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Scanning Eye Movements in Homonymous Hemianopia Documented by Scanning Laser Ophthalmoscope Retinal Perimetry

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ABSTRACT: Sparing or partial recovery of visual fields in hemianopic patients is frequently difficult to document. This is because when testing large field losses, the standard automated or manual visual field testing systems have limited fixation controls. Measured visual field recovery in these cases may not be real but instead may be due to an artifact such as scanning eye movement. This article illustrates a way to separate the actual visual field sparing from scanning eye movement artifact by using perimetry testing with the scanning laser ophthalmoscope (SLO). During the SLO perimetry, the examiner has a direct and magnified view of the retinal fixation locus. This direct view allows for the added ability to monitor the fixation stability during target presentation. When eye movements larger than 1° are noted, the examiner can repeat the trial. During static perimetry, our SLO records the retinal position of the fixation target at the end of the stimulus presentation and corrects scanning eye movements that occur during stimulus presentation. These special features enable us to identify when the apparent sparing of the visual field is due to the artifact of scanning. To demonstrate this, we selected the records of four hemianopic patients whose fields were examined by both standard perimetry and the SLO. We then compared the clinical visual fields with the SLO perimetry fields. One of the patients had a complete homonymous hemianopia on both the clinical perimetry and the SLO perimetry. A second patient was found by the SLO to have unstable fixation during testing. The SLO perimetry revealed that the apparent spared fields seen in standard perimetry were the result of eye scanning and not an actual enlargement of the visual field. Two other patients were confirmed by the SLO findings to have valid partial recovery of the visual field, one with and one without scanning eye movements. The advantages and limitations of SLO perimetry in analyzing hemianopic field sparing are discussed. (Optom Vis Sci 2003;80:495–504)

Key Words: brain injury, visual fields, vision recovery, vision restoration, residual vision, midline sparing, prism treatment

Patients with brain injury secondary to stroke, surgery, or trauma frequently suffer from a homonymous hemianopia. About 45% of stroke survivors have homonymous hemianopia.[1] Approximately 31% of stroke survivors admitted to rehabilitation were found to have homonymous hemianopia.[2] Patients who are hemianopic will sometimes show partial sparing across the vertical midline of their visual field on the affected side, as measured with automated perimetry. One study[3] reported that as many as 40% of hemianopic patients show such midline sparing. In this article, we use the term *sparing* to indicate vision on the affected or blind side that is measured during visual field testing. We use the term *recovery* to indicate a passive or spontaneous increase of the patient's visual field over time due to healing. The term *restoration* refers to an active form of increased visual field as a result of training or other treatment. Without multiple visual field measurements, it is impossible to distinguish sparing from either recovery or restoration. The particular type of sparing we address is not only macular sparing but sparing that can occur at other positions along the midline.[4]

A common adaptation that is noted with hemianopic patients is increased scanning eye movements.[5] These scanning eye movements are considered a useful outcome of vision rehabilitation. However, an enlarged field that appears to represent sparing on standard visual field testing may be an artifact resulting from scanning and not real sparing. We suggest that this artifactual "sparing" must be identified. The scanning laser ophthalmoscope (SLO) perimetry can be used for this identification.

Hemianopic field loss is not always a total or a complete hemifield loss because some patients retain residual vision or have partial sparing of the affected side.[3] Even if the initial loss is complete, sometimes the vision in the blind hemifield may partially recover as documented by successive perimetry recordings. This can be due to one of four causes. First, patients may experience spontaneous healing, resulting in a real partial recovery.[3] Second, partial recovery could be due to active reorganization of the visual system after brain injury (plasticity).[6, 7] Such reorganization of the visual system might be documented with traditional visual field testing. Unfortunately, it might not be possible to distinguish it from spontaneous healing except in a controlled study. Third, an improved field can be the result of a static eye position artifact during perimetry. If fixation is constant, but the forehead, chin, and eye position vary or are not properly controlled, then the visual field might appear to improve.[8] Fourth, homonymous hemianopic patients may develop extensive and rapid scanning eye movements into the blind side, causing the perimetry record to show a recovery in the blind field. Patients may develop such scanning eye movements spontaneously or be trained to execute eye movements.[5] In both of these scanning cases, eye movements may appear during perimetry as restoration of vision, when actually these patients are peeking into the blind side during a target presentation. The standard autoperimeter in our cases can only detect and record this peeking as a fixation loss.

For clinical management and research purposes, it is important to know whether the recorded visual field sparing is real or an artifact. Also, it is useful to determine whether a recorded improvement in visual field is the result of residual healing, active reorganization, head position shift in the perimeter, or dynamic scanning eye movements. The SLO perimetry permits us to note and record the retinal position of the fixation cross at the end of target presentation. The fixation position can be documented and responses corrected for the effects of eye movements. This direct retinal monitoring and correction for eye movement cannot be performed during standard static perimetry.

METHODS

The Rodenstock scanning laser ophthalmoscope was used for the examination of four male patients with homonymous hemianopia (Table 1). All SLO tests were performed by the same examiner (FVdV), who was aware they were hemianopic patients but had not seen the clinical fields. The visual fields of the four patients were tested using the Humphrey field analyzer static perimetry, full-field 120 point screening or the Humphrey field analyzer static perimetry, 30-2 threshold field test. All four had standard Goldmann perimetry (Table 2).

Patient 1 appeared by clinical observation to have steady fixation and did not seem to develop scanning eye movements. His Humphrey and Goldmann visual fields showed complete left hemianopia. Patient 2 presented with clearly visible eye scanning and appeared to see well into the left hemianopic visual field on Goldmann and on Humphrey perimetry. Patient 3 showed apparent recovery on successive Humphrey visual fields and confirmed sparing of the field on Goldmann perimetry. This patient appeared to have stable fixation. Patient 4 showed recovery on successive Humphrey fields, and sparing was confirmed with the Goldmann. This patient also did not appear to have scanning eye movements.

TABLE 1.
Patient characteristics.

Patient	Age	Acuity	Hemianopia	Etiology
1	42	OD 20/20 OS 20/25	Left	Stroke
2	17	OD 20/20 OS 20/25	Left	Brainstem hemorrhage
3	60	OD 20/20 OS 20/25	Right	Stroke after myocardial infarct
4	65	OD 20/25 OS 20/25	Left	Traumatic head injury

TABLE 2.
Perimetry testing conducted with the various patients.

Patient	Humphrey Full-Field[a]	Humphrey 30-2 Field[b]	Goldmann[c]	SLO Static[d] and Kinetic[e]
1	x	—	x	x
2	—	x	x	x
3	x	—	x	x
4	—	x	x	x

[a] Humphrey field analyzer: static perimetry, full-field 120-point screening test performed monocularly with the standard stimulus (III, white).
[b] Humphrey field analyzer: static perimetry 30-2 threshold field.
[c] Goldmann perimeter: kinetic perimetry. With white IV4e stimulus, monocular and binocular fields were tested.
[d] Rodenstock scanning laser ophthalmoscope (SLO): manual static perimetry[7] (see text for details).
[e] SLO kinetic perimetry (see text for details).

SLO Microperimetry

Earlier models of the SLO and previous clinical studies used a copupillary instrument that used one laser only for both imaging of the fundus and projection of psychophysical stimuli.[9] Although the SLO needs far less light than traditional ophthalmoscopes for visualizing the retina (on the order of 100 $\mu W/cm^2$ for a 632.8-nm laser source), this still appears very bright to the observer and is well within the range of bleaching photopigment. Typically, decremental targets that are darker than the background were used. These targets can be seen in the video image of the retina as a modulation of contrast at the target's location. Low-contrast targets were impossible to see. Because of the need for incremental stimuli like standard perimetry and using a much lower intensity photopic background, the second infrared laser was introduced. This solution, however, prevented the direct observation of all but the most intense incremental stimuli against higher background levels. To solve this problem, an overlay frame grabber card (OFG card, Imaging Technology, New Bedford, MA) was used. This card can produce a modulated video signal, representing the targets to control the acousto-optic modulator, and at the same time generates a synchronized graphic overlay on the retinal video image. The end result is a marker of the real-time true stimulus size and location on the retina.

The Rodenstock SLO, which we use as an imaging device, permits a video observation of the retina using a scanning laser instead of conventional optics. The main advantage for our purpose is that the SLO allows the examiner to observe, on a computer monitor, an image of the retina illuminated by one infrared near-invisible laser light source of 790 nm wavelength. At the same time, the examiner is able to see, in real time, the retinal position and shape of superimposed stimuli created by a second scanning visible laser source of 633 nm wavelength. This is done at photopic light levels that are safe for continuous exposure.[10, 11] We projected a wide variety of visual stimuli created with a computer-controlled overlay graphics card. The video output of this card, in turn, controls the acousto-optic video modulation of the visible laser source. In our study, the graphics included cross-shaped fixation targets and Goldmann-like kinetic or static targets.

With the SLO microperimetry technique, we were able to monitor and record on videotape the unambiguous retinal position of the fixation target and stimulus. In addition, with the help of the frame grabber, we could specifically freeze the location of the fixation and stimulus target position on the patient's retina at the time of the last frame of the six video frames-long (200 ms) standard static stimulus presentation. All individual presentation results can then be conveniently represented on one final and single master image at the end of the examination. This single master image was corrected for any fixation shifts that might have occurred at the end of the individual target presentations. To achieve this, the Cartesian coordinates of a fiducial landmark, such as a specific vessels crossing or bifurcation, common to all last video frames of the static stimulus presentation, were manually marked by the operator using a cursor on each frozen frame. Then, all stimulus and fixation locations were corrected with reference to this common retinal landmark. As a result, the stimulus and fixation positions will show up on the master image with their retinal locations indicated as a graphic overlay. In our static perimetry images, the open square overlay symbols indicate unseen targets of a certain size and shape in that particular location. The filled square overlay symbols indicate seen targets. Each black cross, drawn at a smaller fixed scale for the sake of clarity, represents the position of the fixation target during a particular stimulus presentation. The larger white cross is the true graphic overlay outline and position of the fixation target when the master image was acquired. The size and shape of the area covered by the symbolic black crosses, therefore, is a reliable indicator of fixation stability. If the patient maintained stable fixation during the test, then the black crosses will fall into a dense compact area. If the patient was scanning during the examination, the black crosses will be spread over a wide area. Note that with this static technique, the delay in patient response has no impact on the result. Because of this variable reaction time artifact, the above-mentioned correction for fixation shifts has not been applied to kinetic stimuli. Our kinetic perimetry maps, therefore, have uncorrected positions of end-point target locations. Our end-point target location is defined by either the verbal response of the subject or the initiation of saccadic reflex. Kinetic SLO perimetry only offers the ability to visually monitor trials and delete those occurring during eye movements. Trials are also deleted and repeated during the static perimetry if large eye movement occurs at the end of target presentation. Significant eye movements such as saccades are easily recognized on the frozen video image because in the interlaced NTSC video, these movements cause a clearly recognizable misalignment of the two successive interlaced fields of the video image.

The SLO raster covers 30.6° horizontally by 18.8° vertically. In some cases, we expanded this view with a telescope to obtain a field of view of approximately 50° horizontally and 30° vertically. The telescopic system is achieved by placing a -20.0 D trial lens in front of the patient's eye. This, combined with a compensating change in the SLO to refocus the image, creates minification and increases field of view. The Humphrey and Goldmann perimeters cover a substantially wider field of view than the SLO (Fig. 1 A and B). The perimetry stimuli in the SLO are square rather than circular, but the sizes of 4, 8, and 32 pixels width are approximately equal to Goldmann II, III, and V, respectively. In the SLO standard setting, one pixel corresponds to 3 min arc or 15 μm on the retina of a standard observer. The dynamic range of light intensities in the Humphrey and Goldmann covers 2.5 log units or 25 dB relative to the photopic standard background of 31.5 asb. In the SLO, we approximated this with a background of about 100 trolands (Td) of 633-nm light. The maximum stimulus intensity to background ratio was limited with our SLO to 1.5 log units or 15 dB to enable linear calibration. This means that the maximum intensity stimulus available in the Humphrey was 10 times the maximum intensity of the equivalent SLO stimulus.

Fresnel Press on Prism for Visual Field Expansion

The field expansion prism treatment introduced by Peli[12] uses two 40 Δ prism segments, one superior and one inferior on the patient's spectacle lens over one lens only. The prism base is in the direction of the blind field. The eye chosen for the prism is typically on the side of the blind field. The Goldmann fields with the prism applied are included to complete the patient's record of a subjective field expansion induced by an optical means. This illustrates the need to consider actual field sparing but not eye scanning-induced sparing in the application of these prisms.

RESULTS

Patient 1 has a complete homonymous hemianopia. The Humphrey full visual field screening test for the patient's right eye is shown in Fig. 1A. The same field cut is confirmed in the patient's SLO static retinal perimetry for the right eye (Fig. 1B). There was however, a hint of a small macular sparing found by the kinetic SLO perimetry (not shown). The SLO static microperimetry (shown) used a testing stimulus that approximately equals Goldmann III size. The white cross marks the position of the fovea. The multiple black crosses represent the retinal locations of fixation crosses during each of the stimuli presentations. The tight distribution of these black crosses indicates a stable central fixation pattern without significant fixation loss during perimetry. The SLO perimetry areas of field loss correspond to the Humphrey or Goldman areas of field loss by sliding the SLO onto the standard field and inverting it. For example, the anatomical right of the SLO image is the left recorded field on the Humphrey. Likewise, what is up on the SLO photograph is down on the Humphrey.

The patient also had his monocular visual fields measured with the Goldmann perimeter. The Goldmann visual field of the right eye (Fig. 1C) shows a complete left hemianopia with no macular sparing. The left eye Goldmann visual field (not shown) revealed an area of vision in the left inferior quadrant that was not identified on the Humphrey full-field 120-point screening or on the SLO field. The SLO field did not cover that lower section of the field (Fig. 1A). The Humphrey screening test does not have the sufficient density of test points in that section of the field to detect this small midline sparing. When the binocular Goldmann visual field was measured after applying peripheral prisms, an expanded visual field of the magnitude of about 20° was seen at the locations expected (Fig. 1d).

In Patient 2, the Humphrey visual field analyzer full-field 120-point screening tests for both eyes demonstrated left hemianopia and a field sparing across the whole vertical midline. Fig. 2A demonstrates this in the right eye field. The patient was cooperative, but numerous fixation losses were recorded. During Humphrey visual field testing, if fixation losses exceed 20% or if ≥2 losses occur during ≤5 check trials, then "XX" will be printed after the

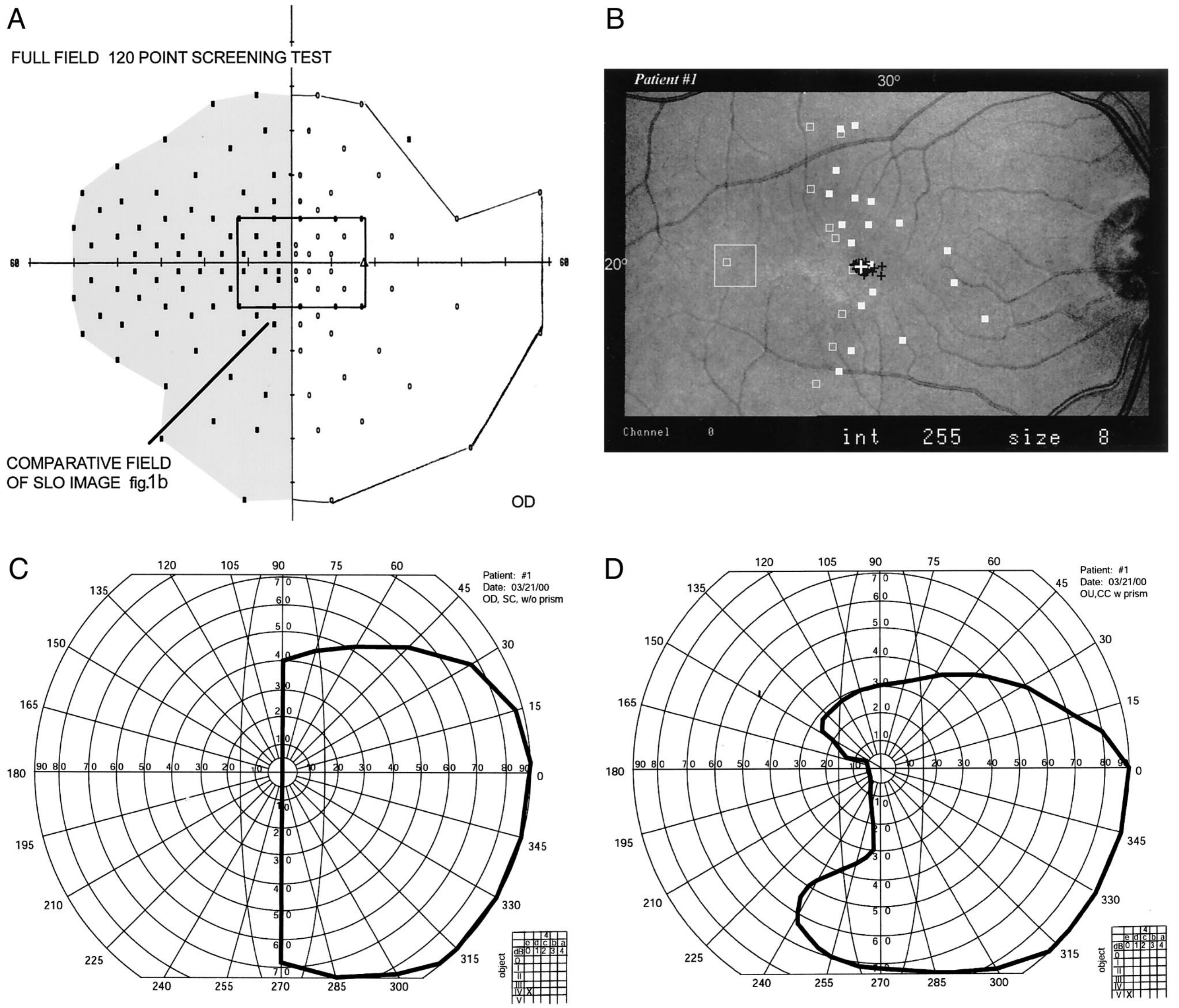

FIGURE 1.

Visual fields of patient 1. A: Humphrey 120 visual field screening test demonstrates a complete left field hemianopia for the right eye. In this field, open ellipses represent targets seen by the patient, and filled rectangles are targets that were not seen. The gray shading of the unseen area was added to aid in interpretation. A thin black line connects the outer boundary of the area seen. The rectangle insert at the center shows the size of the field covered by the scanning laser ophthalmoscope (SLO) image of Fig. 1B for comparison. B: The SLO perimetry of the right eye confirms complete left field hemianopia with no macular sparing. Here, open white squares indicate positions where a stimulus was not seen. Filled white squares indicate positions where the stimulus was seen. The size of the white squares corresponds with the size of the target used. Notice the one very large open square indicating the density of the scotoma at that area. The white cross is the fixation target seen by the patient. The multiple overlapping black crosses at the fovea represent the similar positions of fixation crosses during different trials. The dense accumulation of these crosses at the fovea indicates an accurate and stable fixation for this patient and is comparable to that of normally sighted subjects. C: The right eye Goldmann field demonstrates a complete left hemianopia with no macular sparing. D: Binocular Goldmann visual field shows extended field segments of about 20° below and above fixation after being fit with peripheral prism.

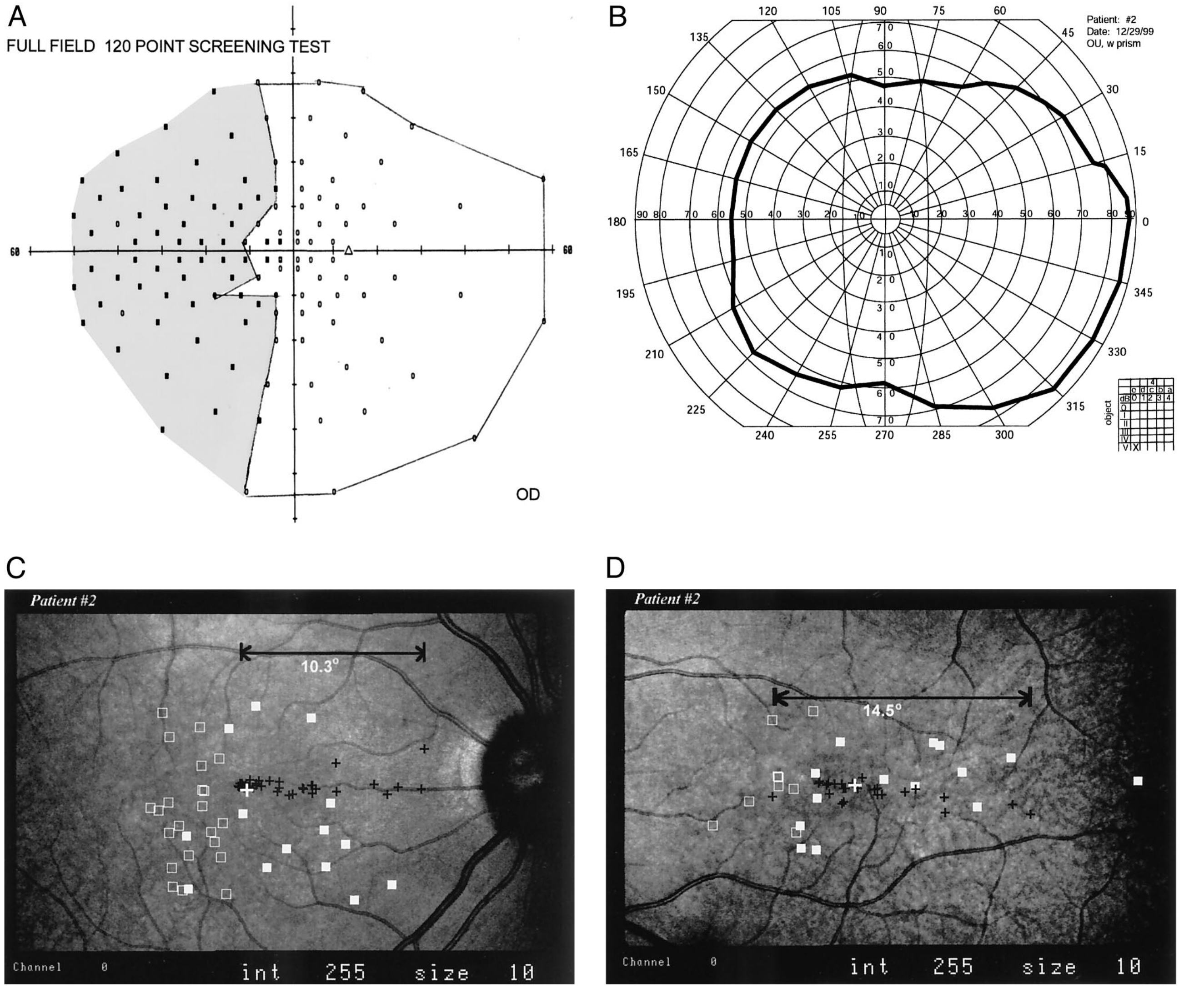

FIGURE 2.

Visual fields of patient 2. A: Humphrey screening field for the right eye shows an incomplete left hemianopia with residual vision extending 5° to 10° to the left of the vertical midline. B: An even greater extension of the seeing area to the left of the vertical midline was recorded with a binocular Goldmann test after being fit with peripheral prisms. This extension is much larger and extends more centrally than what is expected with the prisms (compare with Fig. 1D). Right eye (C) and left eye (D) scanning laser ophthalmoscope fields show a complete left hemianopia with no significant sparing in the left side. The wide distribution of the black crosses illustrates the extent of the scanning eye movements that were corrected when generating the field maps. The dark double-head arrows mark the range of fixation positions recorded. Normal eye fixation movement is <1°.

score. This implies that excessive eye movements were detected.[13] For the right eye, patient 2 had six fixation losses during 18 fixation checks. For the left eye, he had three fixation losses during 17 fixation checks. These left eye fixation losses were truly unexpected. This was because the method for fixation control of the Humphrey field analyzer is to flash a stimulus in the position of the physiologic blind spot. If the flash is detected by the patient, that indicates a fixation loss. Because the patient's left field is blind, the patient should never have seen the flash during the fixation check method. All such left eye, left field fixation losses indicate >15° of eye movements during testing. The normal size of fixation eye movements would be about 1°. See the SLO for patient 1 as an example of normal fixation eye movement range (Fig. 1B).

A binocular Goldmann visual field was also obtained (not shown). The binocular measurements indicated that the patient had 130° of horizontal visual field with about 50° across the midline. This might represent a significant level of midline sparing. However, the perimetrist did note frequent large eye movements that made the control of fixation during the Goldmann perimetry procedure very difficult, with uncertain results.

This patient's frequency of fixation losses in the Humphrey and the apparent eye movements during the Goldmann made us question the validity of the field sparing finding. The SLO static perimetry was used to evaluate the fixation and the fields (Fig. 2 C and D). The SLO static field represents the corrected retinal position of seen targets as filled white squares and the corrected position of the unseen targets as open white squares. The black crosses show the retinal position of the fixation cross at the end of target presentations. A pattern of responses consistent with a complete hemianopia is clearly represented. The wide distribution of the black fixation crosses spread across the retina (the span measured is 10.3° OD and 14.5° OS) documents the active scanning behavior.

The SLO confirmed a complete left hemianopic visual field loss. The SLO fixation positions showed that the reason for the apparent recovery noted in the clinical visual field measurements was eye movement scanning. The binocular visual field with prism (Fig. 2B) illustrates a further expansion of the fields compared with the binocular fields without the prisms (not shown). This indicates that the field expansion effects of scanning eye movements and the peripheral prisms are additive, as expected. It also indicates that the use of the prisms is not contraindicated in patients with very active scanning patterns. However, the prisms may not be as valuable for patients who have already developed an active adaptation process.

Patient 3 had a complete right visual field loss and a partial peripheral left field loss that was greater in the superior quadrant shown with the early Humphrey visual fields (Fig. 3A). The patient was retested 2 months later and appeared to have recovery of the peripheral left field loss with additional partial recovery in the lower quadrant of the right field (Fig. 3B). The fields of the left eye were very similar to those of the right eye, and are not shown. SLO perimetry was performed using the static perimetry presentation (Fig. 3C). A binocular Goldmann field was taken later than the Humphrey field and also showed the right inferior field sector recovery (Fig. 3D). The remaining loss in the upper left quadrant was found to be a result of droopy lids. With SLO perimetry using the kinetic presentation, the same sector recovery was demonstrated (Fig. 3F). Note that the patient's fixations cover a range of about 5° horizontally (Fig. 3C). This indicates a moderate level of scanning. The SLO static field procedure made it possible to correct for these eye movements and confirm the lower right quadrant partial recovery. This was also true for the SLO kinetic field using the monitoring of fixation (Fig. 3F). The binocular Goldmann field with peripheral prisms (Fig. 3e) shows the expected peripheral expansion added to the overall apparent expansion caused by the eye movements.

For patient 4, the early Humphrey fields showed complete homonymous left hemianopia and peripheral loss on the right field bilaterally. A comparison between these early field tests and the later Humphrey visual fields indicates an apparent recovery in the right peripheral visual field of each eye (Fig. 4 A through D). The later Humphrey results for the right eye also showed a left inferior quadrant sector recovery not found for the left eye (Fig. 4B). Note the later Humphrey field of the right eye. The physiological scotoma, representing the nerve head, was not well detected; suggesting an unstable fixation. There were five fixation losses during 12 trials, which suggests that the left inferior quadrant recovery for the right eye only might have been an artifact. The later Humphrey test for the left eye showed a small recovery in the upper left quadrant but not in the lower quadrant (Fig. 4D). The binocular Goldmann field measured after the Humphrey test showed partial recovery in the left inferior and superior quadrants (Fig. 4E). Monocular Goldmann measurements (not shown) demonstrated a partial left field inferior quadrant recovery for the right eye and a partial left field superior quadrant recovery for the left eye. The right eye inferior sector recovery was not replicated by the SLO kinetic field using a stimulus size equivalent to Goldmann V (Fig. 5 A and B). We repeated the right eye Goldmann visual field testing the same day as the SLO perimetry testing and reconfirmed the sparing. The reason that the sector recovery was not shown by SLO might be that the SLO light stimulus intensity is lower than the V4e Goldmann test objects. We further confirmed on the same day that the recovery was not detectable with the Goldmann III target but was detectable with the size V target. The binocular Goldmann field after applying prism is shown in Fig. 4F. This shows that for patient 4, the effect of the prism was minimal compared with the binocular field without the prism. The effect of the prism in the inferior segment is expected to be similar to the naturally occurring recovery in the right eye. In the superior field, the prism should have expanded the field further if its field location exactly coincided with the naturally occurring sparing in the left eye. It appears that this was not the case. Thus, the prism changed the location of the field expansion but did not expand it significantly. In such a case, a lower prism on the right lens with base-in might have been more effective.

DISCUSSION

These four cases present a spectrum of hemianopic conditions that might benefit from the analysis with SLO perimetry we have described. Previous studies have also discussed the use of the SLO to confirm unstable fixation of perimetry. One study by Bischoff et al.[14] used SLO perimetry to test for the existence of macular sparing. They noted that there were scanning eye movements in hemianopic patients and, therefore, concluded that macular sparing is a perimetric artifact. If this were true and sparing was only due to eye movement, then these eye movements should cause sparing along the whole vertical midline and not be restricted to just macular area sparing. Furthermore Bischoff et al.[14] did not correct for the eye movement in the perimetric analysis as we have done. They only monitored eye movements. Another report by Sugishita et al.[15] performed fundus perimetry on two patients with homonymous hemianopia and could not determine whether there was macular sparing on Goldman. They found small eye movements and small, if any, macular sparing. From these findings on only two patients who did not show clear sparing with any technique, they concluded that macular sparing, if it exits, must be $<0.4°$ wide. Trauzettel-Klosinski and Reinhard[4] used a SLO procedure with vertically aligned sets of three dots at different locations relative to the fixation target to test for macular sparing and vertical strip sparing. They also monitored eye movement and repeated trials in which the eye movement was noted. They were able to document macular sparing as well as absence of sparing. They also noted that in the absence of sparing, fixation was less stable. Our case report is different from these previous studies because we specifically attempted to demonstrate how the SLO could be used to correct for or to identify unstable fixation. With this identification of unstable fixation, the SLO can confirm or rule out expanded visual field along the midline or in the blind field. For example, the patient with extensive scanning eye movements (patient 2) has an apparent extension of the visual field across the vertical midline with both Humphrey and Goldmann visual field testing, but not with the SLO. The SLO shows a complete hemianopia with clear evidence of scanning eye movement involving multiple fixations. This confirms that the apparent midline sparing was false or an artifact caused by the eye movements. In this case, the eye movements were very apparent. The artifact could be easily noted and detected by careful clinical observation and by careful analysis of the fixation losses noted by the Humphrey field. This particular example

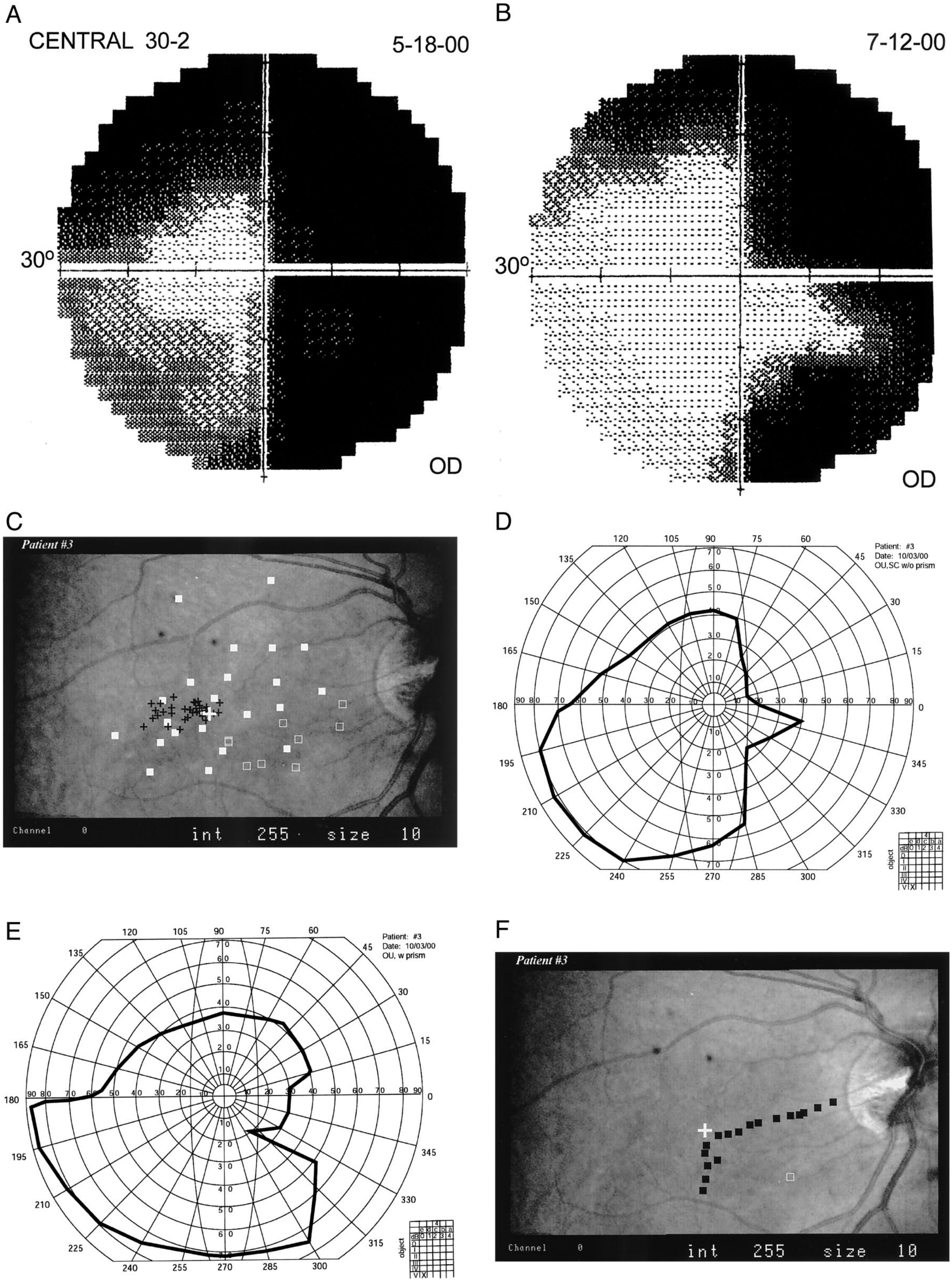

FIGURE 3.

Visual fields of patient 3. A: Central Humphrey 30-2 test showing an early record of complete right hemianopia with a substantial peripheral left field loss. B: Recovery of the peripheral left field loss with some recovery of the inferior right field 2 months later. C: Scanning laser ophthalmoscope static perimetry of the right eye confirms midline sparing of the inferior right visual field. Filled squares represent seen targets in the upper right section of the scanning laser ophthalmoscope image. Note the distribution of the black crosses extending about 5° indicating unstable fixation. D: Binocular Goldmann field confirms the recovery of a section in the inferior right field and the extent of the left peripheral field. The upper left depression of the field is due to a drooping lid. Note the vertical midline shift to the right resulting from the scanning eye movements. E: Binocular Goldmann field with peripheral prisms showing the expected peripheral expansion added to the overall apparent expansion caused by the eye movements. F: Scanning laser ophthalmoscope kinetic field of the same eye confirms the diagonal field cut and the dimensions of the spared field shown on the Humphrey and Goldmann fields. The black squares indicate target transition from unseen to seen, and the open white square indicates the unseen area.

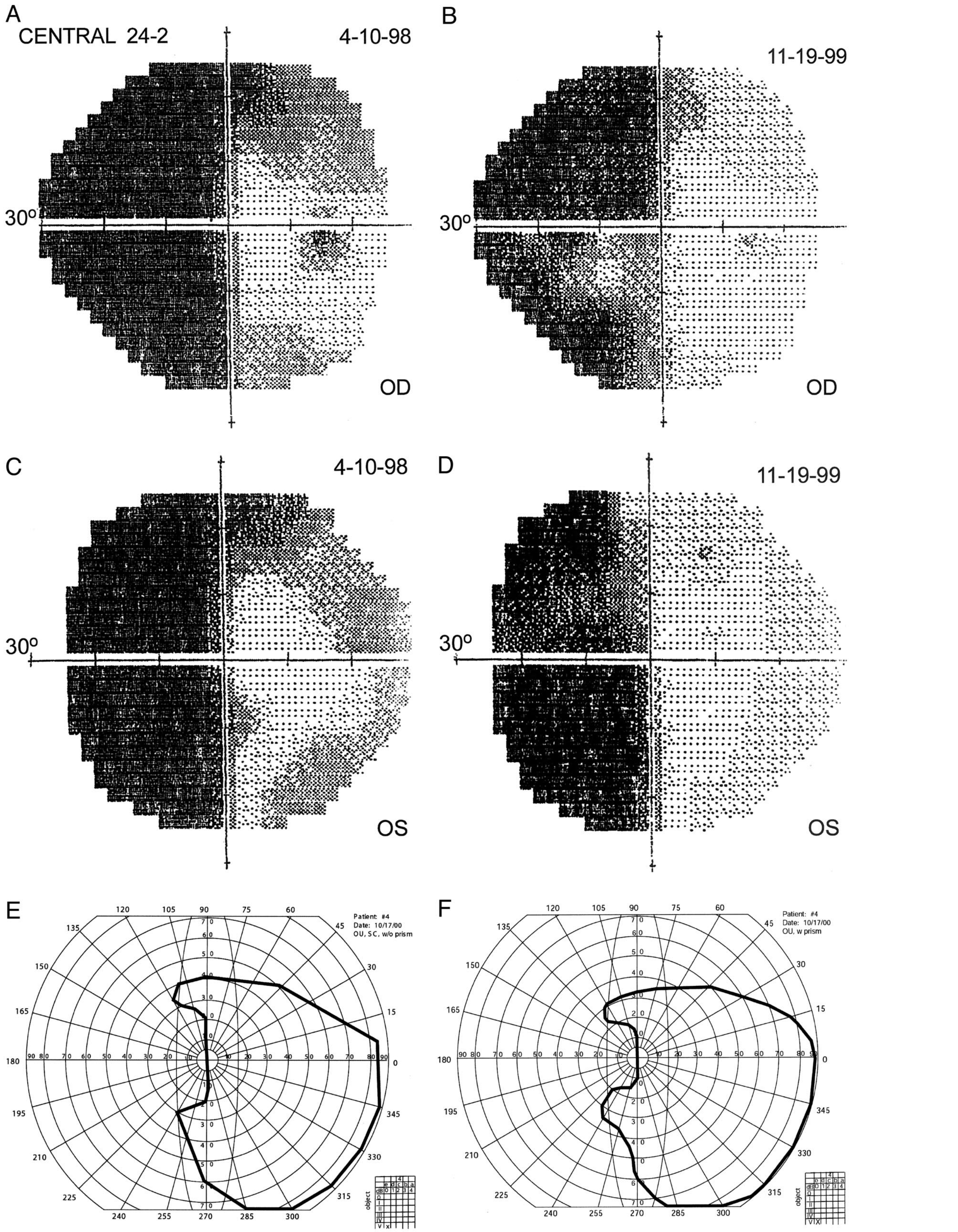

FIGURE 4.

Visual fields of patient 4. A: An early visual field shows complete left hemianopia with partial loss of the right peripheral field. B: A later field demonstrates a partial recovery in left inferior field and an expansion of the right peripheral field. Also, note that the scotoma for the optic nerve is less apparent on the later field, indicating a less stable fixation. C and D: Humphrey fields of the left eye show the same recovery of the right peripheral field but no recovery of the left inferior field seen in the right eye. E: Binocular Goldmann field of patient 4 confirms the recovery in the left inferior field. A recovery on the upper left field is just hinted at with the left eye field Humphrey tests. This is because it was more than 30° above fixation. F: Binocular Goldmann field with prism.

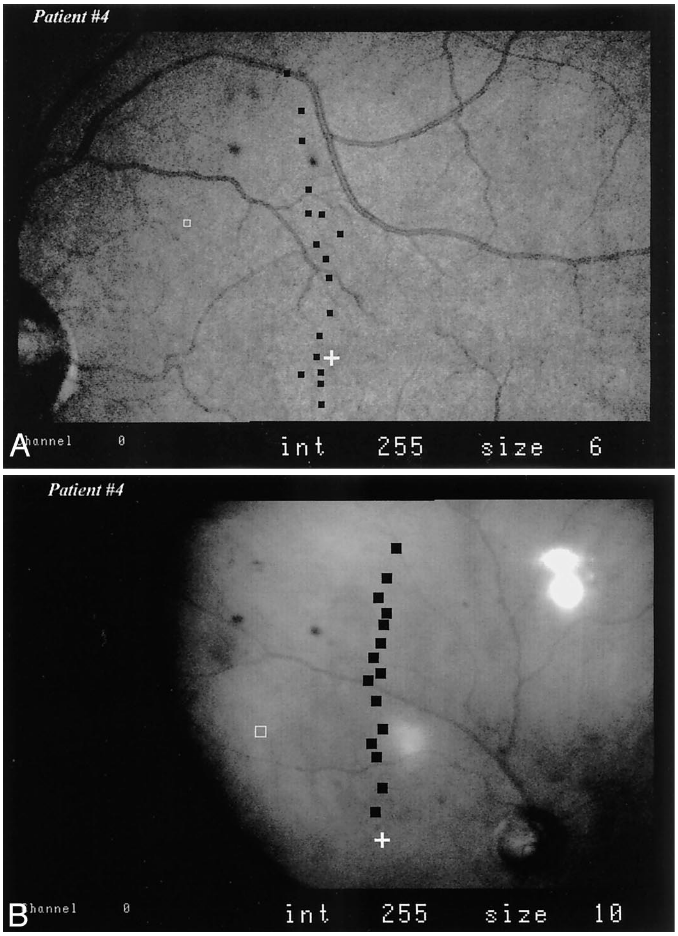

FIGURE 5.

Scanning laser ophthalmoscope kinetic perimetry of the right eye of patient 4 using size 6 stimuli (A). B: Using size 10 stimuli and optical view expander still fails to document the inferior left field (upper retinal) recovery.

points out that any fixation losses recorded in a left eye with a left hemianopia or right eye with right hemianopia should be considered a mark of large scanning eye movement and should cast serious doubt on any other aspects of the recorded field. In other cases, however, it is not always easy to clinically detect and note smaller scanning eye movements. For example, patient 3 had a significant level of eye scanning of 5° that was not noted clinically, and these movements would not cause fixation losses on the hemianopic side. Patient 3 also showed apparent recovery in both eyes. If a careful observer had noted the eye movement, the apparent recovery might have been wrongly attributed to these scanning eye movements. Instead, the recovery was confirmed with SLO even after the eye movements were accounted for. This case illustrates the value of the SLO perimetry in confirming, not just in rejecting, recovery noted in clinical testing. Patient 4 showed recovery of visual field for one eye only. Recovery in one eye might suggest an artifact. Furthermore, this recovery could not be found with the SLO. However, the same day, this recovery was shown again with Goldmann perimetry using the same target. This highlights some limitations of the SLO in detecting very minimal recoveries that are noted only with the largest and brightest Goldmann targets.

All patients were fit with peripheral prisms of 40 Δ for visual field expansion.[12] All patients experienced an expanded field with the prism on binocular Goldmann perimetry. For example, the binocular Goldmann visual field of patient 1 with prism showed a visual field of 115° in the upper and lower quadrants (Fig. 1D). An expansion of fields by approximately 20° with the prism was found in three patients (1, 2, and 3) (Figs. 1D, 2B, and 3E) and was in addition to visual field sparing found with scanning or recovery. Note that if field sparing is identified in one eye only, such as seen in the case of patient 4, then the corresponding prism should be applied to that eye, even if this is not the eye on the side of the visual field loss. With such application, the prism-induced field expansion is added to the field gained by sparing.

Although the SLO offers many advantages in confirming or rejecting a field expansion due to recovery or restoration, it is not without limitations. SLO perimetry cannot distinguish a restoration from spontaneous recovery and, thus, a random control trial, preferably with cross-over design, is needed. Also, the size of the field tested by the SLO is small—only 20° × 30° (Fig. 1 inset). This small size makes it difficult to assess and evaluate any field changes occurring at further eccentricity. It is possible to expand the field area tested by 50% using optical minification (Fig. 5B). However, that modification makes testing more difficult and the field that is tested is still smaller than the field tested by most clinical perimeters. It is important to realize, however, that the central 20° to 30° are the most important to the patient for safe mobility and navigation. The ability to accurately assess the areas covered by the SLO is more important than to assess far peripheral field regions. Note that in most jurisdictions, a patient with peripheral field loss is not considered legally blind until the field is down to 20° in diameter or 10° on each side of the midline.

The stimulus intensity level or dynamic range of our SLO was reduced to achieve a linear calibration. Our SLO targets were not as bright as those of the Goldmann and Humphrey perimeters. Thus, as was found for patient 4, some field sparing may be recorded with the largest brightest Goldmann targets but were not confirmed with our SLO. However, if visual sparing is such that it can only be detected with Goldmann V4e stimuli, the value of that sparing for visual function is questionable. Studies are needed to determine whether a limited sensitivity sector recovery is still useful for a patient's ability to detect obstacles and to aid in navigation.

CONCLUSION

We have shown in these cases that visual field improvement or sparing of patients with homonymous hemianopia can be validated by SLO perimetry. Hemianopic adaptation with scanning eye movements may be falsely interpreted as field sparing when measured by conventional perimetry. Such adaptation might be the result of treatment modalities attempting to provide field restoration or a result of direct training for scanning. Field expansion due to scanning eye movements may actually improve visual function just as much as actual field restoration. But the clinician should understand the difference when planning treatment. In addition, training methods in scanning eye movements may serve as a useful rehabilitation tool. The use of SLO perimetry with its fixation analysis can document such outcomes and help gain a better understanding of the technique, possibly leading to better training or treatment methods. The necessity to confirm the occurrence of spontaneous visual field midline sparing as noted in our patients and in other studies transforms the SLO into an important tool to be used when studies of novel techniques suggest a method of visual field restoration.[16–18] Such studies in which either psychophysical training[16, 17] or a prism device[18] is applied with the intention of providing for visual restoration need to use SLO perimetry or other control methods to clearly confirm that the apparent restoration is true and not an artifact of scanning eye movements. As new effective therapeutic techniques are demonstrated and become incorporated into therapeutic rehabilitation procedures, the ability to determine precise fixation during testing may also become essential.

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