Clinical evaluation of a multi-fixation campimeter for the detection of glaucomatous visual field loss

Erkan Mutlukan, Bertil E Damato, Jeffrey L Jay

Abstract

The multi-fixation glaucoma screening chart, which uses the oculokinetic perimetry (OKP) technique, is a hand-held tangent screen with a central black test stimulus on a white background and a series of 26 numbered fixation targets arranged around the stimulus at various locations. When the numbers on the chart are read by the patient from 40 cm distance, the test stimulus passes through the relevant parts of the central visual field which are most vulnerable to glaucomatous damage. The test is positive (that is, abnormal) if at least one fixation number is associated with consistent disappearance of the stimulus. The OKP test was performed in 222 eyes of 126 glaucoma patients (aged 16-91 years) and 186 right eyes of 186 normal individuals (aged 19-86 years) using a 1.5 mm diameter stimulus. A further 144 eyes of 88 glaucoma patients (aged 60-85 years) and 31 right eyes of 31 normal individuals (aged 60-85 years) were tested with a 3 mm diameter stimulus. All eyes were also tested with conventional perimetry and the results of the conventional perimetry were categorised according to the Aulhorn-Karmeyer classification by four ophthalmologists without any knowledge of the OKP results. When the 1.5 mm stimulus was used, a true positive OKP result was obtained in 45% of eyes with relative scotomas, 81% of eyes with small absolute scotomas separate from the blind spot and 100% of eyes with more severe visual field defects. In the control group, a false positive result was obtained in 1% of the patients under the age of 60 years, 9% of patients aged 60-70 years and 13% of patients older than 70 years. When the 3 mm stimulus was used in the glaucomatous patients above the age of 60 years, the OKP test was positive in 33% of eyes with relative scotomas, 56% of eyes with small absolute scotomas, 80% of eyes with absolute scotomas connected to the blind spot, and 100% of eyes with altitudinal defects. None of the control subjects produced a positive result with a 3 mm stimulus. The OKP glaucoma test may be a useful adjunct to ophthalmoscopy and tonometry when screening for glaucoma in situations which preclude conventional perimetry.

(*Br J Ophthalmol* 1993; 77: 332-338)

The detection of glaucoma in the community is an unresolved problem. Most glaucoma sufferers are recognised only when advanced visual field loss with absolute defects has occurred while most people referred with suspected glaucoma do not have this disease.¹⁻³ This unsatisfactory situation exists because of the asymptomatic onset of chronic forms of glaucoma, the low

prevalence of the disease, and the limitations of tonometry and ophthalmoscopy.⁴⁻⁸ It has been suggested that visual field examination may be a useful method of screening for glaucoma, but conventional techniques are difficult and expensive.⁹⁻¹² As a result perimetry is usually omitted as a first line investigation in the community even when a glaucoma suspect is to be referred to an ophthalmologist.^{13,14}

A simple and inexpensive method of examining the visual field has been developed, which uses movements of the patient's eye to position a static test stimulus in the visual field (that is, oculokinetic perimetry, OKP).¹⁵ This examination is performed with a 'multi-fixation campimeter', which is a white tangent screen having a central, black test stimulus and a series of numbered fixation targets located peripherally at strategic points. When the patient looks at each number in turn from the correct distance, the stimulus is accurately positioned at known points in the visual field. Numbers associated with disappearance of the stimulus are recorded by crossing out the same numbers on a miniature version of the chart so that a plot of the defects is obtained. At the end of the examination, the record sheet is inverted so that the results are comparable with those obtained conventionally.

The general purpose chart, which tests 100 points in the central 25 degree field, has been shown to yield similar results to conventional manual perimetry.¹⁶ Despite its simplicity, however, it was not suitable for screening purposes because it was considered by non-ophthalmologists to be too laborious, taking about 7 minutes per eye (B E Damato, unpublished data). An abbreviated test was therefore developed specifically for the detection of glaucoma. This was done by comparing the results obtained in 50 glaucomatous eyes with those obtained in an age-matched sample of controls.¹⁷ As with other studies, the most informative points were located at 12-15 degrees from fixation, especially in the superior and inferonasal parts of the field. A preliminary evaluation of a hand-held chart provided encouraging results, but problems arose when a ribbon was used to maintain the correct working distance.¹⁸ In addition, the patients tended to read the numbers too quickly so that defects were missed. These problems have been remedied by (i) attaching an eye occluder to the chart by means of a rigid side-arm, (ii) increasing the number of fixation targets to slow down the eye movements, and (iii) considering the test result to be positive only if any number was consistently associated with disappearance of the stimulus on repeated examination.

The main aim of this study was to evaluate the sensitivity and specificity of an improved

Tennent Institute of Ophthalmology, University of Glasgow, 38 Church Street, Glasgow G11 6NT
E Mutlukan
B E Damato
J L Jay

Correspondence to:
Dr Erkan Mutlukan.

Accepted for publication
27 November 1992

glaucoma visual field screening chart with a 1.5/400 mm black stimulus. When the results of this investigation were obtained, the study was extended to establish the effect of using a larger test stimulus (that is, 3/400 mm).

Materials and methods

The hand-held device consisted of a white card (29.5 cm × 42.0 cm), with a campimeter on each side, for the examination of the left or right eye respectively, and a black eye occluder fitted to the lateral edge of the card by means of a rigid arm (Fig 1). This side-arm ensured that the correct side of the card was presented to the eye and that the card was held at the proper distance (40 cm). In the first part of the study, the stimulus was a 1.5 mm diameter black spot (1.8 mm²). This subtended a visual angle of 0.2 degrees, and was known to have a normal 'isoptre' of approximately 20 degrees in keeping with recommendations for the detection of glaucoma using a white stimulus on a black tangent screen. In the second phase of the study, a 3.0 mm diameter stimulus was used (7.1 mm²), which subtended a visual angle of 0.4 degrees. The first fixation target consisted of the letter 'L' or 'R', depending on the eye being examined, and tested the left or right blind spot respectively. The 26 numbered fixation targets spiralled towards the centre of the chart to examine the field at 12.5 degrees superiorly, 15 degrees nasally and inferiorly, and at additional points more centrally.

These fixation targets were coloured light blue so that the patient would not confuse them with the central black test stimulus. A set of instructions was printed adjacent to each test grid, for the benefit of unaccompanied patients and in expert examiners. These advised the patient to look at each fixation target for about 1 second and stated that the test result was abnormal if any

numbers consistently made the black spot disappear and recommended full ocular examination using standard methods if a defect was suspected.

The oculokinetic perimetry (OKP) was performed under good illumination (photopic level, 100–150 lux with 0.2 log unit variation). During the OKP test, the right eye was examined first, with appropriate correction for presbyopia, if necessary. If the edge of the bifocal segment interfered with the examination, the patient was advised to tilt the head backwards or forwards to move the chart into the central part of the near segment. All examinations were performed under supervision, with the stimulus left constantly exposed. If any numbers were reported by the patient to be associated with disappearance of the stimulus, these were deleted on the record sheet by the examiner and the eye was re-examined. This was done without comment by the examiner so as to avoid bias.

Suprathreshold conventional perimetry was performed with three zone quantification (normal, relative, or absolute field loss) before or after the OKP, by an optometrist using either the Friedmann visual field analyser, Dicon 3000 Autoperimeter, Tubingen perimeter or Henson visual field analyser. These perimeters have the same maximum stimulus brightness (1000 Apostilb) and the criterion of a relative or absolute defect is uniform between different devices. Despite the fact that suprathreshold static perimetry with single and multiple stimuli and suprathreshold kinetic perimetry represent different types of testing with major instrument design differences and non-identical response properties, they all give similar results in the detection of visual field loss.^{19,20} The depth of all detected glaucomatous visual field defects is the same with similar topographical distribution when quantified with single kinetic and multiple static stimuli.^{21,22} The results of the conventional

Figure 1 The test grid of improved version of hand-held oculokinetic perimetry (OKP) glaucoma screening chart which has 26 numbers distributed in a spiral fashion in relation to a central black test stimulus. A rigid side-arm ensures that the correct eye is tested at a proper test distance. Instructions are printed on one side of the test grid for the benefit of patients who may need to perform the test without supervision.

Figure 2 Sensitivity of OKP test according to severity of glaucomatous visual field loss (A) in all eyes, (B) in patients categorised according to their worse eye. Severity of visual field defects (Aulhorn-Karmeyer classification): stage 0=no defect; stage 1=relative defect only; stage 2=small absolute scotoma(s) not connected to the blind spot; stage 3=larger absolute scotoma connected to the blind spot; stage 4=absolute hemifield defect.

Figure 4 False positive OKP results in (A) healthy controls, and (B) and glaucoma suspect eyes according to age groups.

perimetry were categorised independently according to the Aulhorn-Karmeyer classification²³ by three ophthalmologists and an optometrist without knowledge of the OKP results and a mean score was calculated for each eye. Although the Aulhorn-Karmeyer classification originally referred to kinetic perimetry, it can also be applied to static perimetry because of the above described similarities between results from both methods.

The perimetrically experienced patients were selected from a hospital glaucoma clinic. The controls consisted of spouses and friends escorting the patients to the clinic as well as hospital workers and patients attending a nearby refraction clinic. In the control group only the right eye was examined. In both groups, individuals were excluded if they appeared to be very frail and eyes were tested only if the visual acuity was 6/18 or better and if there was no other ocular disease.

Figure 3 Sensitivity of OKP test in different age groups. Positive test result rate increases with age.

Results

THE 1.5 MM STIMULUS

Oculokinetic perimetry was performed on 222 eyes (116 right, 106 left) of 126 individuals (68 male, 58 female; aged 16–91 years, mean 66.4 years) attending the glaucoma clinic with known or suspected glaucoma in one or both eyes. All patients were able to complete the test. Figure 2A shows the proportion of eyes missing at least one point, according to the severity of glaucomatous visual field loss. The OKP test was positive in 45% of eyes with only relative visual field loss (stage 1), 81% of eyes with small absolute scotomas separate from the blind spot (stage 2), and 100% of eyes with more extensive absolute visual field defects connected to the blind spot (stages 3 and 4). When the results were categorised according to the severity of field loss in the worse eye, the multifixation campimeter result was positive in 51% of patients with only relative field loss, 86% of patients with small absolute defects, and 100% of patients with large absolute defects extending to the blind spot (Fig 2B). Figure 3 shows the results according to age groups.

A subgroup of 95 eyes of 66 patients attending the glaucoma clinic had no evidence of glaucomatous visual field loss in one or both eyes on conventional perimetry. These eyes had ocular hypertension and/or abnormal optic disc appearances or definite glaucoma in the fellow eye. In this group, an abnormal OKP result occurred in 24% of eyes and was more common in patients older than 60 years of age (8% vs 30%; $p < 0.01$, χ^2 test) (Fig 4B) and in eyes with a visual acuity of less than 6/6 (6.4% vs 41.7%; $p < 0.01$, χ^2 test) (Fig 5).

The cumulative sensitivity of the points examined by the multifixation campimeter with 1.5 mm stimulus showed that the most informative parts of the test array were situated 12.5 degrees superotemporally and 15 degrees superonasally, nasally, and inferonasally (Fig 6).

Figure 5 The effect of low visual acuity on OKP test result. The number of positive results increases significantly with decreasing visual acuity.

The first 17 numbers on the chart detected all OKP positive cases.

There were 38 eyes (30%) with a glaucomatous visual field defect which was missed with OKP (Table 1). In four eyes the depth of the relative scotoma was less than 5 dB and would not universally be regarded as unequivocal field loss.^{11,24} In 26 eyes the field loss was relative and deeper than 4 dB in the central 15 degrees. Two eyes had small absolute scotomas within the 15 degrees, which were missed because they were situated in between the points examined by the OKP chart. In a further six eyes, the visual field defects were more than 15 degrees from fixation. The location and the extent of these field defects are described in Figure 7.

A total of 189 controls (83 male, 106 female; aged 19–86) were examined. Three patients were found to have unequivocal visual field loss on conventional perimetry and were excluded from the study. The results were considered according to age groups and are summarised in Figure 4A. The false positive result rate was 1% in patients under the age of 60 years, 9% between the ages of 60–70 years, and 13% over the age of 70 years.

THE 3.0 MM STIMULUS

In the second phase of the study, the OKP test

Figure 6 Cumulative sensitivities of test points on the oculokinetic perimetry glaucoma screening chart (shown as left eye). All positive cases were detected by the first 17 points.

Table 1 The distribution of oculokinetic perimetry results which were considered false negative according to the referees' clinical classification of conventional perimetry results

	Stage	No of eyes
Borderline loss (depth <0.5 log)	'1'	4
Central loss (depth >0.4 log)	1	26
	2	2
Peripheral loss (eccentricity >15 deg)	1	4
	2	2
Total		38

was performed with a 3 mm stimulus to determine whether the specificity could be improved without a significant reduction in sensitivity.

The OKP test was performed on 144 glaucoma eyes (73 right, 71 left) of 88 patients (35 female, 53 male; aged 60–85 years, mean 70 years), and 31 right eyes of 31 normal individuals (15 female, 16 male; aged 60–85 years, mean 70 years). The patients and healthy volunteers in this part of the study were different from those examined with a 1–5 mm stimulus. In the sample of abnormal eyes, the OKP test result was abnormal in 33% of eyes with relative defects only (stage 1), 56% of eyes with absolute scotomas separate from the blind spot (stage 2), 80% of eyes with arcuate defects extending to the blindspot (stage 3), and all eyes with altitudinal defects (stage 4) (Fig 8B). None of the 13 'glaucoma suspect' eyes of 13 patients produced an abnormal OKP result. None of the control cases produced a false positive OKP test result. The relationship between the sensitivity of the OKP glaucoma screening test and stimulus surface area in patients over the age 60 years is shown in Figure 9.

Discussion

When testing the visual field, the examination should always be as sensitive as possible. However, it is important to adapt the examination strategy and the sensitivity according to circumstances such as the patient's level of cooperation, the time available, and the expertise of the examiner. When, for example, a highly cooperative glaucoma suspect with a raised intraocular pressure is being examined for glaucomatous visual field loss, it would be ideal if automated threshold static perimetry was performed. However, when examining an uncooperative patient or when large numbers of apparently healthy individuals are being screened randomly by non-specialists in the community, such exquisite sensitivity cannot be achieved. This is because the automated threshold perimetry would be too difficult and laborious for many patients and too time consuming and expensive for the examiner.^{25–29} Additionally, highly sensitive perimetry would detect many people with subtle defects caused by various conditions such as refractive errors, media opacities, and such individuals would unnecessarily be referred for specialist opinion. Without deviating from the fundamental principle of striving for maximum sensitivity, it is, therefore, necessary to make compromises if screening for glaucomatous visual field loss is to become routine practice in the community. Despite the availability of tono-

Figure 7 The location and extent of glaucomatous field defects missed by multi-fixation campimetry outside central 15 degrees in six eyes with relative and absolute defects, and inside 15 degrees (test area) in two eyes with absolute defects. Each point belongs to one eye and according to the size of the scotoma, more than one point may belong to the same eye.

metry and ophthalmoscopy, there is evidence that many, perhaps most, glaucoma sufferers are still not being detected until they have developed dense visual field defects extending close to fixation.^{1-3 30} Further research is required to establish whether or not such individuals could be detected sooner than at present and with greater cost efficiency by the large scale application of simple visual field tests that are designed to detect only dense visual field loss. Such studies have hitherto been hampered by the lack of perimetric methods that could widely be used by non-specialists.

The purpose of the OKP glaucoma chart is to enable non-specialists to examine for the presence of glaucomatous visual field loss in the

Figure 8 Sensitivity of OKP glaucoma screening test according to severity of glaucomatous visual field loss above the 60 years of age (A) with 1.5 mm diameter stimulus, and (B) 3 mm diameter stimulus.

Figure 9 The relationship between the oculokinetic perimetry glaucoma screening chart stimulus size (area) and positive result rate according to severity of glaucomatous visual field loss.

community. Initially, an attempt was made to encourage the use of a 100 point chart for this purpose. However, although the chart was inexpensive and the examination simple, such workers considered the examination time of approximately 7 minutes to be excessive and were reluctant to assume responsibility for the proper selection of test stimuli and for the interpretation of results (D Sheldon, B E Damato, and others; unpublished data). Further studies indicated that non-specialists also preferred a portable hand-held version of the chart to a desk-top device, for reasons of space and time (E Mutlukan, and B E Damato, unpublished data). It is for these reasons that the hand-held glaucoma chart was developed with only 26 test locations and a simple 'positive-negative' type of result.

The findings of the present study suggest that when a 1.5 mm stimulus is used, the 26 number OKP chart does indeed detect large, dense areas of visual field loss within the central 15 degree field, with a false positive result of about 10% in apparently healthy individuals in the seventh decade of life. Such results are similar to those predicted in previous studies.^{17 18} The false positive rate diminishes to a low level of approximately 1% when the diameter of the stimulus is increased to 3 mm, but at the cost of missing eyes with only relative glaucomatous visual field defects. There are two main conclusions to be drawn from such results. Firstly, the OKP glaucoma screening chart should be used only in combination with ophthalmoscopy and tonometry, if possible, and not as a substitute for these tests. Secondly, it would seem useful to vary the size of the stimulus according to the age and visual acuity of the patient (Table 2). Whether or not the test is universally useful cannot be concluded from the present investigation and will depend on the circumstances in which it is applied and the way in which patients are managed when a positive result is obtained. Additionally, oculokinetic perimetry is user

Table 2 The suggested oculokinetic perimetry stimuli for different age and visual acuity levels

Age (years)	Visual acuity		
	>6/9	6/9	<6/9
<60	1	1.5	2
60-70	1.5	2	2.5
>70	2	2.5	3

dependent, despite its simplicity, so that the results vary according to the examination technique. Further studies are therefore indicated in a variety of situations.

This study has led to a number of revisions in the design of the OKP chart. This has three interchangeable stimuli which are 1 mm, 2 mm, and 3 mm in diameter, which could be selected according to the visual acuity and the age of the patient in order to improve the ratio between sensitivity and specificity. The visibility of a dark stimulus on a bright background is more constant under variable lighting conditions than a reflective light stimulus on a dark background.^{31,32} A black stimulus is therefore preferable for the OKP glaucoma test, which is intended for use in the community, where standardisation of the ambient illumination is impractical. It is tempting to vary the contrast instead of the size, but as with white stimuli, grey stimuli would require the illumination to be carefully standardised. Peripheral contrast sensitivity is known to be reduced in glaucoma,³³ and preliminary studies suggest that dark on bright stimuli may detect defects which are missed by conventional luminous stimuli.^{31,34-37} In the present study, the discrepancy between the results of the OKP glaucoma test and conventional perimetry in the 'glaucoma suspect' eyes may partly be due to this factor, but probably reflects the false negative results with the conventional manual perimetry and false positive results with the OKP test caused by reduced visual acuity. Such problems may not have occurred if automated threshold perimetry had been used instead of automated suprathreshold and manual perimetry. However, this would have resulted in a biased sample of patients, because it is known that many individuals are not cooperative enough for automated threshold perimetry. In any case, the OKP chart under investigation was designed to detect dense visual field loss which was readily identified with the conventional perimeters used in the study.

The introduction of interchangeable stimuli allows the visual field to be examined to 25–30 degrees with the hand-held chart. This change inevitably increases the number of fixation targets from 26 to 60 but has the advantage of making the hand-held chart useful not only for glaucoma detection but also for other purposes. In the new version of the chart, the sequence of the numbers is reversed, so that they spiral outwards instead of inwards, thereby making it easier for the examiner to decide whether to examine only the central 15 degrees or the central 25 degrees of the visual field from fixation.

The current strategy for testing the blind spot is designed to help the patient to position the chart correctly, to understand the principle of the examination and, in addition, to help the examiner to assess the patient's reliability. A more efficient method of achieving these objectives, however, might be for the blind spot to be discovered by the patient in exactly the same way as abnormal scotomas are detected, using numbered fixation targets.³⁸ Accordingly, the revised version of the chart is designed so as to test the blind spot three times. This strategy makes it easier for the examiner to decide

whether it is safe to leave the stimulus constantly exposed or whether to cover and uncover the stimulus with a white card with the patient indicating when the stimulus appears and disappears.

In the present study, the result was considered abnormal only if any points were consistently missed when the examination was repeated. However, we have shown that such criteria result in small relative defects being missed; a better method of confirming the presence of a defect would be to cover and uncover the test stimulus as described above. It has been suggested that OKP may give spurious results because of the Troxler phenomenon when the stimulus is left constantly exposed.³⁹ Although this should not happen when the patient looks at each number for only 1 second, as currently recommended, the possibility of false positive results is reduced even further when the stimulus is made to appear and disappear, so that this precaution should be taken routinely when an abnormal result is suspected.

In conclusion, this study gives an indication of the results that can be expected in different age groups with the 26 number OKP glaucoma screening chart. The investigation has also enabled several revisions for the chart to be made, which should increase the scope of the test in situations where conventional perimetry is not possible.

We are grateful to Dr G N Dutton and Miss E McClure for their help with the categorisation of the conventional visual field results, to Mr R R Stevenson and his students for control subjects, to Mr I Ramsden for the artwork of the OKP glaucoma screening chart, and to Mr J McCormack for the photograph. This study was supported financially by the International Glaucoma Association; The Royal National Institute for the Blind; Merck, Sharp and Dohme/Chibret International, and W H Ross Foundation for the Prevention of Blindness (Scotland).

- Harrison RJ, Wild JM, Hobley AJ. Referral patterns to an ophthalmic outpatient clinic by general practitioners and ophthalmic opticians and the role of these professionals in screening for ocular disease. *BMJ* 1988; 297: 1162–7.
- Clearkin L, Harcourt B. Referral pattern of true and suspected glaucoma to an ophthalmic outpatient clinic. *Eye* 1983; 103: 284–7.
- Elkington AR, Lewry J, MacKean J, Sargent P. A collaborative hospital glaucoma survey. *Res Clin Forums* 1982; 4: 31–40.
- Eddy DM, Sanders LE, Eddy J. The value of screening for glaucoma with tonometry. *Surv Ophthalmol* 1983; 28: 194–205.
- Bengtsson B. The variation and co-variation of cup and disc diameters. *Acta Ophthalmol* 1976; 54: 804–18.
- Bengtsson B. The alteration and asymmetry of cup and disc diameters. *Acta Ophthalmol* 1980; 58: 726–32.
- Klein BEK, Moss SE, Magli YL, Klein R, Johnson JC, Roth H. Optic disc cupping as clinically estimated from photographs. *Ophthalmology* 1987; 94: 1481–3.
- Jonas JB, Fernandez MC, Naumann GOH. Glaucomatous optic nerve atrophy in small discs with low cup-to-disc ratios. *Ophthalmology* 1990; 97: 1211–5.
- Trobe JD, Acosta PC, Shuster JJ, Krischer JP. An evaluation of the accuracy of community based perimetry. *Am J Ophthalmol* 1980; 90: 654–60.
- Rabin S, Kolesar P, Podos SM, Wilensky JT. A visual field screening protocol for glaucoma. *Am J Ophthalmol* 1981; 92: 530–5.
- Enger C, Sommer A. Recognising glaucomatous visual field loss with the Humphrey STATPAC. *Arch Ophthalmol* 1987; 105: 1355–7.
- Bickler-Bluth M, Trick GL, Kolker AE, Cooper DG. Assessing the utility of reliability indices for automated visual fields. *Ophthalmology* 1989; 96: 616–9.
- Tuck M, Crick R. Testing and referral for chronic glaucoma. *Health Trends* 1989; 21: 131–4.
- Tuck M, Crick R. Efficiency of referral for suspected glaucoma. *BMJ* 1991; 302: 998–1000.
- Damato BE. Oculo-kinetic perimetry: a simple visual field test for use in the community. *Br J Ophthalmol* 1985; 69: 927–31.
- Alvarez E, Damato BE, Jay JL, McClure E. Comparative evaluation of oculo-kinetic perimetry and conventional perimetry in glaucoma. *Br J Ophthalmol* 1988; 72: 258–62.
- Damato BE, Ahmed D, Allan E, Jay JL. The detection of glaucomatous visual field defects by oculo-kinetic perimetry: which points are best for screening? *Eye* 1989; 3: 727–31.

- 18 Damato BE, Chyla J, McClure E, Jay JL. A hand-held OKP chart for the screening of glaucoma: preliminary evaluation. *Eye* 1990; 4: 632-7.
- 19 Keltner JL, Johnson CA, Balestrery FG. Suprathreshold static perimetry. *Arch Ophthalmol* 1979; 97: 260-72.
- 20 Batko KA, Anctil J, Anderson DR. Detecting glaucomatous damage with the Friedmann analyser compared with the Goldmann perimeter and evaluation of stereoscopic photographs of the optic disc. *Am J Ophthalmol* 1983; 95: 435-47.
- 21 Hicks BC, Anderson DR. Quantitation of glaucomatous visual field defects with the mark II Friedmann analyser. *Am J Ophthalmol* 1983; 95: 692-700.
- 22 Sponsel WE. Visual field quantification in the diagnosis and assessment of chronic open angle glaucoma. MD Thesis, University of Bristol, 1985.
- 23 Aulhorn E, Karmeyer H. Frequency distribution in early glaucomatous visual field defects. *Doc Ophthalmol Proc Ser* 1977; 14: 75-83.
- 24 Parrish RK, Schiffman J, Anderson DR. Static and kinetic visual field testing. *Arch Ophthalmol* 1984; 102: 1497-1502.
- 25 Sommer A, Duggan C, Auer C, Abbey H. Analytic approaches to the interpretation of automated threshold perimetric data for the diagnosis of early glaucoma. *Trans Am Ophthalmol Soc* 1985; 83: 250-67.
- 26 Wilensky JT, Joondeph BC. Variation in visual field measurements with an automated perimeter. *Am J Ophthalmol* 1984; 97: 328-31.
- 27 Heijl A, Drance SM, Douglas GR. Automated perimetry (Competer): ability to detect early glaucomatous field defects. *Arch Ophthalmol* 1980; 98: 1560-3.
- 28 Duggan C, Sommer A, Auer C, Burkhard K. Automated differential threshold perimetry for detecting glaucomatous visual field loss. *Am J Ophthalmol* 1985; 100: 420-3.
- 29 Heijl A, Drance SM. A clinical comparison of three computerised automated perimeters in the detection of glaucoma defects. *Arch Ophthalmol* 1981; 99: 832-6.
- 30 Jay JL, Allan D. The benefit of early trabeculectomy versus conventional management in primary open angle glaucoma relative to severity of disease. *Eye* 1989; 3: 528-35.
- 31 Mutlukan E. Perimetry with dark stimulus and testing off-centre ganglion cells in glaucoma. Dr Mary Hawthorne Research Essay in Medical Ophthalmology. Glasgow: University of Glasgow, 1991.
- 32 Mutlukan E, Damato BE. The dark perimetric stimulus. *Br J Ophthalmol* 1992; 76: 264-7.
- 33 Falco-Reis F, O'Donoghue E, Buceti R, Hitchings RA, Arden GB. Peripheral contrast sensitivity in glaucoma and ocular hypertension. *Br J Ophthalmol* 1990; 74: 712-6.
- 34 Mutlukan E. Computerised off-pathway testing: the dark stimulus in diagnosis of visual dysfunction. Presented at the Symposium on Ophthalmological Image Processing, The Rank Prize Funds, June 1992, Windermere, England.
- 35 Mutlukan E, Damato BE, McFadzean R, McGarvie J, Evans A. Computer assisted moving eye campimetry in neuro-ophthalmology. Presented at the IXth International Neuro-ophthalmology Symposium, June 1992, Williamsburg, VA, USA.
- 36 Mutlukan E, Bradnam M, Keating D, Damato BE. Visual evoked cortical potential (VECP) recordings with transient bright and dark pattern stimuli: selective On and Off pathway testing? *Doc Ophthalmol* 1992; 80: 171-81.
- 37 Mutlukan E, Damato BE. The visibility threshold for dark perimetric stimulus. *Perimetry Update* 92/93. Amsterdam: Kugler-Ghedini, 1993.
- 38 Mutlukan E, Damato BE, Tavadia S. Clustering of fixation targets in multi-fixation campimetry. *Eye* 1993 (in press).
- 39 de Jong LS, Felijs J, Langerhorst CT, van der Berg TJTP, Greve EL, Spekrijse H. Oculokinetic perimetry compared with standard perimetric threshold testing. *Invest Ophthalmol Vis Sci (Suppl)* 1992; 33: 1386.