Octopus). Time consumption is furthermore shortened with new ultra-short threshold algorithms: TOP (5, 6) (Octopus) and SITA Fast (7-10) (Humphrey).

SITA Fast algorithm uses one or few stimuli presentations

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for each explored test location whose luminance is opportunely chosen according to statistical evaluations in order to be moderately supraliminal.

The Continuous Light Increment Perimetry (CLIP) (11) strategy of the Oculus Twinfield perimeter (Oculus Inc., Wetzlar, Germany) is inspired to a very different method: time saving is obtained by eliminating the idle time between stimuli exposures. In all test locations CLIP presents a static stimulus with continuous luminance increment until perception is reached. CLIP reproduces in static conditions a way to approach to light threshold with psychophysical analogies with manual or automated kinetic perimetry.

SITA Fast and CLIP represent the two shortest threshold strategies of the HFA and Oculus perimeter respectively and are proposed as screening tests for VF damages. Psychophysical tests are influenced by the experience of the patient that leads in perimetry to the improvement in light sensitivity defined learning effect (12). The purpose of this study is not only to analyze the results obtained by an ultra-short threshold algorithm (SITA Fast) using few short stimuli and those obtained by continuous light increment presentation, but also to evaluate their accuracy compared with conventional FT strategy, learning effect, and patient acceptance in damaged glaucomatous VF.

METHODS

Twenty-one glaucoma patients (14 female and 7 male; 55–82 years; mean age: 68.2±8.3 years), with characteristic changes of the optic disc and field defects (mean deviation [MD] worse than –8 dB) (third and fourth mixed stages of the Brusini's Glaucoma Staging System) (13), confirmed in at least two previous examinations, were consecutively recruited from the Perimetry Service of the Department of Neurosciences, Ophthalmology and Genetics–Clinica Oculistica, of the University of Genoa. The study was performed under the tenets of the declaration of Helsinki. All patients provided informed consent before being recruited for the study. Patients had former experience with automated static threshold perimetry and all the tests were performed by the same perimetrist. The best-corrected visual acuity was 7/10 or better and the spherical equivalent refractive error within ±6 diopters in all the subjects. The mean refractive error was –0.52 (±2.74) diopters spherical equivalent. VF test results were obtained with SITA Fast, CLIP, and FT strategies in the right eye. Exclusion criteria were IOP not controlled by therapy, abnormal VF reliability parameters (>20% fixation losses and >30% false-positive and negative answers), pupil diameter less than 3 mm, and ocular disease other than glaucoma.

All subjects underwent two sessions of perimetric examinations, using a 750 II HFA and a Twinfield II Oculus perimeter. In the first session, each patient underwent a FT strategy VF examination with the central 30-2 program of the HFA or the 30-2 area of the Oculus perimeter followed by an examination with CLIP (Oculus) and SITA Fast (HFA) strategies in random order.

To avoid fatigue effect, every examination was followed by at least 20 minutes resting time and rest breaks were allowed when required. The CLIP examination was preceded by a short training test.

In the second session, at least 3 days later (average 4.7 days), the FT strategy examination was carried out with the perimeter not used in the first one and the order of the two ultra-fast strategies was inverted. Unreliable VF were not included for analysis. A VF was considered unreliable for SITA Fast and CLIP if it had >30% fixation losses and >30% false-positive answers. False negative answers were not considered because this reliability parameter is not available in the Twinfield perimeter. The fixation reliability values of the Oculus perimeter are obtained by light suprathreshold stimuli in the fixation point during the examination with more rigorous criteria than HFA.

At the end of each session a questionnaire of four degrees values scale about the compliance for every examination was proposed to the patient. An acceptance index (AI) was calculated and compared for all the strategies.

CLIP strategy

The CLIP strategy of the Oculus perimeters (Oculus Inc., Wetzlar, Germany), in contrast with the other static strategies, uses stimuli with consecutive light increment with 1 dB intervals in order to generate in the observer the impression of a continuous increment. Stimulus presentation is continued until perception by the patient. Central threshold is measured at the beginning of the test with full threshold strategy in order to define the individual threshold while the reaction time is tested in eight locations in the four quadrants with 5 dB suprathreshold; then the mean of reaction times is calculated. The starting light intensity at every test location is 5 dB dimmer than the presumed threshold value according to pre-test central individual threshold value, eccentricity, and neighboring points threshold values. Patient's reaction time is used to define the rate of increment of light intensity: 1 dB per reaction time interval. Stimulus is retested starting from 5 dB dimmer luminance if seen within less than three patient's reaction times. Stimulus luminance enhancement of 2 dB per reaction time is used for three steps if no answer is obtained in stimuli presentations after eight reaction times (8 dB) and successively a 4 dB per reaction time luminance enhancement is then used. At the end of the examination all the locations in which the threshold value differs more than 10 dB from the quadrant mean value are retested.

SITA Fast threshold algorithm

SITA Fast threshold algorithm was developed by Olsson et al for the Humphrey HFA II perimeter (Carl Zeiss, Humphrey Instruments, San Leandro, CA) (1-3, 7).

In this strategy, a model of visual field, based on information about the age-corrected normal and glaucomatous visual field, is continuously modified according to the answers of every tested point and neighboring locations by calculating Bayesian posterior probability calculation of frequency of seeing (FOS) curves. The continuous estimation of measurement errors of threshold values allows the interruption of the staircase procedures when, according to mathematical and statistical evaluations, further stimuli are unnecessary. The continuous adaptation of the VF model, starting from a prior defined one, allows considerable time saving and improves patient compliance. The elimination of catch trials, the improvement in time pacing during the examination, and the reduction of needless stimuli are other sources of test duration shortening. The SITA concept was applied to the SITA Fast algorithm in order to maintain the characteristics of this already approved strategy with a considerable time saving. The four primary points (12.7° of eccentricity in each quadrant) are tested with a sequence of stimuli with a single reversal; a second sequence is presented by a 4 dB steps staircase to obtain a first reversal. The information gathered is used to calculate the starting staircase stimuli luminance in the other test points. In SITA Fast the locations are tested with a single stimulus if a positive answer is obtained with a measurement error statistically lower than a predefined value, otherwise a second reversal staircase with 4 dB steps is used. A complete staircase takes place at points where the difference between the obtained and the expected value is greater than 12 dB.

Statistical analysis

In order to measure the difference in the evaluation of the light sensitivity threshold between the Oculus and the HFA perimeters the two FT strategies were compared. A pointwise comparison of threshold values obtained in every patient with the FT strategy with the two instruments was carried out with the Wilcoxon test.

The average pointwise difference in light sensitivity (absolute values) within the same strategy in the two sessions was considered to evaluate the variability in two following examinations owing to the learning effect (Wilcoxon test).

The accuracy was calculated as the mean pointwise error between the threshold values obtained within the FT strategies and those obtained within the first session of their intended replacement SITA Fast and CLIP (Wilcoxon test).

The average pointwise difference in light sensitivity between the two fast threshold strategies CLIP and SITA Fast was evaluated by the comparison of the values obtained in each first session with the Wilcoxon signed rank test.

The absolute values of the VF indices mean defect (Oculus) and mean deviation (HFA) (MD) were compared.

Between-algorithm pointwise differences were correlated with absolute sensitivity in order to evaluate repeatability according to defect values (Bland-Altman analysis).

Between-algorithm pointwise differences of the total deviation plot (HFA) and the age-related value deviation plot (Oculus) values were compared. In the test locations of the Oculus age-related value deviation plot corresponding to absolute defects, represented with black squares, the defect depth value was calculated.

RESULTS

In the first session, 11 subjects underwent first FT examination with the HFA and 10 with the Oculus perimeter.

The average (±SD) HFA FT strategy mean sensitivity (MS) was 15.73 dB (±11.19 dB); the Oculus FT strategy MS was 6.83 dB (±7.05 dB); the first and second SITA Fast sessions MS were 16.58 dB (±11.94 dB) and 17.25 dB (±11.92 dB), respectively; 8.54 dB (±7.08 dB) with the first CLIP session and 8.93 dB (±8.04 dB) with the second session. The MS values of the second sessions were higher than the first ones ($p<0.001$).

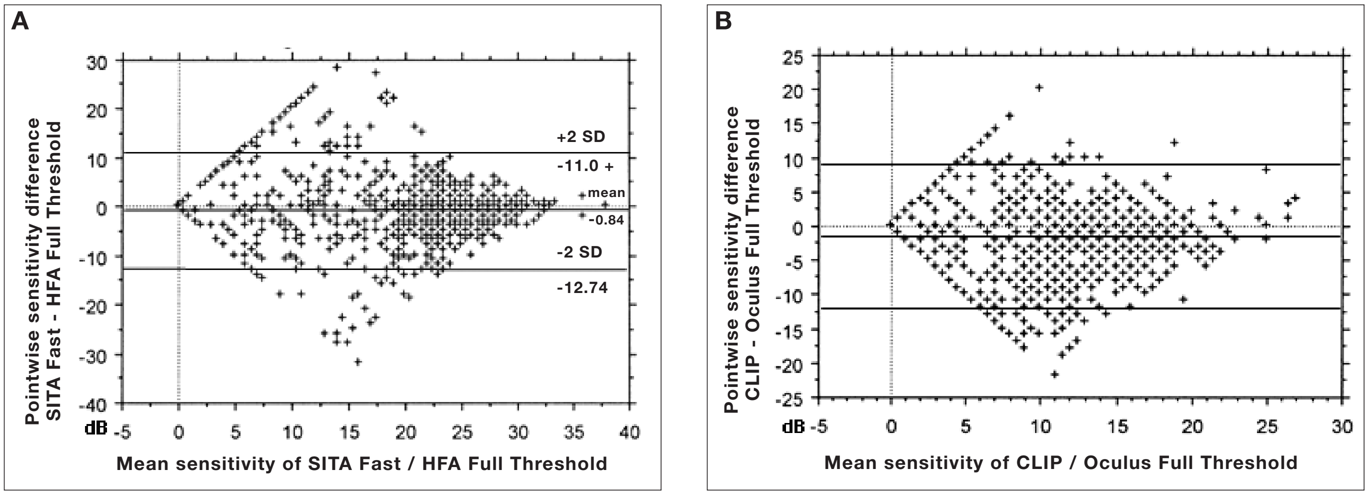

Fig. 1 - *Bland-Altman analysis.* **(A)** *Pointwise sensitivity difference plotted against average pointwise sensitivity for all tested points of all patients for HFA Full Threshold and SITA Fast strategies.* **(B)** *Pointwise sensitivity difference plotted against the average pointwise sensitivity for all tested points of all patients for the Oculus Full Threshold and CLIP strategies.*

The Oculus FT strategy showed a significantly lower average MS than the HFA one due to the lower maximum luminance level ($p<0.0001$) (Wilcoxon test).

The points with normal sensitivity showed a lower dispersion than abnormal points with reduced sensitivity (Bland-Altman analysis).

Between-algorithm pointwise differences of the total deviation plot (HFA) and the age-related value deviation plot (Oculus) values for the FT strategies (Bland-Altman method) showed 3.02 dB (ds±7.8) higher mean values for HFA with homogeneous behavior for points with total deviation values better than 15 dB and the limits of agreement were between –12.6 and 18.6 dB.

The average MS difference between the SITA Fast and HFA FT strategies (0.85 dB) was significantly lower ($p<0.001$) than between the CLIP and Oculus FT algorithms (1.71 dB).

A slightly higher sensitivity was observed for Fast Threshold strategies when compared with the respective FT strategy of each perimeter (Bland-Altman analysis) (HFA: 0.15 ± 6.8 dB; Oculus: 1.77 ± 6.13 dB) with lower dispersion of pointwise differences for both algorithms when the sensitivity was better than 21 dB for HFA and the corresponding corrected value of 11 dB for Oculus (limits of agreement for both instruments : ±12.2 dB) (Fig. 1).

The average MS of SITA Fast and CLIP in the second session turned out to be significantly higher than the ones obtained in the first session (0.67 dB for SITA Fast and 0.39 dB for CLIP) showing a learning effect also in trained patients; this phenomenon was more evident with SITA Fast.

The pattern of reproducibility (Bland-Altman analysis) showed a homogeneous behavior with differences lower than 10 dB for both strategies when sensitivity levels were better than 20 dB for SITA Fast and 10 dB for CLIP, respectively. A greater dispersion was revealed where sensitivity was reduced: the difference increasing as the magnitude of the defect increased (Fig. 2).

The visual field indices are shown in Table I.

The average MD absolute values of the two fast strategies compared with the respective FT strategy showed a higher value for SITA Fast (0.77 dB) and lower for CLIP (1.79 dB).

The Oculus LV values, opportunely converted as the corresponding PSD values, were significantly ($p<0.001$) lower than HFA (PSD: Oculus FT: 5.79±4.0 dB; HFA FT: 9.97±4.06 dB).

Between-algorithm pointwise differences of the total deviation plot (HFA) and the age-related value deviation plot (Oculus) values (Bland-Altman analysis) of the two sessions of the two fast strategies showed no significant mean difference but more homogeneous behavior and a lower dispersion for values higher than 18 dB for HFA and 6 dB (corresponding to 16 dB when corrected for the different maximum stimulus luminance) for Oculus (Fig. 3).

Topographic analysis of the total deviation plot (HFA) and the age-related value deviation plot (Oculus) showed similar defects for both fast strategies and the respective FT.

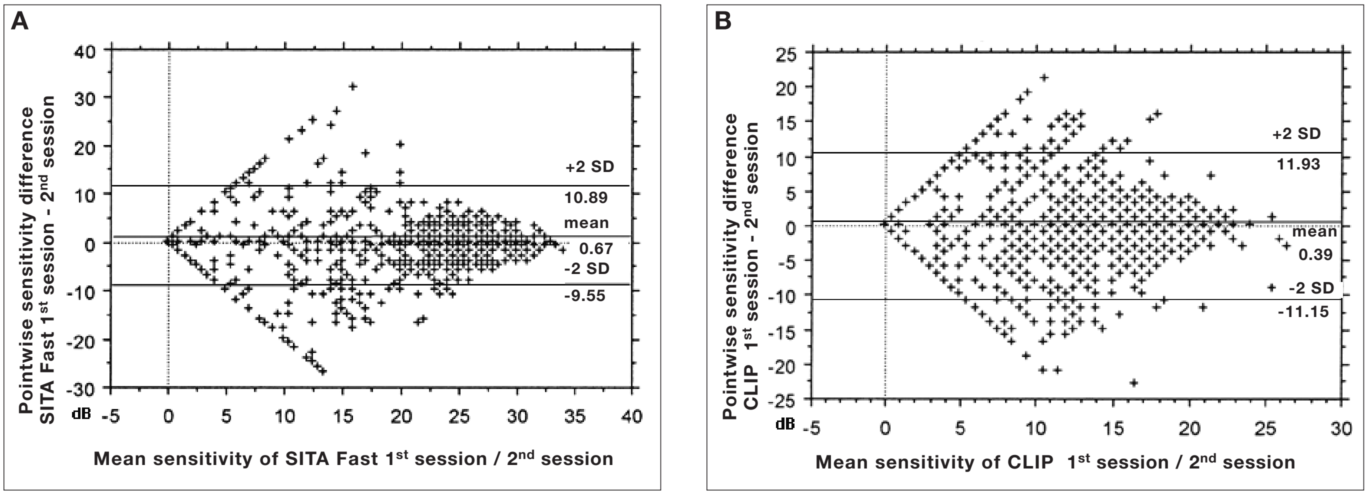

Fig. 2 - *Bland-Altman analysis.* **(A)** *Pointwise sensitivity difference plotted against the average pointwise sensitivity for all tested points of all patients for the SITA Fast strategy in the two sessions of examination.* **(B)** *Pointwise sensitivity difference plotted against average pointwise sensitivity for all points of all patients for the CLIP strategy in the two sessions of examination.*

An example is shown in Figure 4.

The mean test duration was 693±75 sec for the Oculus FT strategy, 811±213 sec for the HFA FT strategy, 450±100 sec for the CLIP, and 366±72 sec for SITA Fast strategies. These values were significantly different ($p<0.0005$, paired *t*-test).

The AI comparison showed a significantly better acceptance for fast algorithms and particularly for CLIP (CI: HFA FT 1.30±0.4, SITA Fast 2.68±1.9; Oculus FT 1.26±1.0, CLIP 3.54±1.0) ($p<0.001$).

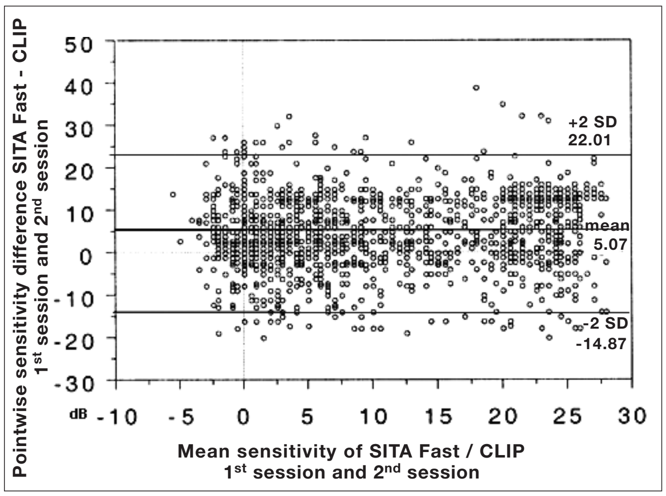

Fig. 3 - *Bland-Altman analysis. Between-algorithm pointwise differences of the total deviation plot (HFA) and the age-related value deviation plot (Oculus) values of the two sessions of the two fast strategies SITA Fast and CLIP.*

DISCUSSION

In this study we compared the accuracy in threshold evaluation compared to FT strategy, variability in two examinations, expression of the learning effect, and light sensitivity difference between two fast algorithms using very

TABLE I - VALUES OF THE VISUAL FIELD INDICES, RELIABILITY INDICES, AND TESTING TIME IN THE SIX EXAMINATIONS

Index	MS (dB)	MD (dB)	PSD (dB)	Time test (sec)	FP (%)	AI
HFA FT	15.73 (±11.19)	13.08 (±7.09)	9.97 (±4.06)	811 (±213)	1	1.30 (±0.4)
Oculus FT	6.83 (±7.05)	9.57 (±3.37)	5.79 (±4.00)	693 (±75)	0	1.26 (±1.0)
SITA Fast 1st session	16.58 (±11.94)	13.85 (±7.57)	9.36 (±4.10)	366 (±72)	2	2.68 (±1.9)
SITA Fast 2nd session	17.25 (±11.92)	13.18 (±8.84)	9.21 (±4.18)	368 (±69)	1.9	2.70 (±1.8)
CLIP 1st session	8.54 (±7.08)	7.78 (±4.83)	6.15 (±4.70)	450 (±100)	0	3.54 (±1.0)
CLIP 2nd session	8.93 (±8.04)	7.97 (±5.06)	6.03 (±4.65)	455 (±97)	0	3.58 (±0.9)

MS = Mean sensitivity; MD = Mean deviation; PSD = Pattern standard deviation; FP = False positive answers; AI = Acceptance index; FT = Full threshold.

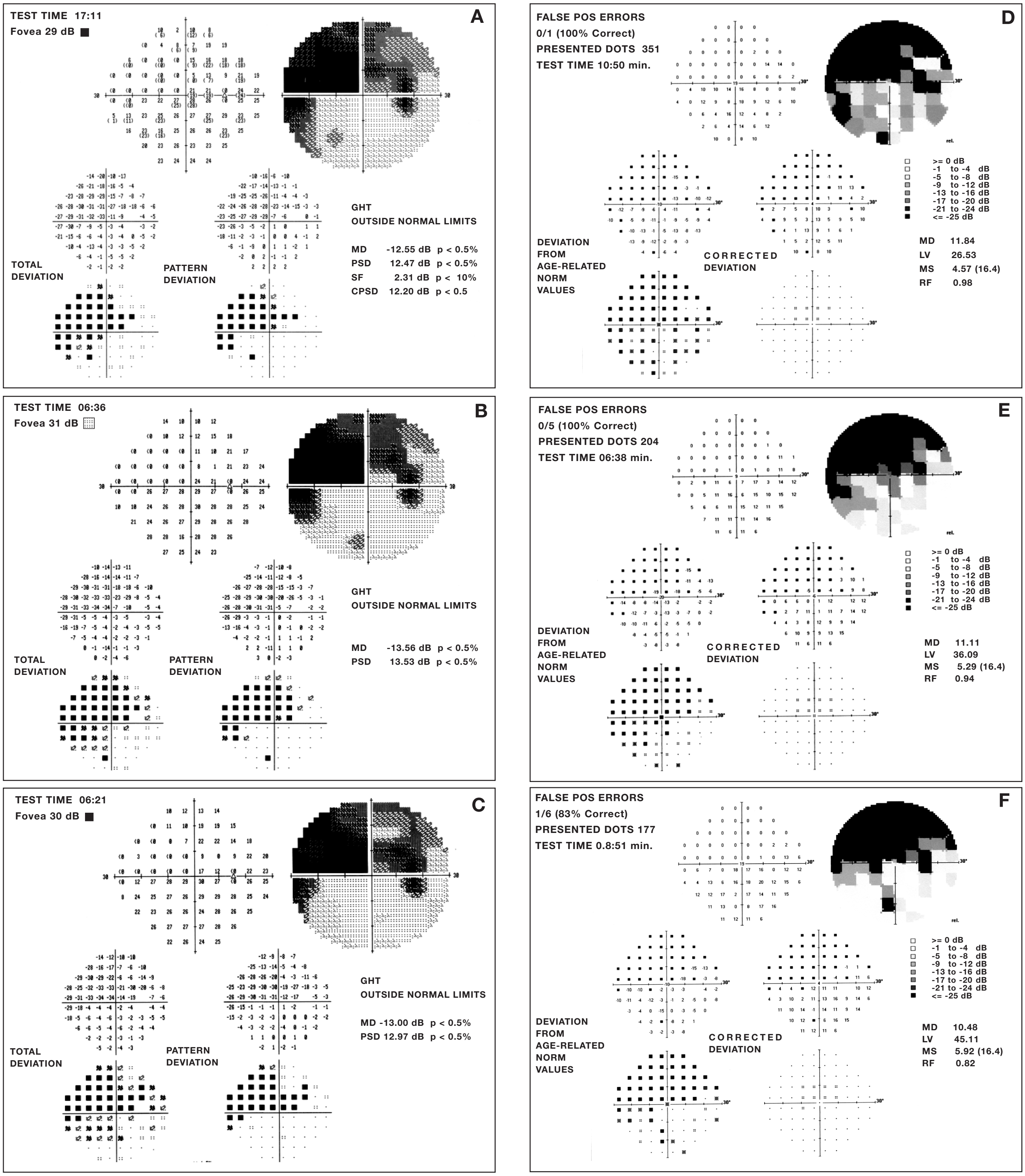

Fig. 4 - *Example of printouts of the absolute values, grayscale and statistic plot of a Humphrey Full Threshold* **(A)** *and SITA Fast, first* **(B)** *and second session* **(C)** *and Oculus Full Threshold* **(D)** *and CLIP, first* **(E)** *and second session* **(F)** *visual fields from the same patient. Absolute Bjerrum scotoma with good correlation between the two perimeters and negligible learning effect.*

different methods to obtain shortest examination duration. The two models of the HFA and the Oculus used in this study are the last generation of the two series with close characteristics of shape and dimension of the bowl and background luminance, but different stimulus and threshold measurement characteristics.

The HFA uses projected stimuli with a luminance range of 0–10,000 asb while the Oculus Twinfield perimeter uses back-projected stimuli through a semi-transparent bowl with a luminance range of 0–1000 asb; the same background luminance (31.5 asb) and stimulus duration (200 ms) are used. These differences in the characteristics of the maximum stimulus luminance are responsible for two phenomena. The first one is the overestimation of sensitivity decay in areas where the maximum intensity of the Oculus perimeter is not perceived, that leads to consider, as the site of an absolute defect, a tested point in which stimuli of higher luminance (>1000 asb) could be perceived. The second phenomenon is the different baseline value of luminance of the stimulus luminance that is assumed by the two instruments for the sensitivity scale of the absolute values expressed in logarithmic scales (dB). In fact, assuming as the minimum level of sensitivity (0 dB) the maximum luminance value of 1000 asb, the starting value of the sensitivity scale of the Oculus perimeter theoretically corresponds to the HFA value of 10 dB (0 dB corresponding to 10,000 asb).

In order to make easier the interpretation and comparison of the Oculus results with other instruments, a proper option is available, in the display of the Twinfield perimeter, to turn absolute sensitivity values in the corresponding HFA ones.

The average sensitivity measured by the Oculus FT strategy was 8.90 dB lower than HFA.

The MS difference between the two FT strategies is lower than the theoretical value of 10 dB calculated according to the different maximum luminance levels.

The higher MS values of Oculus, when corrected for the different maximum luminance (+1.1 dB), is probably due to different staircase thresholding algorithms and the different estimation of the threshold values. HFA FT value is determined as the stimulus luminance which is last seen in staircase of 2 dB. Higher Oculus MS (corrected for the different maximum luminance) was already found by Wabbels (11) compared to the HFA SITA Standard strategy and the Oculus FT strategy in healthy subjects (+0.5 dB).

In the present study the small sample size and the lack of a control group of normal subjects surely limit the value of the results even if the number of data (six threshold measurements for 1596 test points) could permit the comparison of behavior of threshold estimation of the SITA Fast and CLIP strategies according to light sensitivity that ranged from normal to absolute defect.

The comparison of the two MD indices of the two FT examinations revealed a 3.51 dB higher value for HFA than Oculus as a consequence of the different maximum luminance level of the stimuli.

The MS of the first session of two fast strategies was higher than the respective FT. These data were in agreement with the results of Wabbels et al (14), who found, with CLIP, 2 dB higher MS than FT, and Bengtsson et al (2), who found, with SITA Fast, 2.18 higher values than HFA FT.

The average HFA FT MD was 0.75 dB lower than SITA Fast, while Oculus FT MD was 1.79 dB higher than CLIP. The average MS and MD difference between Oculus FT and CLIP is not in agreement with the expected value. These data suggest the hypothesis that MD underestimation in CLIP may be due to comparison with FT normal reference values.

When comparing the between-algorithms differences in the two sessions for each fast threshold test, the average MS of SITA Fast and CLIP in the second session turned out to be significantly higher than the ones obtained in the first session (0.67 dB for SITA Fast and 0.39 dB for CLIP) showing a learning effect also in trained patients; this phenomenon was more evident with SITA Fast. This learning effect was not found by Wabbels et al (14) probably for a more rigorous training of patients who underwent three CLIP examinations. Bengtsson and Heijl (1) found a 0.22 dB effect for SITA Fast in glaucoma subjects.

The time saving of the two fast threshold strategies (SITA Fast 55%, CLIP 35%) was highly significant ($p<0.0005$), with a mean test duration of 366 sec for SITA Fast and 450 sec for CLIP.

The better acceptance for CLIP is due, as for SITA Fast, to the shorter duration and particularly to the less stressful approach to stimulus presentation with a more gratifying examination given by the impression that some stimulus could always be perceived in every supposed test location without answer time limits. These results were already registered in an experimental study with a giant screen projection perimeter in normal subjects (15) and by Wabbels et al in normal (11) and glaucoma subjects (14, 16) and in children (17).

Even if CLIP is clearly in contrast with the assumption that short exposure time avoids eye movements to search stimuli and spatial randomization prevents phenomena of dazzle of the tested point by suprathreshold stimuli, CLIP has shown a good comparability with SITA Fast, a very different strategy using a sophisticated algorithm. The fixation losses value of CLIP was slightly greater than the respective FT value as evidence that eye movements to search stimuli are more frequently evoked, as expected (FL: Oculus FT 24.7%; CLIP 27.8%).

The results of this study confirm that, with the two fast strategies SITA Fast and CLIP, test time is about 55% and 35% shortened in comparison with the respective full threshold algorithms.

The less time saving of CLIP is well justified by the fact that this strategy may be considered as a single reversal full threshold one with 1 dB steps without time interval between stimuli presentations. This represents a real threshold measurement in every tested point, while SITA Fast threshold estimation is only obtained by means of few stimuli presentations and the statistically based evaluation of the threshold values.

These two very different methods to estimate threshold sensitivity revealed low learning effect and good comparability with FT strategies as already shown in other studies (1-3, 13-16). SITA Fast revealed better characteristics of reproducibility and comparability with the respective FT strategy due to the wider range of stimulus luminance levels of the instrument and the threshold estimation based on statistical and mathematical extrapolation, and not only on the response to a simple sequential series of increasing luminance stimuli like CLIP.

The better acceptance of the CLIP strategy is justified by the more gratifying perception of stimuli of the same apparent characteristics in all the test locations, with the comfortable sensation of having more available time to perceive the stimuli.

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