AUTOMATIC STATIC FUNDUS PERIMETRY FOR PRECISE DETECTION OF EARLY GLAUCOMATOUS FUNCTION LOSS

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Abstract

Purpose: To establish a short routine method for fundus perimetry which allows detection of beginning visual field defects due to glaucomatous nerve fiber bundle damage.
Methods: Sixty-five eyes of 44 patients (45 ± 21 years) were examined using our automatic static threshold fundus perimetry with the scanning laser ophthalmoscope (SLO), two different test grids (30 and 80 points), and argon blue nerve fiber layer imaging. Patients were divided into three groups: 1. those suspected of having glaucoma due to increased cupping and/or beginning visual field defects (MD <2dB, Octopus 500); 2. those with glaucomatous field defects; and 3. controls. We compared the results with visible nerve fiber layer defects and visual field defects in conventional cupola perimetry.
Results: The automatic threshold fundus perimetry allowed documentation of all visual field defects observed during conventional perimetry, while all controls remained normal. Examination time was 4.5 ± 0.6 minutes for the peripapillary test grid with 30 points. In addition, we were able to delineate beginning field defects sharply (5-14 dB loss to normal values) due to nerve fiber layer bundle damage which was not observed during conventional perimetry.
Conclusions: Fundus perimetry using the SLO enables detection of early visual field defects, especially when using age-related sensitivity values. Exact projection of the stimuli onto specific retinal locations enables exact function testing relative to retinal nerve fiber layer defects. This method may help in finding early glaucomatous functional damage within a short examination time.

Introduction

Early detection of glaucomatous alterations is one of the major aims in ophthalmological practice. Clinical tools consist of tonometry, visual field testing and quantification of the optic disc morphology. Perimetry has become the screening method of choice because measurement of intraocular pressure (IOP) has only low sensitivity and is not part of the major criteria for the diagnosis of glaucoma[1,2]. In addition, for exact evaluation of the optic disc, the pupil needs to be dilated. However, morphological alterations to the nerve fiber layer (*e.g.*, nerve fiber bundle defects) precede detectable visual field defects by years[3]. Even advanced methods such as computerized perimetry

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often cannot detect beginning visual field defects, especially when routine programs are used. This is due to the inadequate test grid which is not oriented according to the nerve fiber directions, and the concordant localization of a bundle defect. In addition, functional impairment due to instability of fixation might be missed during the examination.

The scanning laser ophthalmoscope (SLO) allows for automated threshold perimetry with simultaneous fundus visualization[4] and therefore enables us to accurately present light stimuli onto reproducible locations on the fundus. Therefore, we wanted to evaluate the feasibility and clinical value of our fundus perimetry in patients suspected of having glaucoma, and to establish a short routine method of fundus perimetry to detect beginning visual field defects due to glaucomatous damage.

Patients and methods

Sixty-five eyes of 44 patients (45 ± 21 years) were included in the study. They were divided into three groups according to the visual field obtained with computerized cupola perimetry (Octopus 500, Interzeag):

Normals had no ophthalmological pathology or increased IOP and had normal visual fields. Glaucoma patients presented with glaucomatous visual field defects, *i.e.*, three contiguous test point locations with 10dB loss or a mean deviation (MD) of more than 4dB during standardized computerized perimetry. Patients suspected of suffering from glaucoma either had an elevated IOP or an increased disc cup. Computerized visual fields were normal or showed a beginning visual field defect, while the mean deviation in conventional cupola perimetry was less than 2dB, and the criterion for glaucomatous damage was not fulfilled. The informed consent of all patients was obtained before inclusion in this study.

Ophthalmological examination of all patients included measurement of visual acuity, applanation tonometry, slit-lamp examination of the anterior and posterior segments with the Goldmann three-mirror lens or 78-D lens after pupil dilation. Perimetric examination was performed using Program 38 of the Octopus 500.

In addition, fundus perimetry was performed with the SLO (Rodenstock, Munich, Germany)[5-7] using an external personal computer (Pentium 233 MHz) and our static threshold perimetry software[4,8]. The background illumination was set at 10 cd/m^2, stimulus presentation time was 120 msec. The stimulus intensity could be varied in 0.1 log steps from 0-21dB. In addition, intensities of 23.6 and 26dB were possible. We used a 4-2-1dB staircase strategy. We tested about 5% false positive and false negative test answers.

A landmark was set on a reliable position, *e.g.*, a vessel crossing, which enabled the computer to calculate the real point of fixation as well as the actual location of the stimulus. After definition of the landmark by the investigator, the next stimulus was automatically presented by the computer and corrected for eye movements. In the middle of each stimulus presentation, the actual fundus image was again stored by a frame grabber. This enabled us to observe deviation from the earlier point of fixation and to re-test the stimulus if necessary.

The perimetry software allows the examiner to choose freely any test grid pattern or even to define stimulus locations, as well as to change the size or time of stimulus presentation.

Following earlier reports of the ability to detect functional alteration due to peripapillary glaucomatous damage[9,10], we decided to test two different test grids: first, our standard rectangular three-degree pattern with up to 86 test point locations[4,11], and second, a newly developed test grid consisting of 30 test point locations located superior and inferior to the optic nerve head margin (Fig. 1). The option exists to adjust for different disc areas by enlargement of the diameter of the inner circle in three defined steps and to add stimulus locations following the examination.

We compared threshold values from fundus perimetry with our database of normals, and calculated deviation values according to the age for each stimulus location as well as for the whole examination (MD)[11]. The visual fields were given as defect plots. The result was projected onto the fundus with open rectangles representing sensitivity values greater than normal and filled rectangles demonstrating a defect, as illustrated in Figure 1, in comparison to the standard differential light sensitivity threshold presentation.

Results

Only a short examination time of 4.5 ± 0.6 minutes was necessary for the peripapillary test grid with 30 stimulus locations. Since all defects were observed during fundus perimetry using this test grid in an identical manner to the rectangular grid with 80 points, we report the findings of the new grid:

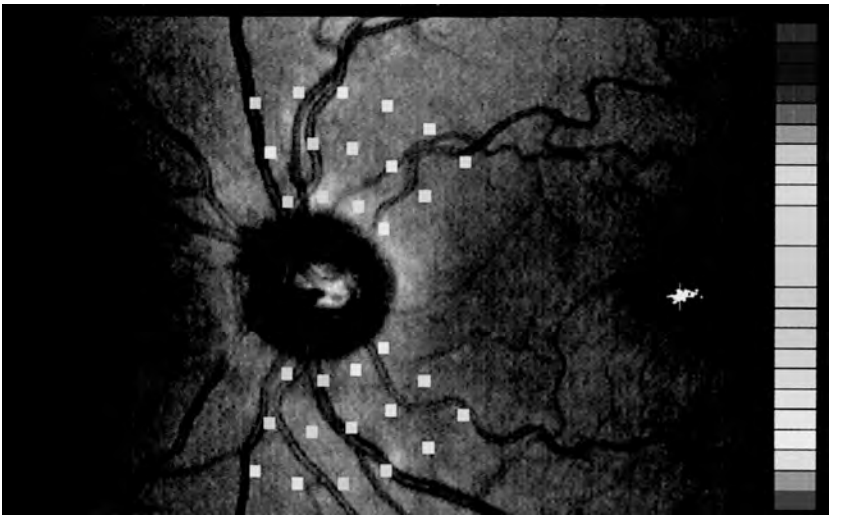
For the normal eyes, fundus perimetry did not reveal any pathological findings (Fig. 1). In other words, no false visual field defects were observed in this group with completely normal conventional visual fields.

In the glaucomatous eyes, conventional cupola perimetry and fundus perimetry showed the same result, *i.e.*, both methods detected all defects (Fig. 2), although in some eyes, during conventional cupola perimetry, the scotomas were located even further in the periphery than observed during fundus perimetry. Some eyes showed defects only at locations near the margin of the optic disc (Fig. 2). However, using fundus perimetry, we did not see any eyes with normal sensitivity values around the optic disc and scotomas more peripherally.

The most interesting group were the patients suspected of having glaucoma. In this group, all defects observed during conventional perimetry were also found with our new fundus perimetry (a defect of 7dB at two or more stimulus locations was set as cut-off).

However, scotomata due to nerve fiber defects could be detected better by means of fundus perimetry compared to conventional visual field testing (Fig. 3). Two eyes showed normal Octopus fields, while fundus perimetry revealed an absolute glaucomatous visual field defect overlying the nerve fiber damage associated with enlarged cupping of the disc (Fig. 3). In two eyes with no morphological alteration of the disc, there were isolated defects during fundus perimetry in the parapapillary area that might indicate beginning damage comparable to the glaucomatous alteration (Fig. 4). We could not support the earlier finding that beginning scotomas caused by nerve fiber bundle defects were located in the periphery.

Since the software allows additional stimuli even after the examination, it is easy to delineate the border of scotomas overlying deep nerve fiber bundle defects accurately (Figs. 2 and 3).



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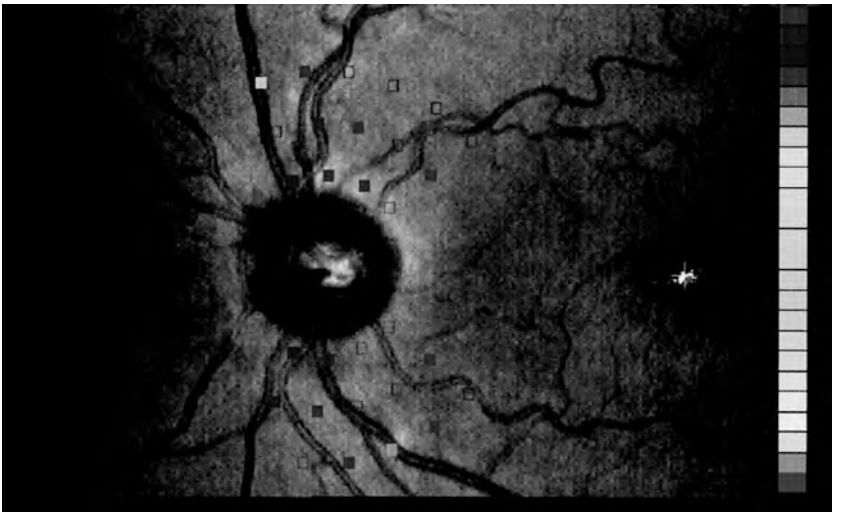

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Fig. 1. Test grid with 30 peripapillarily located stimulus locations for threshold fundus perimetry in a left normal eye. *a.* Normal threshold values, where the scale on the right represents the threshold in 1dB steps with the highest stimulus illumination (0dB) at the top. Fixation is very stable (white points in macula). *b.* The same examination presented with deviation values according to our database of normal eyes[11]. Open rectangles represent thresholds better than age-corrected normal values, while filled rectangles represent defects. The scale on the right is again coded in 1dB steps. All locations show thresholds of less than ±2dB from normal.

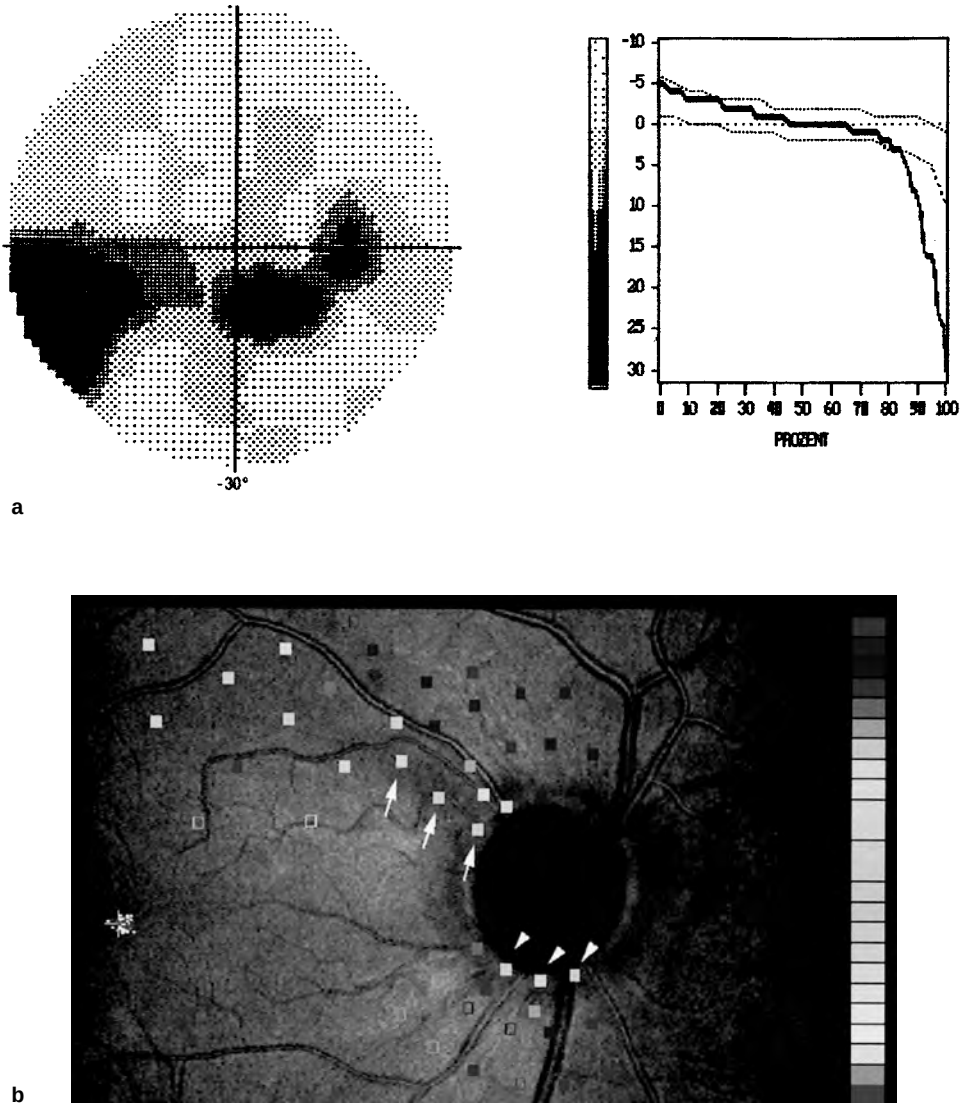
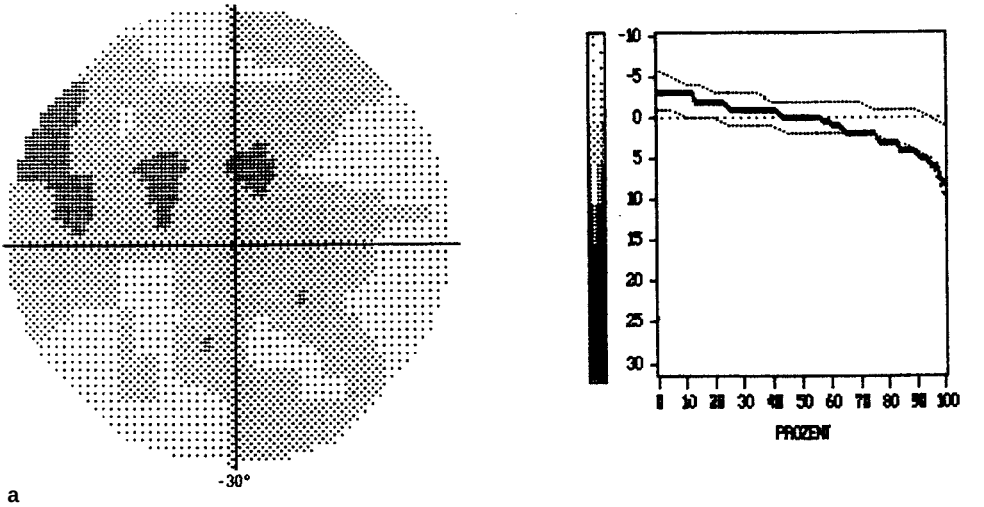


Fig. 2. Right eye of a 47-year-old patient with a glaucomatous bundle defect. *a.* Conventional perimetry demonstrates a visual field defect in the inferior hemisphere with more than three contiguous locations with a 10dB loss or more, although MD is only 1.7dB. *b.* Fundus perimetry shows a corresponding defect in the superior retina (arrowheads) with more than 10dB loss at three locations during our 30 point test (arrows). Addition of more test points enables exact delineation of the scotoma overlying the visible nerve fiber bundle defect with a more peripheral absolute scotoma. In addition, there are three defects at the inferior disc margin (arrowheads). Open rectangles represent thresholds better than age-corrected normal values, while filled rectangles represent defects according to the scale on the right in 1dB steps.



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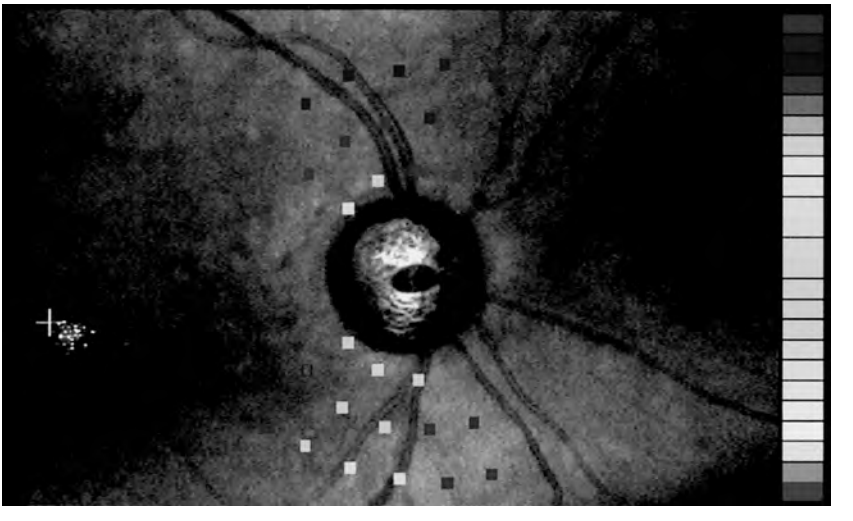

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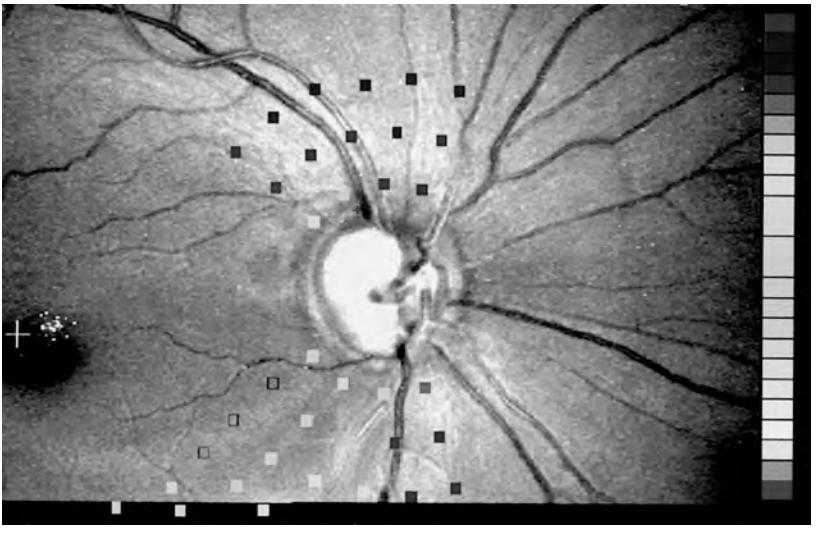

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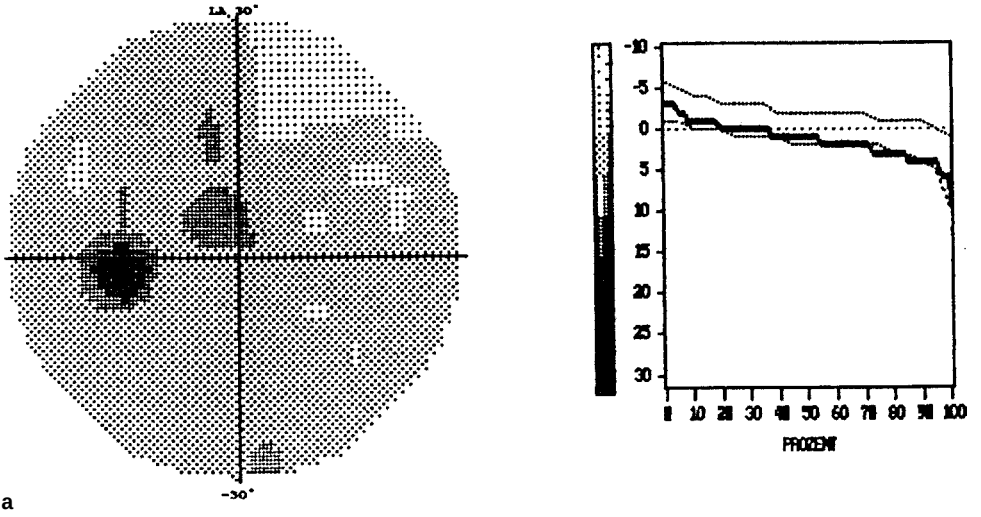

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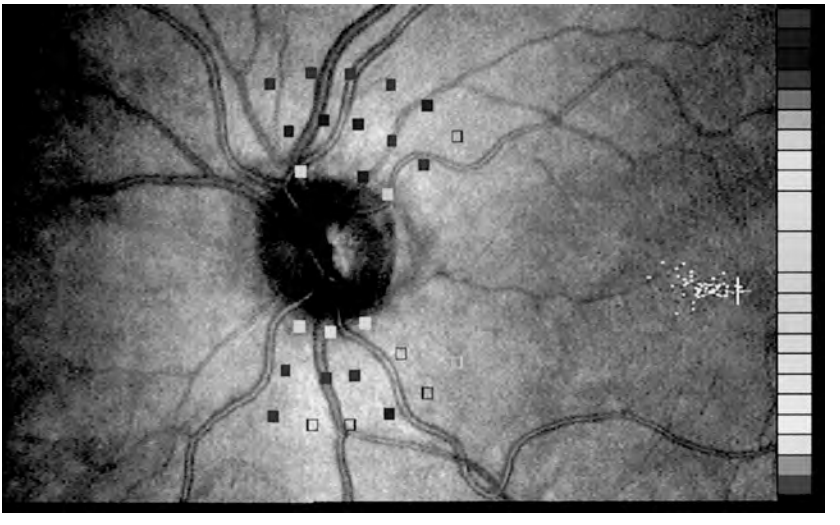

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Fig. 4. Left eye of a 65-year-old glaucoma suspect woman with increased IOP but normal optic disc. *a.* Normal visual field during conventional perimetry with MD of 1.4dB. *b.* Fundus perimetry demonstrated reduced light sensitivity of 7dB or more at three points located near the inferior optic disc margin during our 30-point test. Open rectangles represent thresholds better than age-corrected normal values, while filled rectangles represent defects according to the scale on the right in 1dB steps.

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Fig. 3. Right eye of a 66-year-old glaucoma suspect woman with enlarged disc cupping. *a.* Conventional perimetry shows only slightly decreased thresholds following the superior bundle with MD of 0.7dB. *b.* Fundus perimetry revealed a more pronounced visual field defect in the inferior retina (green rectangles) with a deep scotoma during our test at 30 locations. Open rectangles represent thresholds better than age-corrected normal values, while filled rectangles represent defects according to the scale on the right in 1dB steps. *c.* The addition of more test points in the area of the visible nerve fiber bundle defect demonstrates the exact concordance between morphology and function (fundus image obtained using the argon blue laser demonstrates the nerve fiber defect more clearly).

Discussion

The development of automatic static threshold perimetry was a major step towards the early detection of beginning visual field defects and the more reliable follow-up of patients suffering from glaucoma. During recent years, it has been shown that fundus perimetry using the SLO enables an exact correlation between fundus morphology and function[12-16]. Earlier investigations using fundus perimetry in glaucoma patients could not be performed using automated threshold perimetry[17-19]. With our automated threshold software[4] and the help of a database of age-related sensitivity values[11], the detection of beginning visual field defects in the context of glaucoma is now feasible.

Our results indicate that the peripapillary test grid enables visual field defects to be detected in a short examination time (less than six minutes). However, the SLO only allows fundus perimetry within a central field of 33 × 21° in diameter. This would seem to be in contrast to the obvious beginning of glaucomatous visual field defects in the periphery. However, with this new technique, fixation loss does not influence the examination[8]. Therefore, the threshold values are more reliable and peripapillary damage may be detected earlier compared to conventional cupola perimetry. The finding of peripapillary depressions in glaucomatous eyes could be explained by morphological changes which may, later on, lead to parapapillary choroidal or so-called 'halo glaucomatous' atrophy. These morphological alterations typically precede enlargement of the blind spot during perimetry[10]. More recently, it was noted that there is a peripapillary depression in eyes with even beginning glaucomatous alteration[9,18]. In another study using fundus perimetry with the SLO, it was speculated that the size of the blind spot might depend on the topography of the optic nerve head, due to the influence of light scattering during stimulus presentation[20]. Because the SLO uses monochromatic red light for stimulus presentation, light scattering should be reduced compared to the white light used during conventional perimetry[4]. We did not observe that the area of the physiological scotoma surrounding the optic disc extended the disc area by more than one degree, using either static or kinetic fundus perimetry in normal eyes (unpublished data). Because there has been controversy about the enlargement of the blind spot in glaucomatous eyes in the past[21-23], further investigations are necessary.

Since the additional option of argon blue laser imaging allows the documentation of visible nerve fiber damage[24,25], there is the option to add test point locations, especially at these locations (Figs. 2 and 3). This could simplify the early detection of beginning field defects. As reported earlier[19], we could also demonstrate the exact correlation between visible nerve fiber defects and corresponding field defects (Figs. 2 and 3). In contrast to the former investigations, we are now able to perform automated threshold perimetry that leads to significantly reduced examination times, even for a complete 4-2-1dB staircase strategy[4,8]. Due to knowledge on age-corrected sensitivity values, we can detect functional damage when the threshold is reduced by more than 4dB[11]. In our opinion, visual fields obtained during fundus perimetry with the peripapillary grid with two or more defects of 7dB or higher, are pathological. The difficulty in showing the extension of bundle defects towards the blind spot seems to be the result of fixation instability and concordant deviation of the projection of numerous stimulus intensities of the same test point location at different places on the fundus. Nevertheless, fine grid cupola perimetry may also allow the detection of beginning field defects, but with the drawback of longer examination times.

Our results indicate that this test grid using fundus perimetry, may perhaps serve as a screening method with a significantly reduced examination time compared to conventional perimetry. Further studies with larger numbers of patients are necessary to prove these results. Nevertheless, we could demonstrate early field defects in three patients in whom conventional perimetry using the Octopus did not reveal glaucomatous damage or showed only beginning depressions (Figs. 3 and 4). Although pupil dilation might be a disadvantage, especially for a screening method, additional clinical examinations, including fundus examination and fundus photography or laser scanning tomography, will also need this dilation.

In conclusion, static threshold fundus perimetry may be helpful, not only in patients suffering from morphological alterations in the macular area, but also with beginning field defects or missing fundus changes. Even when only two stimulus locations show a depression of 7dB or more, functional damage can be assumed. Examination times of about five minutes are acceptable.

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