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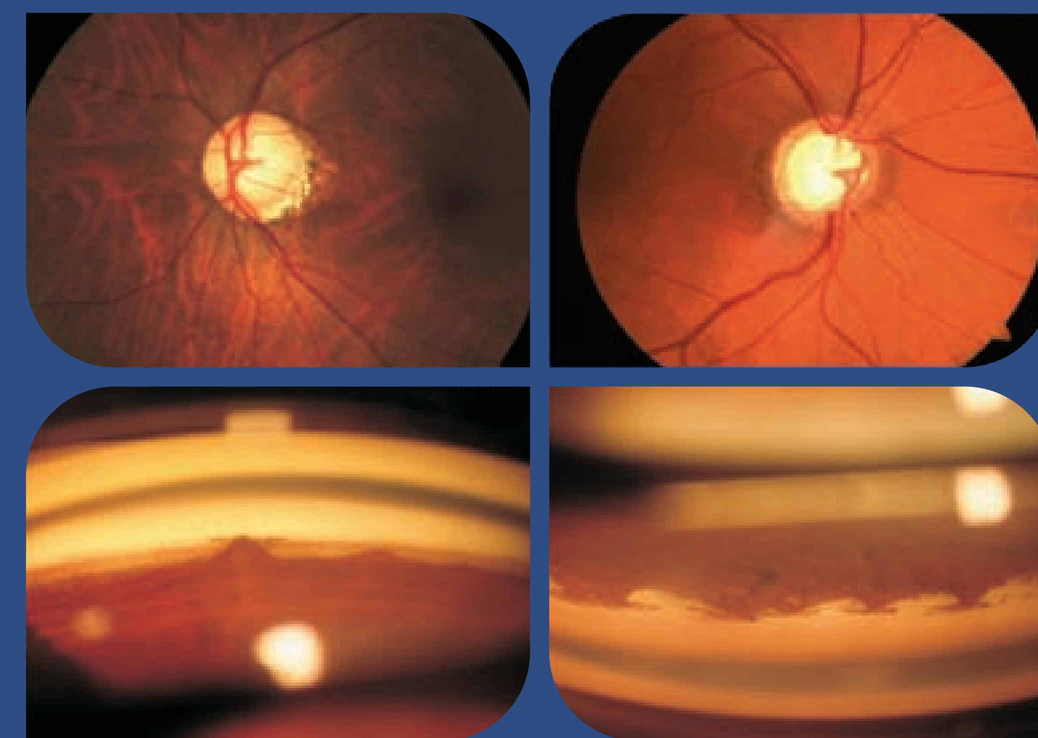
Glaucoma Fundamentals

Editor : Tanuj Dada

ALL INDIA OPHTHALMOLOGICAL SOCIETY

National Post Graduate Education Programme



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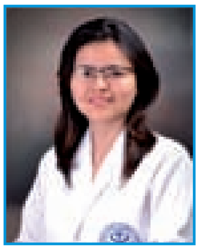

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FOREWORD

Glaucoma , "The Silent Killer" has become the leading cause for blindness in India which is not reversible with medical or surgical therapy. One of the main reasons for this is the delay in diagnosis due to inadequacy of public eye care facilities and the lack of health education on the gravity of the disease. However this problem is compounded by the inadequate training in post graduate medical education in key diagnostic skills such as gonioscopy, optic nerve head evaluation and interpretation of perimetry. Dr. Anita Panda and myself had a discussion with Dr. Tanuj Dada on the creation of a national skill transfer programme for augmentation of basic training in Glaucoma diagnostics and an audio-visual module was created with didatic lectures, video assisted skill transfer followed by hands on training within premises of medical colleges. Two such programmes were conducted on a pilot basis at GR Medical College Gwalior and LLRM Medical College Meerut which were highly appreciated by the residents and attending practitioners. There was a demand to supplement this course with a practical manual to consolidate the knowledge imparted in these workshops which could be kept in the library as a resource material for easy reference.

This manual prepared by Dr Tanuj Dada along with top glaucomatologists of the country provides a unique learning experience for the reader with basic illustrated text, colour atlas of gonio & disc photos, an atlas of visual fields, faculty lectures in the DVD along with video based skill transfer in performing these investigations.

We hope to conduct this programme in each regional institute of ophthalmology and medical colleges to improve the glaucoma training and help fight the challenge of glaucoma blindness.

FROM DARKNESS TO LIGHT

AIOS

तमसो मां ज्योतिर्गमय

Dr Anita Panda
President AIOS

Dr Lalit Verma
Secretary General AIOS

EDITORIAL

Glaucoma is the leading cause for irreversible blindness in the world and in India. It is estimated that currently nearly 70 million people are affected by glaucoma worldwide and 7 million are blind due to glaucoma. In India, nearly 12 million people have glaucoma (this figure is likely to increase to 16 million by 2020). The burden of glaucoma blindness in India is 1.2 million. Treatment for glaucoma is widely available and blindness from glaucoma can be prevented if the disease is detected early and treatment given in time.

However the main challenge in glaucoma facing our country is that nearly 90% of glaucoma in the community is undetected. Since glaucoma is a progressive disease, these high rates of undetected glaucoma translate into significant rates of glaucoma blindness. The other major issue is the poor level of awareness of glaucoma among the public. There is also a need for improving training for ophthalmologists for diagnosing glaucoma as there is a poor diagnostic rate for those who undergo a routine ophthalmic evaluation. I see a number of patients who have been diagnosed to have glaucoma, started on medical treatment without gonioscopy being performed, when the case was actually having primary angle closure, where a simple laser iridotomy should have been performed. On the other hand, patients come to my clinic with unreliable visual fields showing artifacts with a normal optic nerve head who have been put on life long treatment or advised surgery.

When a patient is evaluated in the out patient department, it is critical for the ophthalmologist to evaluate the optic nerve head to detect early changes in the retinal nerve fiber layer and optic nerve head. It is also essential to view the anterior chamber to identify if the patient has primary angle closure disease or an open angle glaucoma. Once there is suspicion of glaucoma, standard automated perimetry should be performed and repeated in case a visual field defect is seen. All of these basic examinations techniques need to be performed atleast on an annual basis in patients suspected to have/ having glaucoma for the rest of their life.

This manual has been published to serve as a basic practical illustrated text on gonioscopy, optic nerve head evaluation and standard automated perimetry, the key techniques for diagnosing and monitoring glaucoma patients. This should be used along with hands on training in the clinic to gain expertise in these diagnostic techniques. A Video DVD accompanies the text which includes skill transfer from experts for practical benefit to the reader. I hope that this publication will help in augmenting the training being imparted and improve the diagnostic skills of the trainee as well as the practicing ophthalmologists to ultimately help in early detection of glaucoma and benefit our patients.

Tanuj Dada

ACKNOWLEDGEMENTS

I would like to thank **Prof. Rajvardhan Azad**, Chief of Dr Rajendra Prasad Centre for Ophthalmic Sciences, All India Institute of Medical Sciences, New Delhi for his constant encouragement and support. We are indeed privileged to have an excellent working environment with the best of clinical and research facilities under his able guidance and leadership.

I would like to express my appreciation for the untiring efforts put in by the torch bearers of the All India Ophthalmological Society, especially Dr. Lalit Verma for the cause of ophthalmic education and glaucoma awareness in the country. I also would like to thank my colleagues Prof. Ramanjit Sihota and Dr. Viney Gupta, who has been instrumental in making the Glaucoma Services at our centre one of the best in the world.

A publication like this one involves hundreds of hours of hard labor and toil, which is put in by the residents of RP Centre. My humble gratitude for some of our exceptional residents who have over the years put in their time and effort for collection of the clinical material presented in this manual - Drs Rajamani Muralidhar, Vivek Dave, Munish Dhawan, Anand Agarwal, Shalini Mohan, Subroto Mandal, Ritu Gadia, Sujith Vengayil, Shveta Jindal , Amit Sobti, Mathew James, Digvijay Singh, Dewang Angmo, Reetika Sharma, Neha Chaturvedi, Bharat Patil, Vishal Arora, Bhaskar Jha, Anubha Rathi, Shikha Gupta, Dhawal Patel, Shreyas Temkar, Amar Poojari, Ritu Shah, Divya Singh, Rohit Aggarwal and Manish Mahabir. A special thanks to Mr Ajay Sharma and Mrs Vijeta who take care of our Glaucoma clinical and research laboratory.

Editor

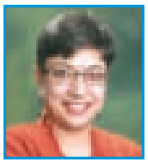
"I long to accomplish a great and noble task, but it is my chief duty to accomplish humble tasks as though they were great and noble. The world is moved along, not only by the mighty shoves of its heroes, but also by the aggregate of the tiny pushes of each honest worker."

Helen Keller

Contents

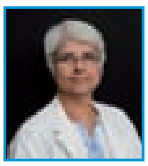
DVD CONTENTS

How to perform Applanation Tonometry
Dr. Manav Deep Singh
Associate Professor, PGIMER, RML Hospital, New Delhi



Tonometry and Pachymetry
Dr. Sushmita Kaushik,
Asssociate Professor, Advanced Eye Centre, PGIMER Chandigarh

Corneal Hysteresis
Dr. Sathi Devi A V
Head Glaucoma Services, Narayana Nethralaya, Bangalore



Gonioscopy Pearls
Dr. Ramanjit Sihota
Professor & Head, Glaucoma Service, RP Centre, New Delhi

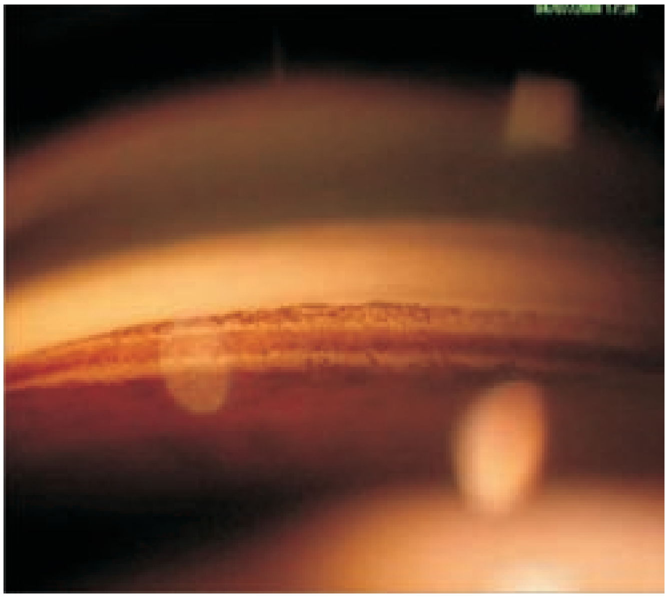
Optic Nerve Head Evaluation
Dr. Parul Ichhpujani
Assistant Professor, Government Medical College, Chandigarh

How to identify (non) glaucomatous cupping
Dr. Gowri J Murthy
Chief Glaucoma Service, Prabha Eye Clinic & Research Centre, Bangalore

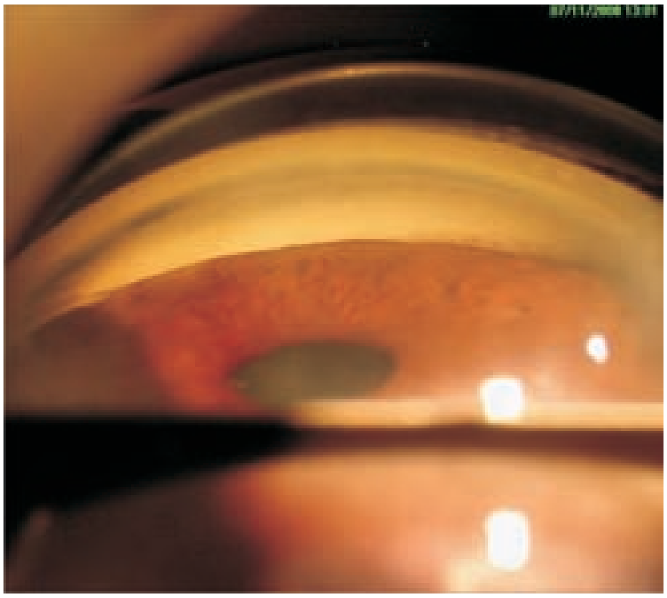
Single Field Analysis
Dr. Murali Ariga
Director and Consultant
Swamy Eye Clinic & Chennai Glaucoma Foundation, Chennai

Visual Field Progression
Dr. Ronnie George
Senior Consultant, Glaucoma Services, Sankara Nethralaya, Chennai

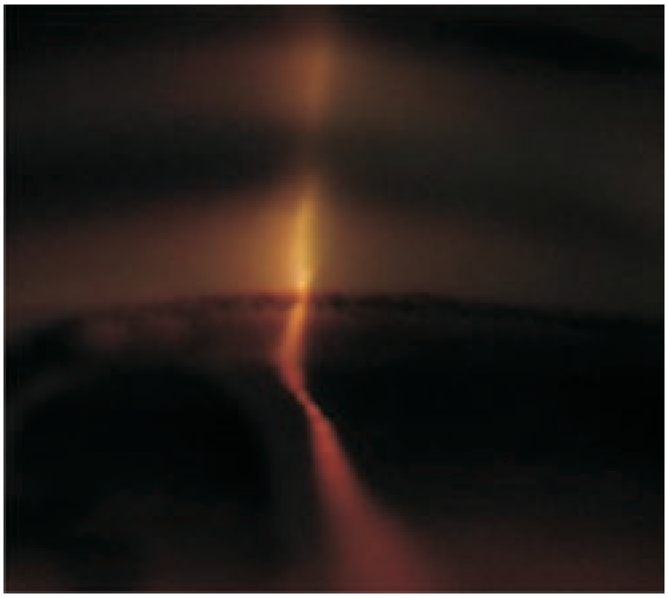
Atlas of Gonio Photographs



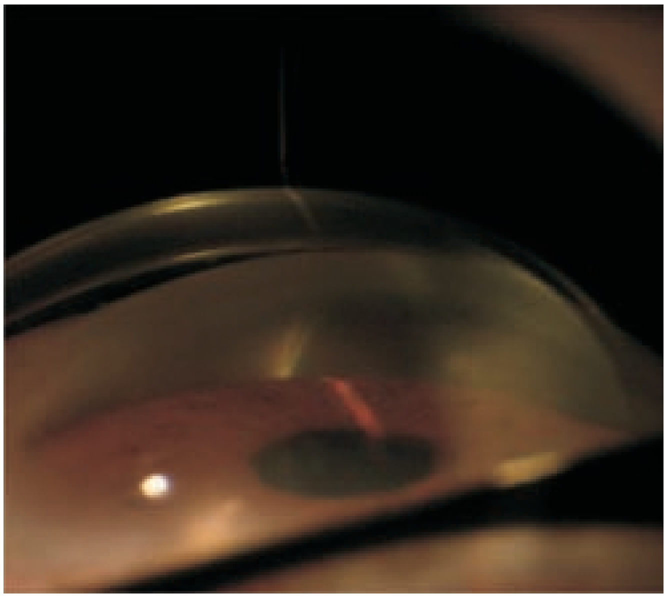
Open angle with view of iris, ciliary body, scleral spur and trabecular meshwork



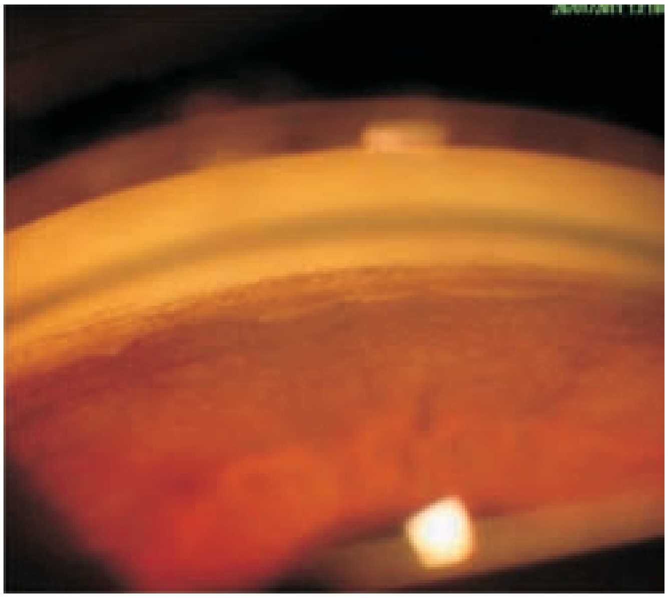
Closed angle with no structure visible between iris and corneal periphery



An open angle, with a continuous beam of light from the iris going upto the angle and the cornea

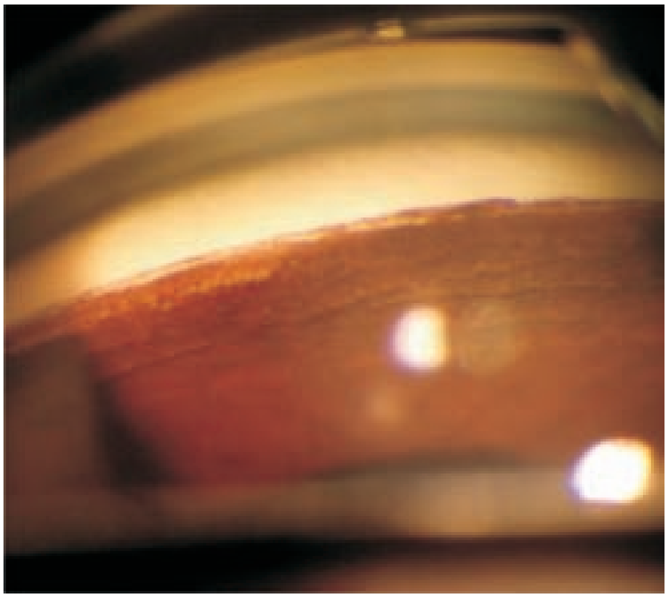


A closed angle - see the parallax between the beam of light on the iris and the one on the cornea

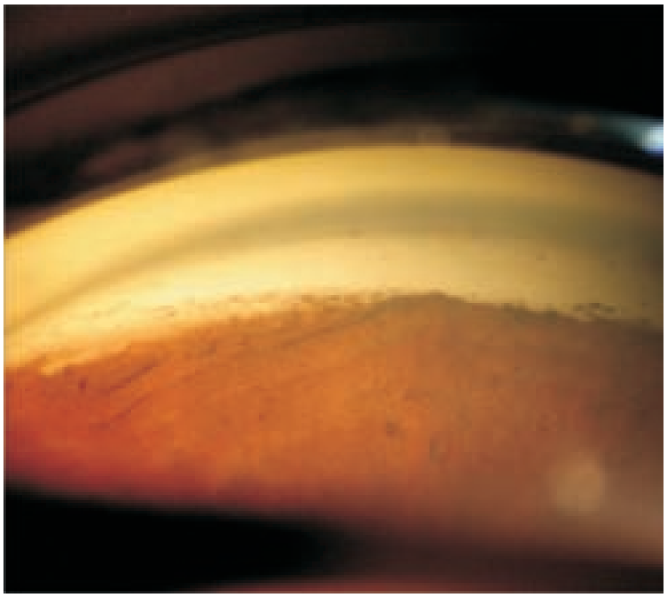


Primary angle closure with pigment clumps of the trabecular meshwork and early synechiae formation

Primary angle closure glaucoma with no angle structures visible and a convex iris configuration

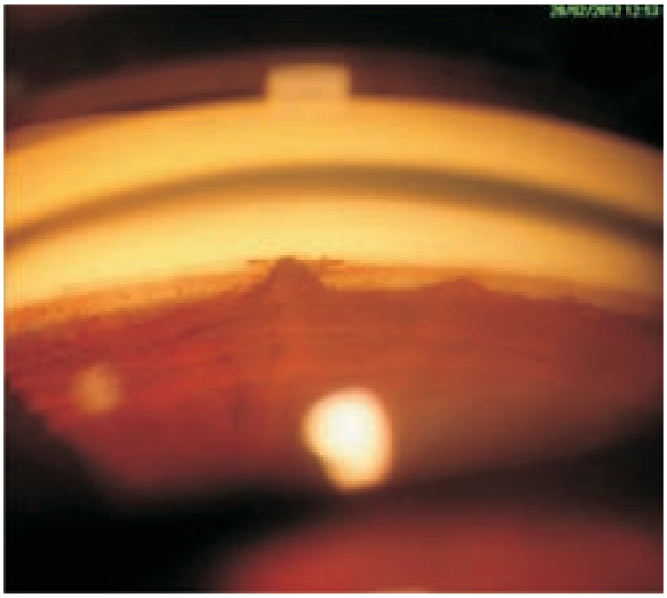


Creeping angle closure with open angle on the left and synechial angle closure on the right half of the angle

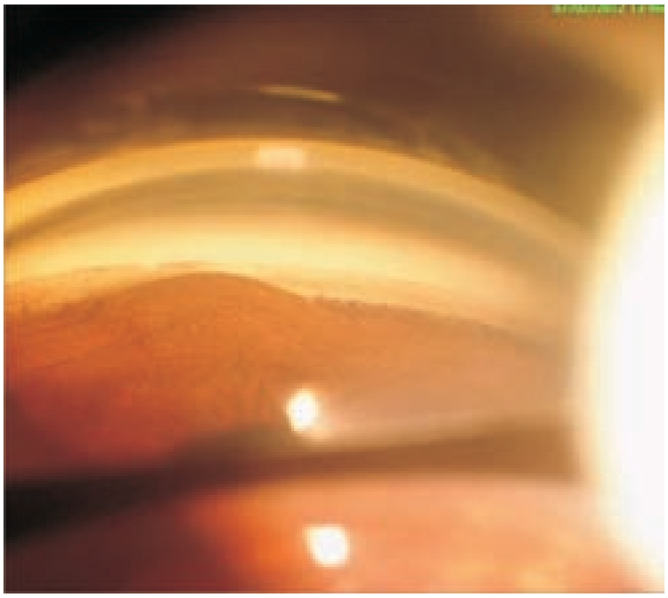


Uveitic glaucoma with large area of broad based synechiae formation with some part of the angle still open

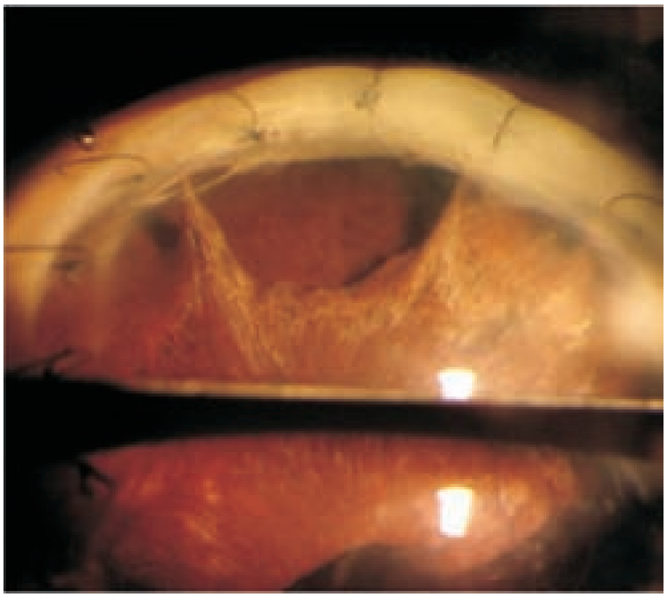
Large adhesion between iris and the trabecular meshwork -Goniosynechiae



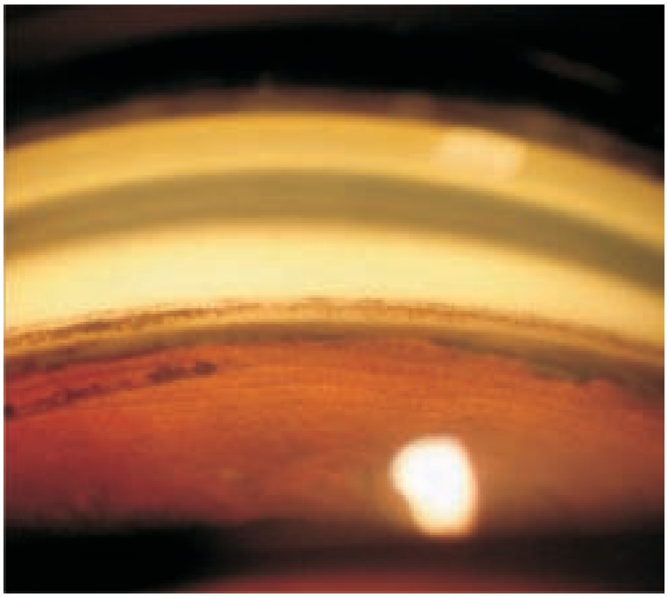
Peripheral anterior syenchiae in inferior angle



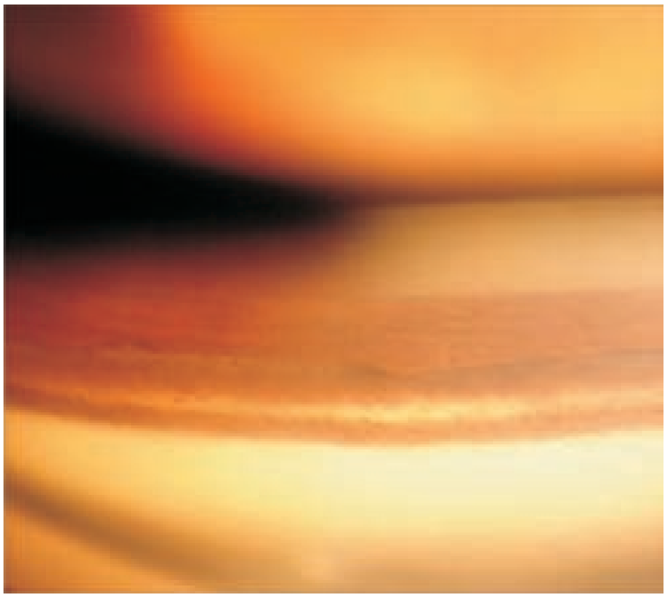
Dome shaped elevation of iris caused by pigment epithelial cyst



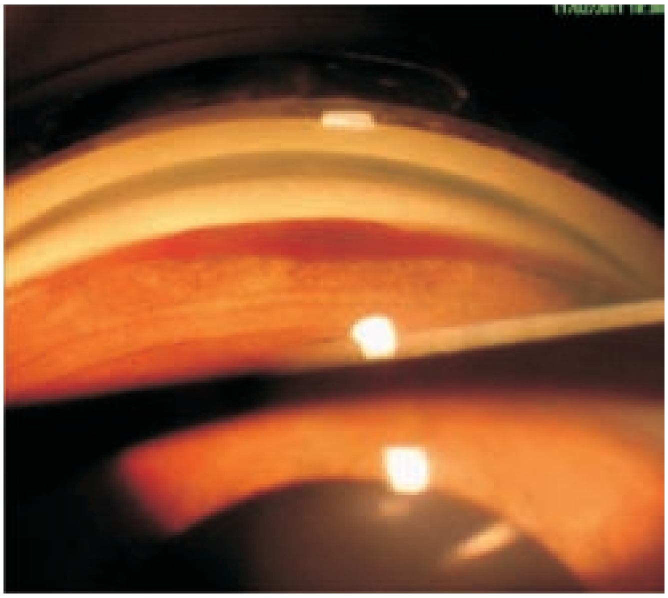
Graft host junctional synechiae in post keratoplasty glaucoma



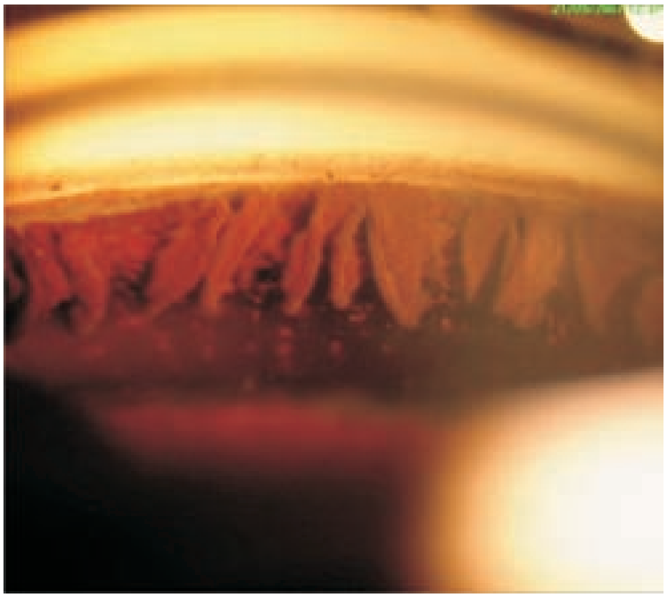
Angle recession with widening of ciliary body band and irregular angle pigmentation



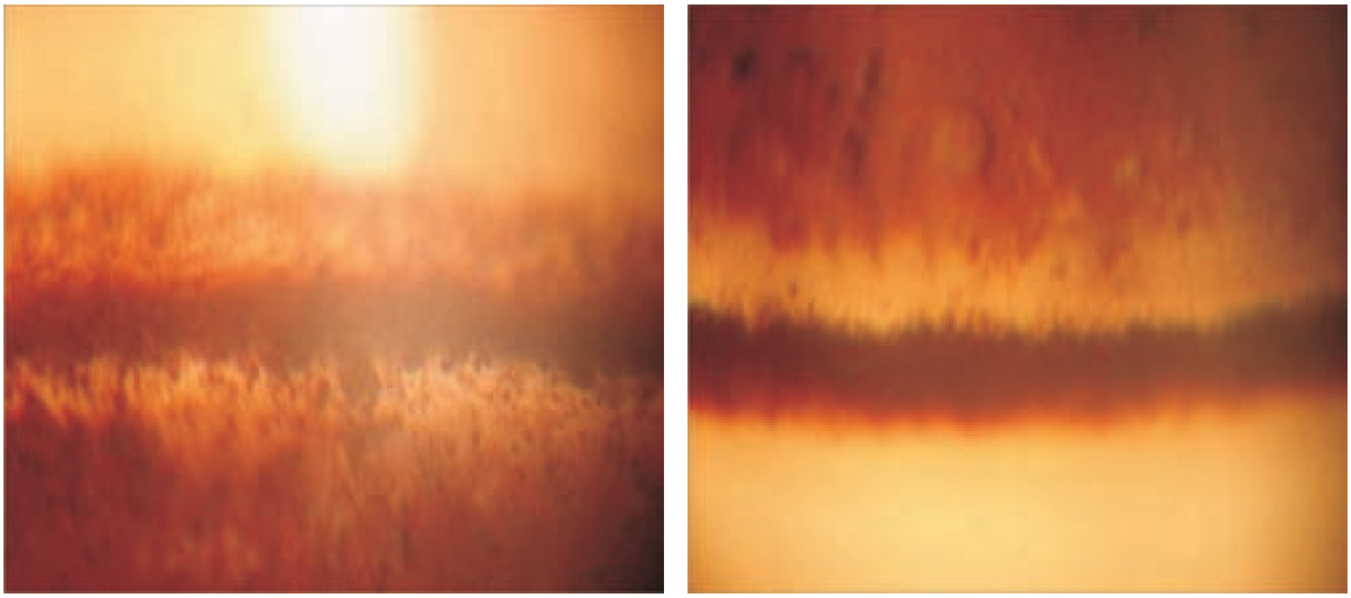
Post traumatic angle recession with wide ciliary body band



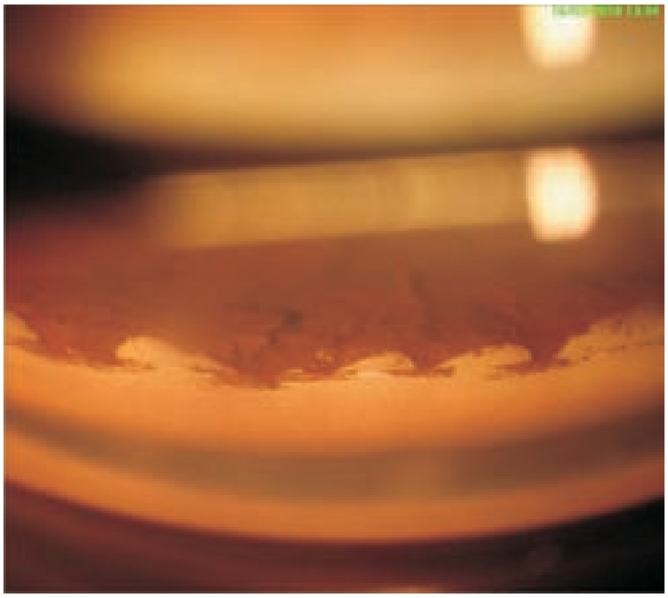
Post traumatic hyphema



Cyclodialysis cleft with ciliary processes visible in an closed globe injury with disinsertion of iris from ciliary body



Pigmentary glaucoma with heavy pigment occluding the trabecular meshwork

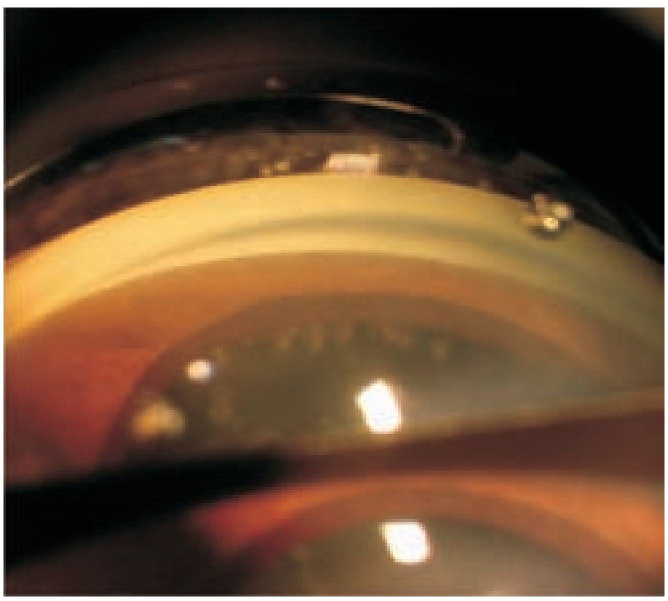


Dense irido-corneal adhesions in anterior segment dysgenesis

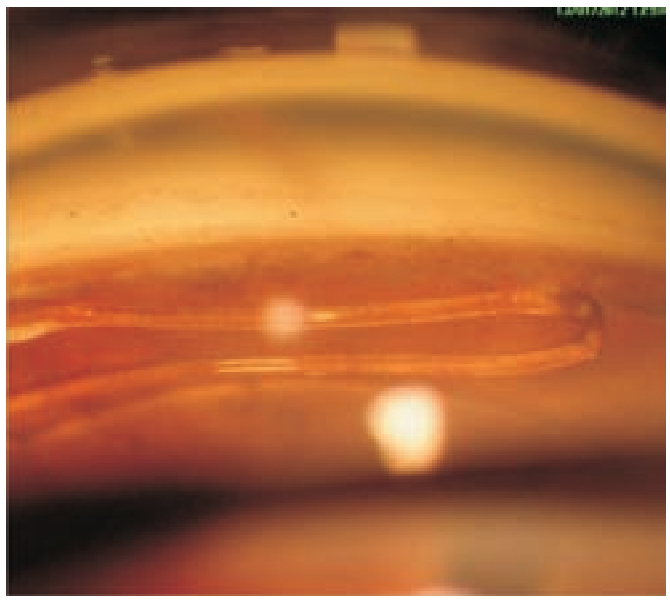
Aniridia with atrophic iris stump and ciliary processes

Juvenile Glaucoma with anterior insertion of iris covering the trabecular meshwork

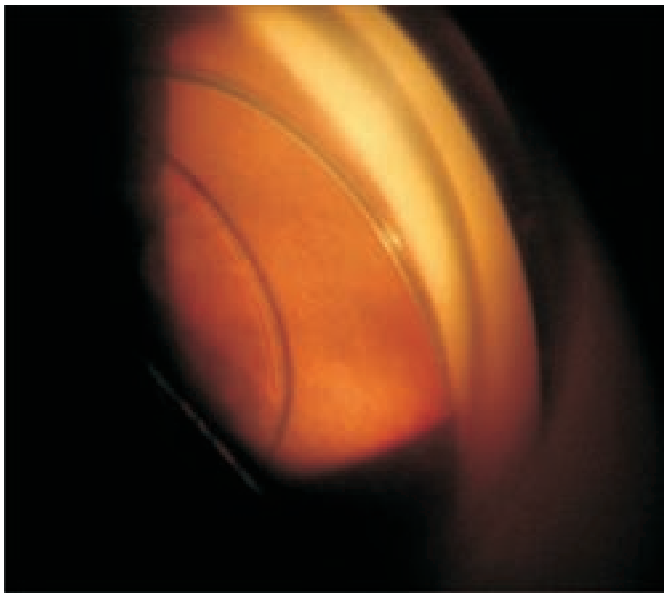
Neovascularizatiion of the iris with secondary angle closure



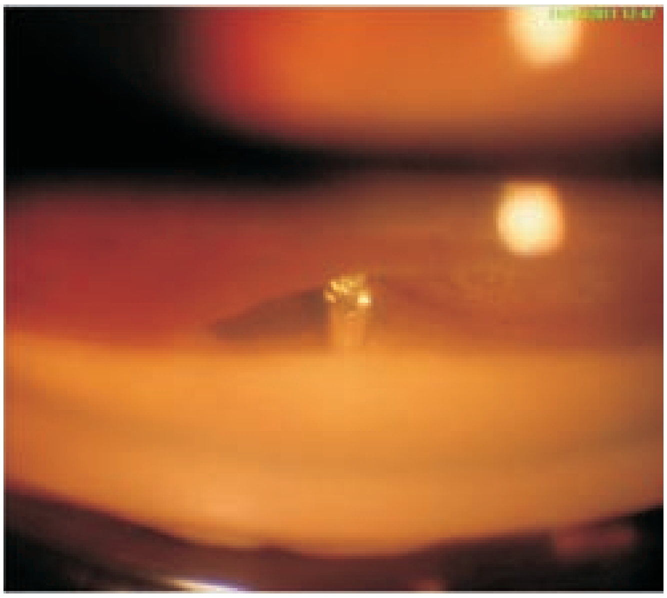
Neovascular glaucoma with secondary angle closure and ectropion uveae



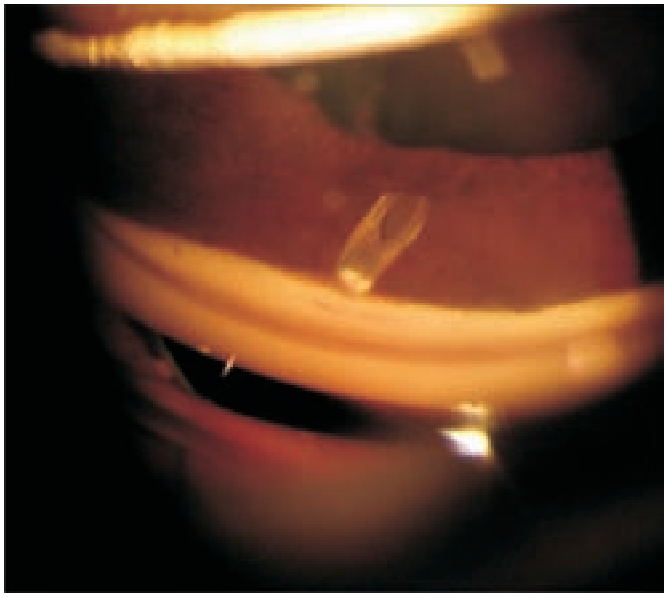
Haptic of anterior chamber IOL in the angle



Haptic of posterior chamber IOL in the angle



ExPress glaucoma filtration device in the angle with tip touching the iris

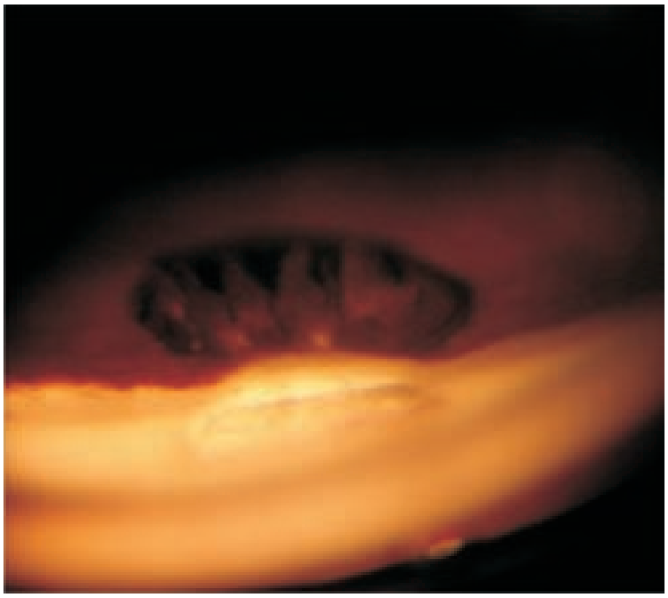


Iris occluding tip of AGV tube

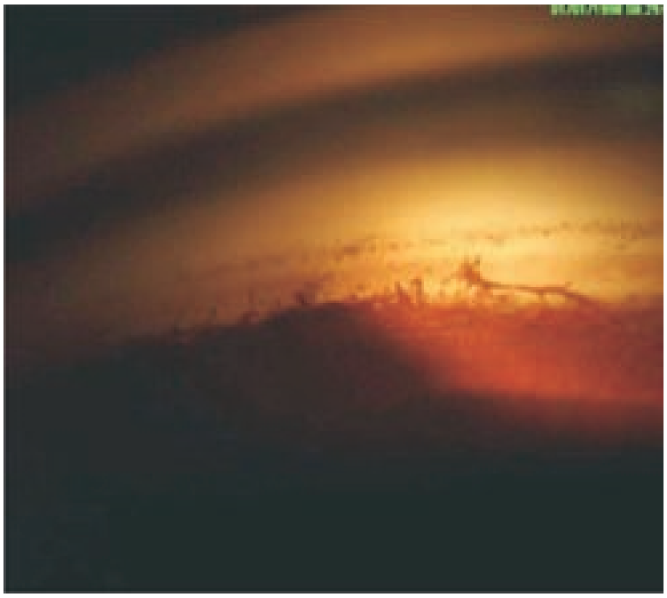
Prominent band like Schwalbe's line

Pigmented anteriorly displaced Schwalbe's line

One new vessel crossing the scleral spur with adjacent PAS formation



Trabeculectomy ostium with ciliary processes visible through iridectomy



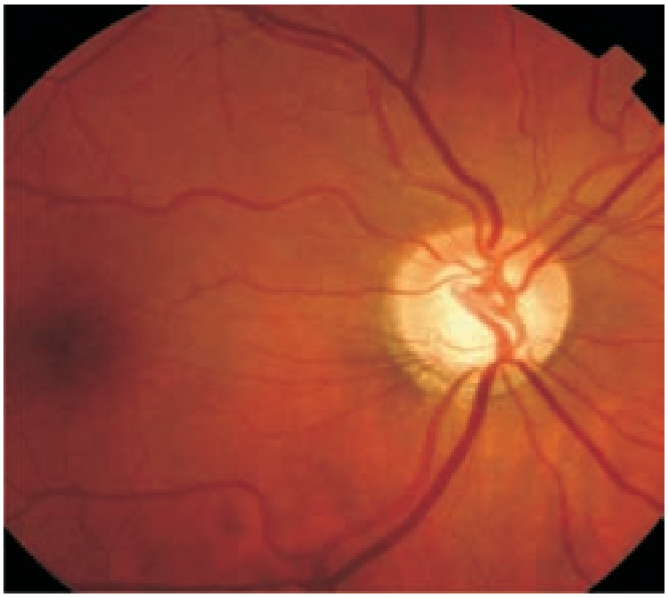
Open angle with prominent iris process attached to trabecular meshwork

Atlas of
Optic Nerve Head

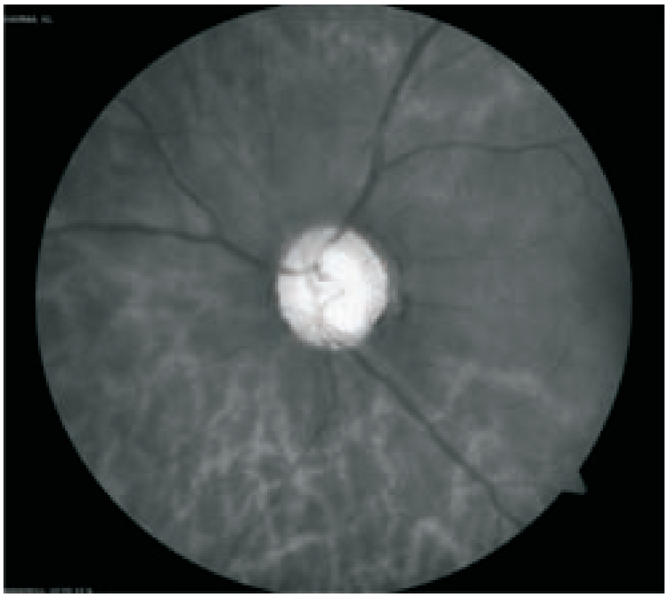
Physiological cupping: Symmetrical, large cups

Normal healthy disc OS

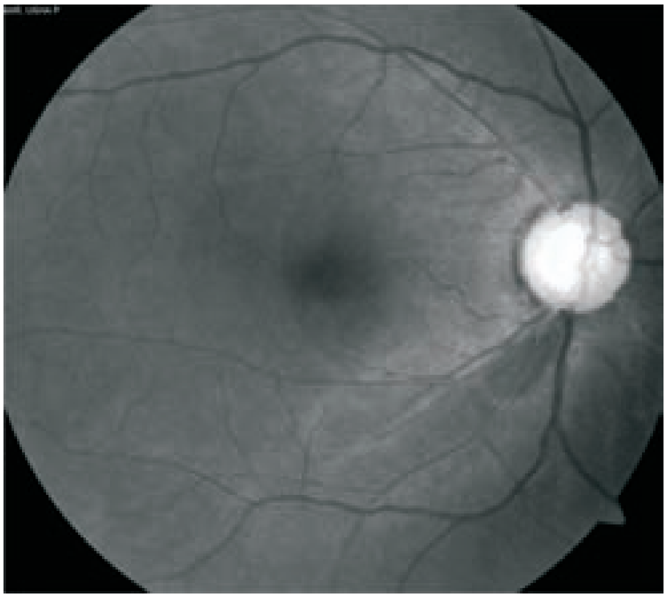
Physiological cupping with
ISNT rule maintained



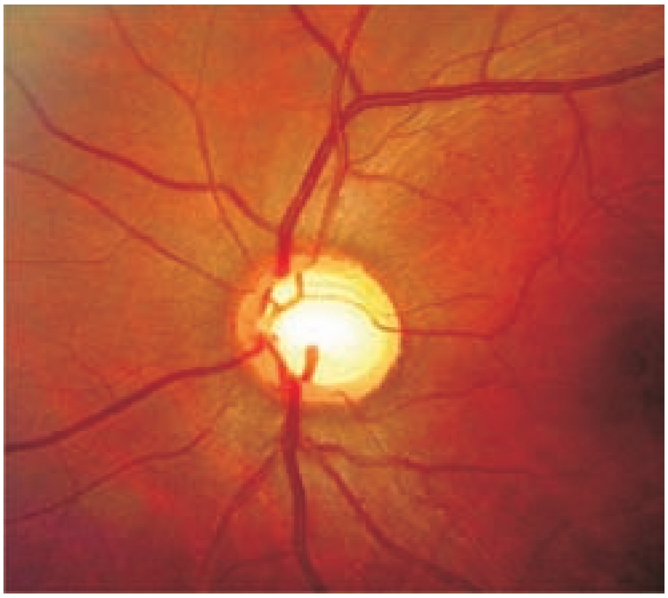
Glaucomatous disc with loss of
neuroretinal rim in inferior sector



Red free fundus photo showing inferior NRR thinning

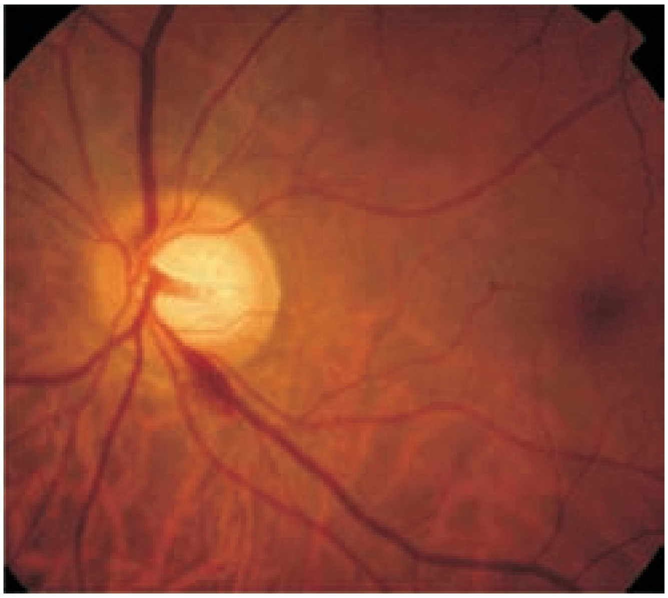


Inferior wedge shaped RNFL defect emnating from disc margin



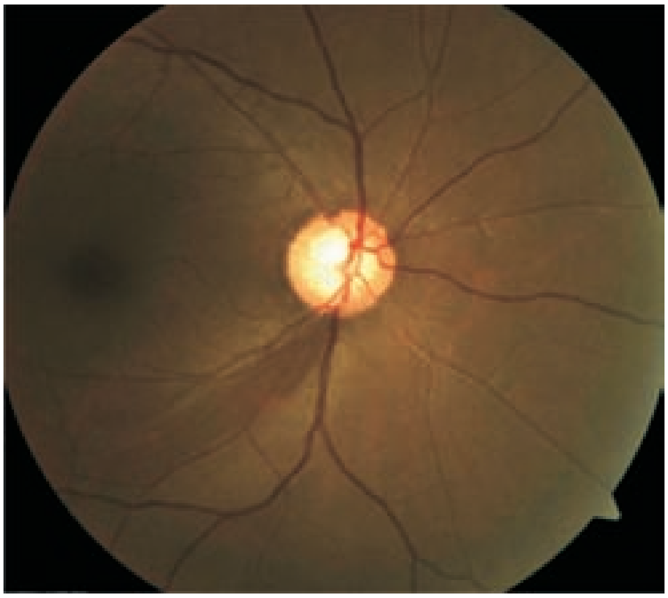
High myopia with large disc

Large sized disc with healthy rim



Focal ischemic disc with
inferior disc hemorrhage

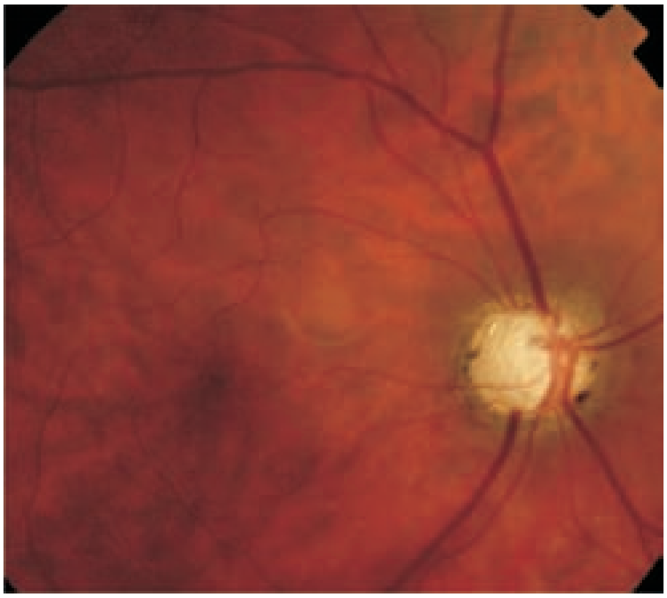
Inferior notching of ONH with
peripapillary atrophy



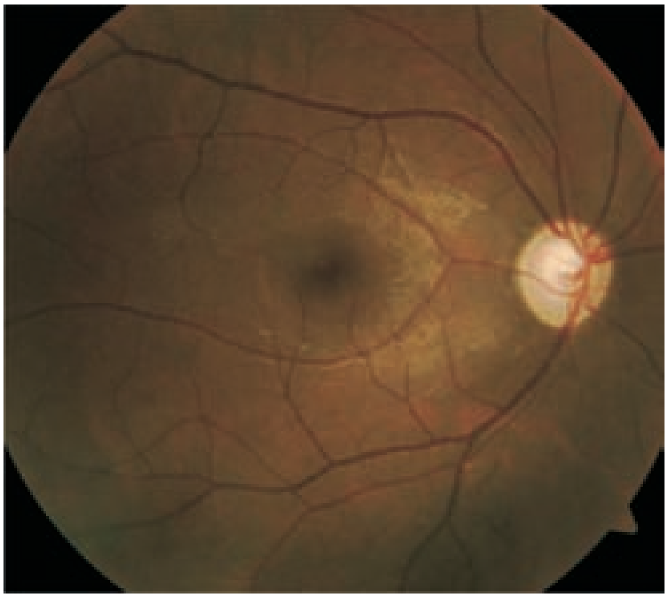
Inferior retinal nerve fiber layer defect

Typical glaucomatous cupping with
loss of inferior NRR

Senile sclerotic disc with
inferior NRR thinning



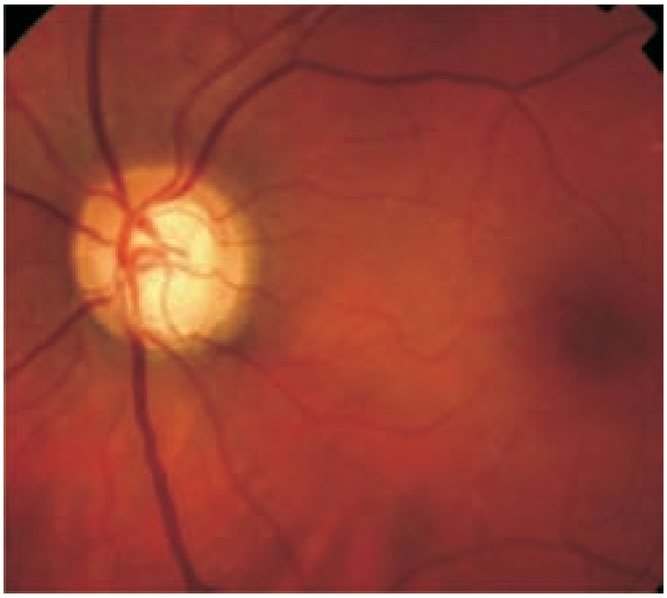
Bean pot cupping with bayonetting of vessels
with peripapillary atrophy



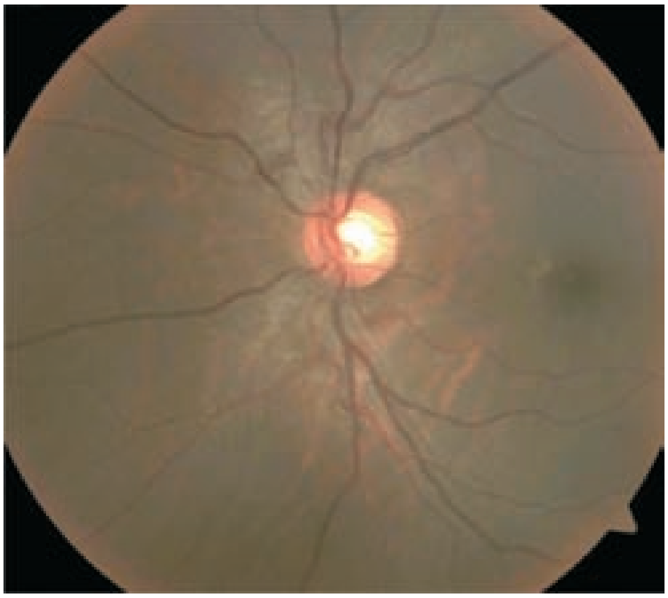
Pale disc with pallor more than cupping

Large disc with peripapillary
atrophy in high myopia

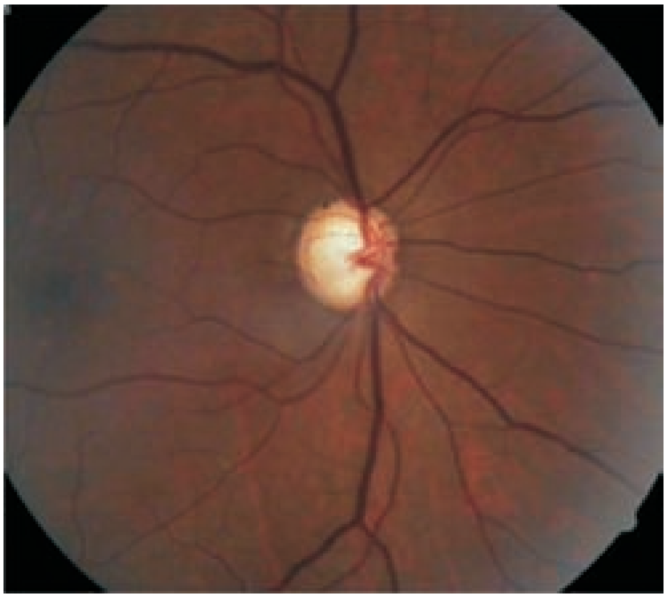
Tilted Disc with physiological cupping with peripapillary atrophy



Loss of inferior NRR with RNFL defect



Normal optic nerve head and retinal nerve fiber layer



Glaucomatous cupping with baring of circum linear vessels

Gonioscopy

GONIOSCOPY

Introduction

The term “gonioscopy” is derived from the Greek words gō’nē (angle) and ŏs’k-pē (view). It is a clinical biomicroscopic technique of examining the angle of the anterior chamber of the eye with the use of a special contact lens known as the gonioscope. It was Alexios Trantas in 1907, who first visualized the angle in a living eye, in a case with keratoglobus by indenting the limbus and also coined the term gonioscopy. The goniolens was introduced by Salzmann, father of gonioscopy, in 1914 and the gonioprism by Goldmann in 1938.

Principle

It is not possible to view the iridocorneal angle of the normal eye directly, because light from the angle strikes the cornea at an angle of incidence > 460, which is the critical angle (cornea-air interface) for total internal reflection. Thus light rays coming from the anterior chamber angle exceed this critical angle and are reflected back (Figure 1.1) into the anterior chamber, thereby preventing visualization of the angle. A gonioscope facilitates examination by obviating the air cornea interface (Figure 1.2), thereby allowing light from the angle to exit the eye. Since the index of refraction of the contact lens approaches that of the cornea, there is very little refraction at the interface between these two media, which eliminates the optical effect of the front corneal surface.

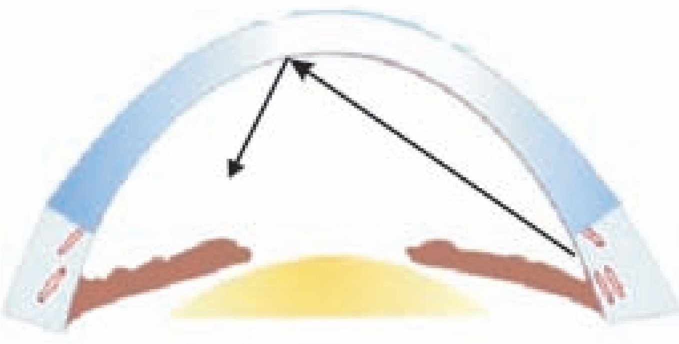


Fig 1.1 Total internal reflection

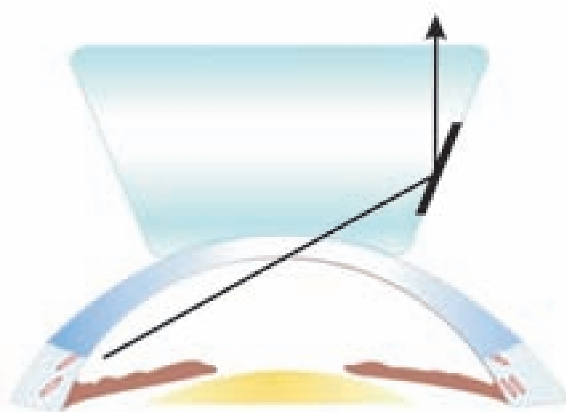


Fig 1.2 Gonioscope over the cornea

Indications

Gonioscopy is an invaluable tool in diagnosing and planning management for glaucoma cases. The purpose of gonioscopy is to view the drainage system of the eye (trabecular meshwork) and determine the cause for elevated IOP. One of the most common indications for performing gonioscopic examination is to identify angles at risk of closure and distinguish between primary angle closure disease and primary open angle glaucoma. Other critical uses include diagnosis of neovascularization of the angle in eyes with retinal ischemia (eg. CRVO).

Other diagnostic indications include the following (Table 1):

Table 1 : Indications for Gonioscopy

Diagnostic

- Classification of glaucoma – open angle or closed angle
- To assess the anterior chamber angle recess and risk of angle closure
- To identify plateau iris
- To note the presence and extent of neovascularization of angle
- Assessment of abnormal angle pigmentation
- Visualization of pseudoexfoliative material in the angle
- To look for post traumatic angle recession, cyclodialysis
- Rule out foreign body in the angle after open globe injury
- Neoplastic invasion into angle structures (ciliary body tumour)
- Diagnosis of blood in the Schlemm's canal (raised EVP)
- To view copper deposition on Descemet's membrane (KF ring)
- Evaluation of trabeculectomy fistula
- Visualization of glaucoma drainage devices
- To diagnose anterior insertion of iris in developmental glaucoma
- Visualization of congenital anomalies – aniridia, iris processes

Therapeutic

- Laser trabeculoplasty / goniophotocoagulation
- Goniotomy/gonioplasty/trabectome surgery
- Reopening of a blocked trabeculectomy opening
- Nd-YAG laser after deep sclerectomy
- Laser of suture tied around tube of a glaucoma drainage device
- Indentation gonioscopy to break an acute attack of angle closure

When to perform gonioscopy?

Gonioscopy should be performed as a part of routine evaluation for all patients visiting an ophthalmologist and is mandatory for all glaucoma patients at diagnosis and during follow up (atleast once a year).

How to perform gonioscopy?

Gonioscopy is best performed in a dark room with minimal slit lamp illumination and beam height (preferably 1 mm) aimed at the angle, taking care that the slit beam never crosses the pupil and the patient maintains gaze in the primary position. This avoids pupillary constriction which can lead to artificial opening up of the angle in eyes with angle closure. If the angle structures are not visualized , a bright wide slit is used initially at low magnification to identify the angle and then changed to a short-narrow slit. The examiner should wait for atleast 60 seconds for the light induced change in pupillary diameter before commenting on the angle detail. Once the gonioscope is placed, view the inferior and superior angle without crossing the pupil, turn the beam 90 degrees and then view the temporal-nasal angle. The observer should see if the posterior pigmented (functional) part of the trabecular meshwork is visible or not. If the posterior part of the trabecular meshwork is not visible, it indicates that there may be irido-trabecular contact (angle closure) and further manipulation/indentation has to be done to view the angle and distinguish between appositional versus synechial closure.

What to look for during gonioscopy?

While doing gonioscopy the observer should comment on the visibility of the angle structures and report the posterior most structure visible. The following key features should be reported:

1. Scleral spur visible or not
2. The width of the angle recess
3. Level of insertion of the iris
4. Degree of trabecular meshwork pigmentation
5. Shape of the iris
6. Effect of indentation / manipulation on a narrow angle
7. Presence and extent of peripheral anterior synechiae (PAS)
8. Symmetry of gonioscopic findings between the two eyes
9. Other pathologies like neovascularization of the angle, angle recession, silicone oil, foreign bodies, blood reflux in Schlemm's canal etc

Since the main role of gonioscopy is for the diagnosis of primary angle closure disease, four critical questions need to be answered while performing gonioscopy:

Q1. Does the iris touch the trabecular meshwork ?
Q2. Is there any sign of previous irido-trabecular contact (pigmentation)?
Q3. Is the irido-trabecular contact appositional(reversible) or synechial?
Q4. What is the extent of circumferential synechial closure?

The corneal wedge

Identifying the corneal wedge is the key step in defining the angle structures. By using a thin slit of light inclined 15-200 from the angle of the oculars and sharp focus, projected onto the iridocorneal angle, 2 light reflections are noted, one from the external surface of the cornea and and the other from the internal surface of the cornea. These two reflections meet at the end of Descemet's membrane which is the beginning of Schwalbe's line (Figure 1.3 -1.5). At this landmark the external and internal reflections of the three-dimensional parallelepiped of light merge into a two-dimensional single line with a brighter luminance, which extends in a perpendicular direction across the trabecular meshwork. This method is of great value in lightly pigmented angles and in angles where there is difficuty in identification of normal landmarks or if there is pigment deposition anterior to the Schwalbe's line. However identifying the corneal wedge may be difficult in some cases. By gently sliding the gonioscopy lens in the direction of the mirror being used, the examiner gains a better view of the cornea and the corneal wedge. Locating the wedge is easiest in the superior and inferior angles as it is easy to generate a vertical slit.

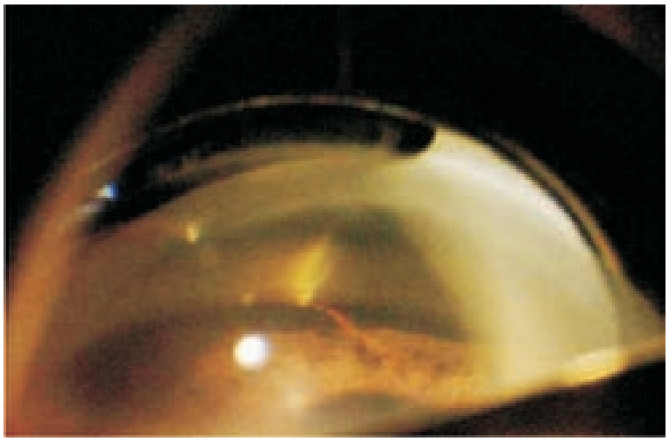


Fig 1.3 Corneal Wedge as seen on the slit lamp through the gonioscope

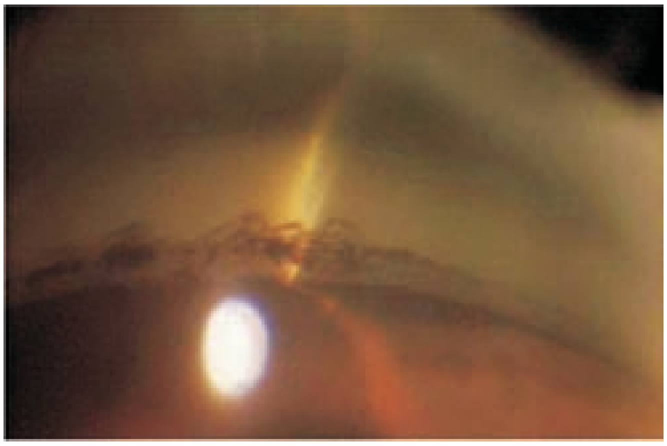


Fig 1.4 The apex of the Corneal wedge meets posterior to the pigmented structure, indicating that this pigmentation is anterior to the Schwalbe's line (not the pigmented trabecular meshwork)

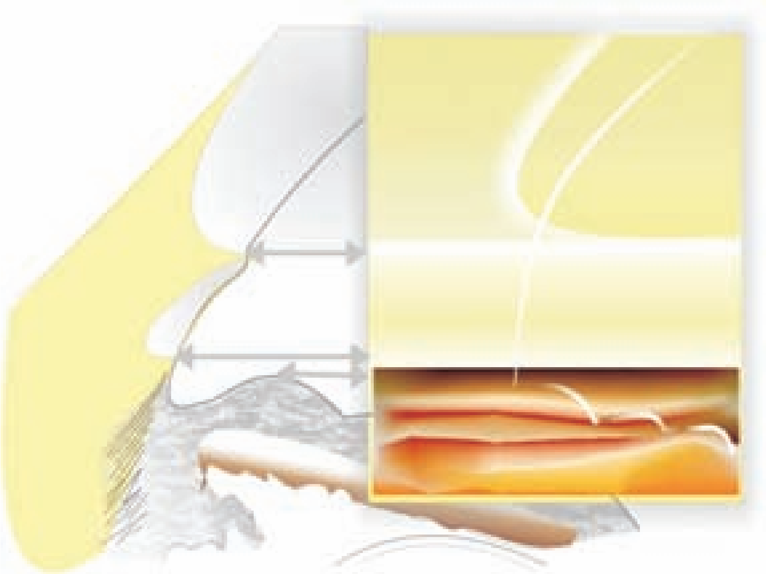


Fig 1.5 Parallelopiped / corneal wedge method of identifying the junction between the external corneal surface (thick light beam) and the internal corneal surface (thin light beam), which marks the Schwalbe's line

What is an occludable angle ?

If the posterior (pigmented) part of the trabecular meshwork is not visible in more than 180 degrees of the angle, this is known as an occludable angle.

What type of gonioscope should be used ?

A 4 mirror lens with a diameter less than that of the cornea should be used, so that indentation gonioscopy can be performed. This is mandatory in the diagnosis, classification and management of primary angle closure disease. However the use of a Goldmann type lens gives a better and clear view of the angle structures and facilitates the identification of angle structures, especially during training. A two mirror Goldmann goniscope is a good , cost effective choice for routine use. The ideal standard for practice is to use both type of lenses (Zeiss type and Goldmann type) as they complement each other.

How to perform gonioscopy in an eye with a steep iris configuration ?

Manipulative Gonioscopy

Manipulation is of value in studying angle anatomy in narrow iridocorneal angles. A more tangential viewing of the angle aids in identification of angle structures obscured by a convex iris. This can be achieved in Goldmann type lenses by simply asking the patient to look in the direction of the mirror or moving the mirror towards the angle being viewed (Figure 1.6- 1.9).

The examiner should report the normal angle view in primary gaze and then document the opening of the angle on manipulation by asking the patient to look into the mirror of the gonioscope, opposite to the angle being examined. For example if you are examining the inferior angle with a Goldmann single mirror gonioscope, the mirror is positioned superiorly. After viewing the angle in primary gaze, you now

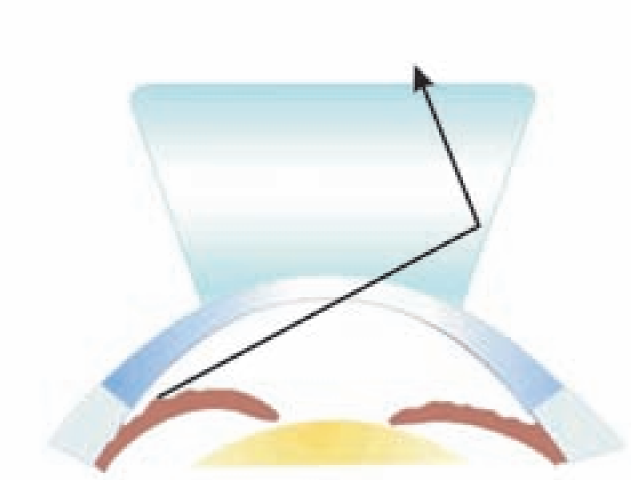


Fig 1.6 A steep iris does not allow view of the angle recess

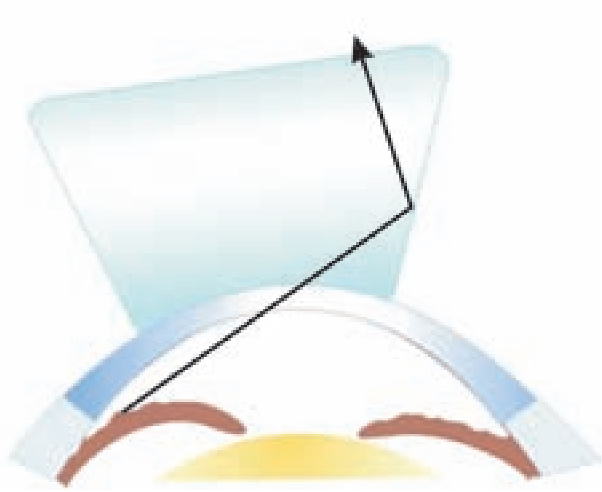


Fig 1.7 Manipulation of Gonioscope towards angle being viewed

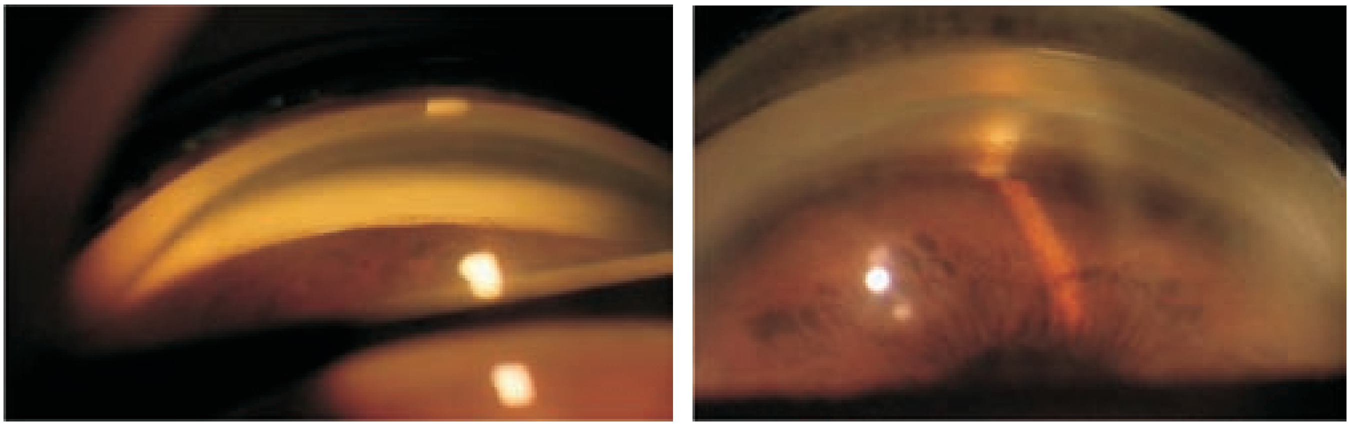


Fig 1.8 -1.9 Closed angle opening on manipulation

ask the patient to look upwards, ie. towards the mirror. This allows a better view of the inferior angle as the examiner can look over the iris and into the angle. If the patient looks in the direction opposite of the mirror, the angle appears narrower and vice versa.

This manipulative maneuver can be facilitated by shifting the fixation light, which is positioned in front of the other eye, in the same direction as that of the gonio-mirror being viewed. The examiner can produce a similar effect by moving the lens towards the part of the angle to be examined (eg. By displacing a goniolens inferiorly when examining the inferior quadrant).

Once the goniolens is displaced inferiorly, the superior rim of the goniolens can be used to indent the central cornea and force fluid into the angle thereby opening it. However this technique is cumbersome and indentation gonioscopy using Zeiss type lenses is ideal to confirm degree and type of iridotrabecular contact. The examiner must never apply undue posterior pressure with the Goldmann type lenses as it would lead to a narrowing of the angle as the lens exerts direct pressure at the perilimbal region.

How to distinguish between appositional vs synechial angle closure ?

Indentation Gonioscopy

This type of gonioscopy requires the use of a special type of gonioscopes known as corneal type goniolenses, typified by the Zeiss lens. These have a 9 mm diameter corneal segment and a radius of curvature of 7.72 mm which approximates that of most corneas. This allows the lenses to be used without a coupling fluid, using the tear film of the cornea. With the corneal type goniolenses, that have a small diameter, the central cornea may be indented to force the aqueous out and artificially widen the angle. Because the smaller radius of curvature allows these lenses to come into direct contact with the anterior corneal surface, central depression of the cornea will displace aqueous humor peripherally and the iris root posteriorly (Figure 1.10). This technique is also known as pressure or dynamic gonioscopy. When the iridocorneal angle is optically narrow, indentation gonioscopy also facilitates the identification of angle structures. Should the angle be closed, indentation helps differentiate appositional from synechial angle closure. This is important as synechial closure is irreversible, while appositional closure can be reversed.

When no angle structure is directly visible before indentation, four things can happen on indentation (Figure 1.11-1.14):

Fig 1.10 Indentation gonioscope placed on cornea

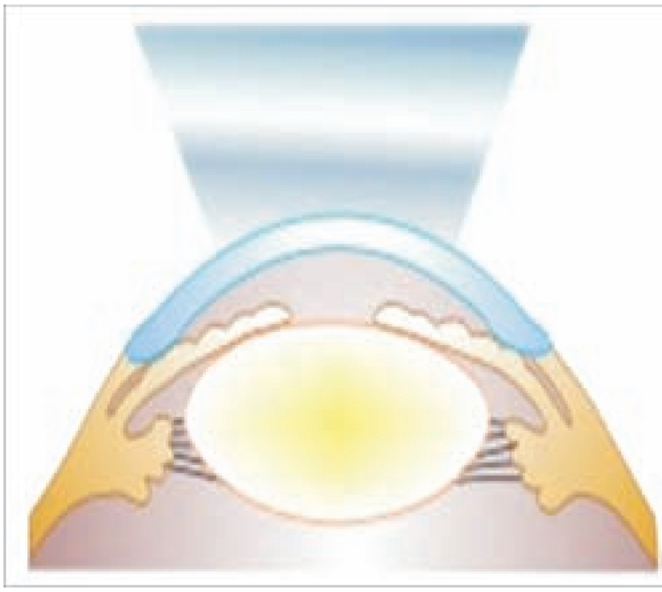


Fig 1.11 Indentation gonioscopy in an apparently closed angle

Fig 1.12 If the angle opens up, it was a case with appositional closure

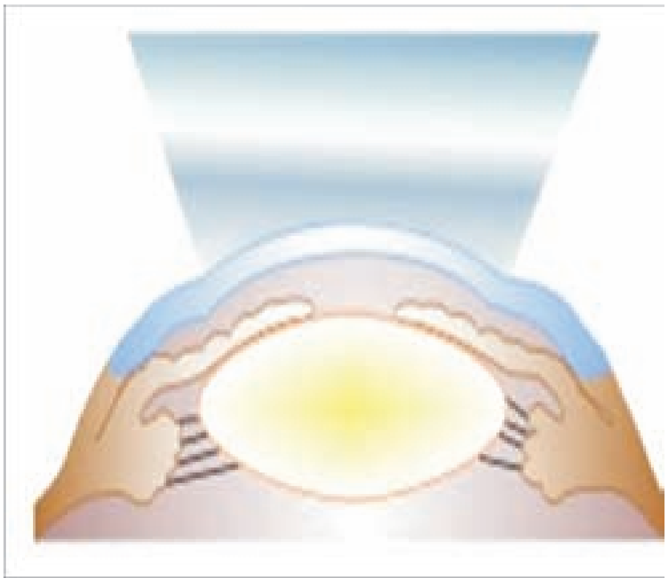


Fig 1.13 If the angle remains closed, indicates synechial angle closure (PAS)

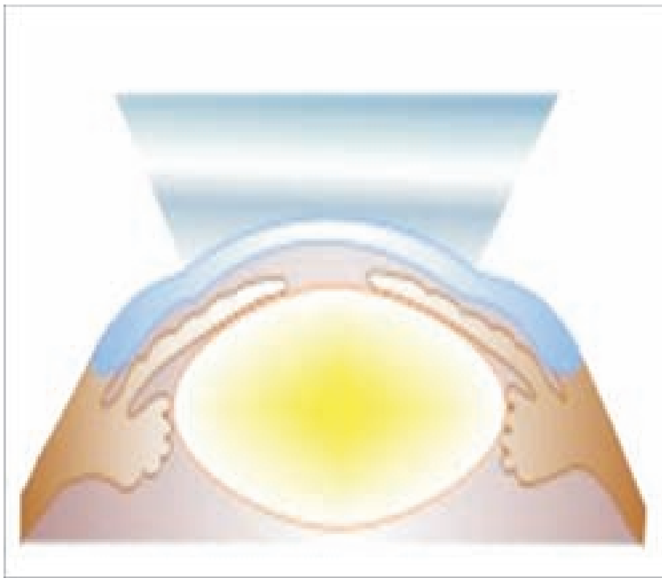


Fig 1.14 A thick lens with no/mimimal iris movement

A) The iris moves peripherally backwards, assumes a concave configuration and the angle recess widens. This represents an appositional closure with a suspicion of a relative pupillary block (Figure 1.12).

B) The iris moves peripherally backwards, but the periphery of the iris bulges out and does not assume a concave configuration. This represents an anteriorly displaced ciliary body and iris root, typically seen in plateau iris.

C) The angle widens but iris strands remain attached to the outer wall of the angle. This represents organic synechial closure of the angle (Figure 1.13).

D) The iris moves only slightly and evenly backward, but retains a convex profile. This can occur due to an anteriorly displaced lens or a large diameter (thick) lens (Figure 1.14).

Indentation gonioscopy with Zeiss type lenses (Posner, Sussman) is the "Gold Standard" for detecting angle closure and differentiating appositional from synechial closure.

Sterilization and Disinfection of Gonioscopes

Special precautions regarding the disinfection of gonioscopes are mandatory as gonioscopy is a contact investigation which can transfer pathogens from one eye to another. The following steps may be taken to disinfect the gonioscope after use in a patient.

1. Washing the lens on removal with soap and water.
2. Soaking the lens for 5-10 minutes in a fresh solution of diluted sodium hypochlorite (household, bleach:water = 1: 10).
3. Rinsing with sterile water.
4. Air drying the lens.

3% hydrogen peroxide or 1% formaldehyde can also be used as disinfectants. The inside of the gonioscope can be wiped for 10 seconds with a sterile swab soaked in 70% isopropyl alcohol. The sterilization of direct gonioscopes (Koeppe, Swan Jacob etc) used during surgery can be done with ethylene oxide gas sterilization.

How to depict gonioscopic findings?

There are different classification systems used to grade the angles like Shaffer, Spaeth, Scheie etc but are not practical for routine use. Simply the gonioscopy findings should mention the posterior most structure visible on gonioscopy in the primary position in the superior and inferior angle. Additionally the examiner may comment on the estimate of the angle recess in degrees, iris configuration/ insertion level and degree of pigmentation. Making a diagram of the gonioscopic findings (Goniogram) can help us to compare our findings on serial gonioscopic examinations and is also easy to interpret for other clinicians.

The angle is basically written as superior and inferior angle and the most posterior structure seen. If manipulation/indentation is done, an arrow is put and the structure thus exposed is mentioned (Fig 1.15).

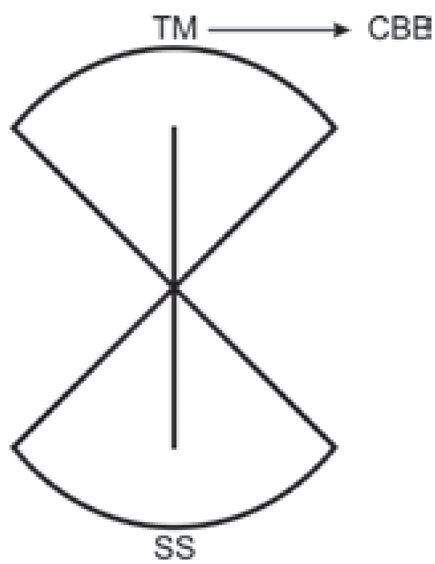


Fig 1.15 Diagram representing angle structures

Another method is to draw a goniogram in the form of 3 concentric circles. The inner circle denotes the scleral spur (SS), middle one is the trabecular meshwork (TM) and outer one is the Schwalbes line (SL). Presence of peripheral anterior synechiae (PAS) or other pathologies like new vessles (NVI) can be drawn in the corresponding clock hour as visible on gonioscopy (Fig 1.16).

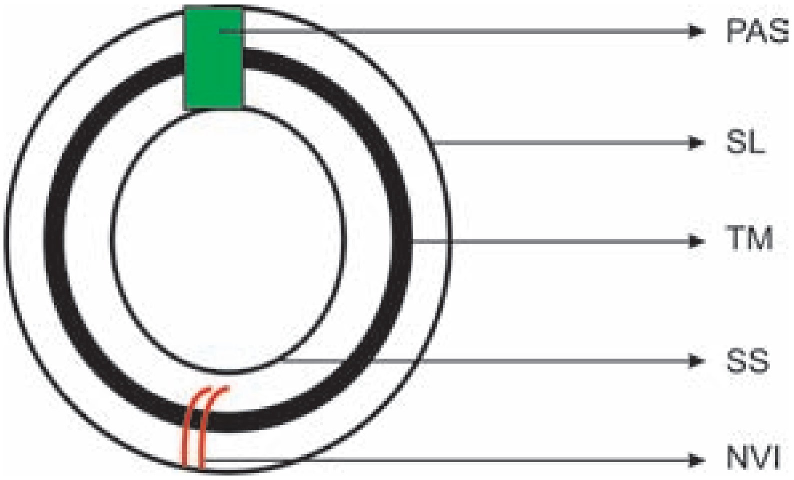


Fig 1.16 Goniogram

What are the limitations of gonioscopy ?

- Gonioscopy is a contact investigation which causes discomfort to the patient.
- It can transmit a conjunctival infection to the patient.
- Gonioscopy should not be performed in suspected open globe injury or early in the course of closed globe injury with hyphaema as pressure can precipitate re-bleed.
- Gonioscopy is difficult in cases of acute angle closure with corneal oedema and eyes with corneal opacification.
- Excessive pressure while using Goldmann type of lens may artefactually close the angles and while using corneal type of gonioscopes it may give a open angle appearance in narrow recess angle configuration.
- Use of slit lamp illumination while doing gonioscopy leads to pupillary constriction and opens up/ changes the angle configuration.
- Gonioscopy cannot objectively quantitate the angle parameters and there is a wide inter-observer variability .
- Gonioscopy is not useful to identify pathologies behind the iris.
- Indentation gonioscopy can lead to formation of corneal folds, distorting the view of angle structures and may cause corneal epithelial injury .
- Mastering gonioscopy has a long learning curve requiring regular practice on a large number of patients.

Gonioscopy remains the “Gold Standard” for evaluation of the anterior chamber angle and should be performed as a basic test like ophthalmoscopy or tonometry. The following section depicts some characteristic gonio-pathologies visible on gonioscopy.

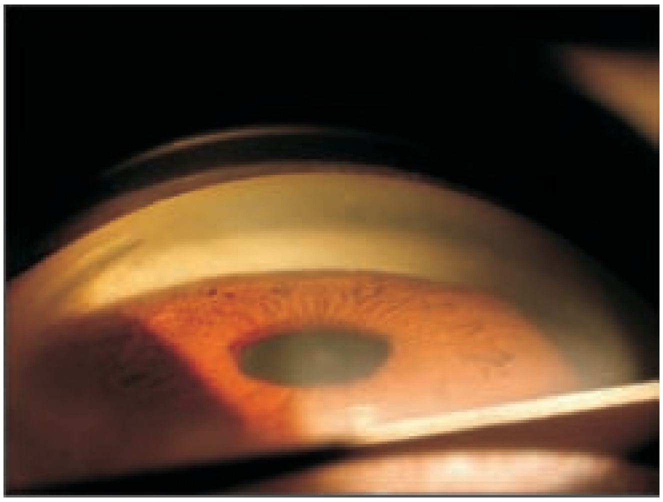


Fig. 1.17 Closed Angle with no structure visible

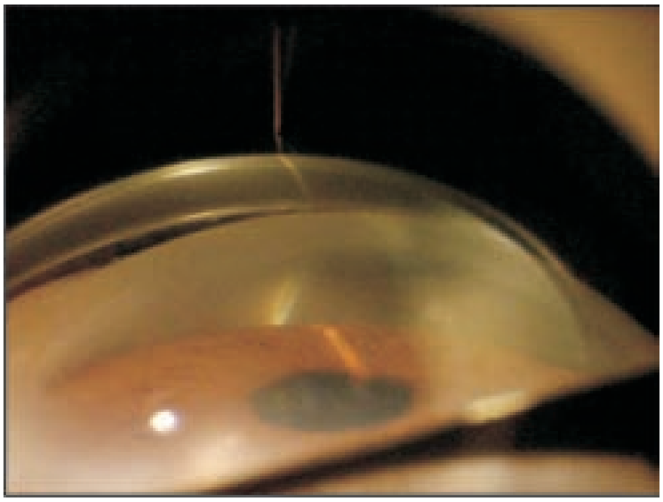


Fig. 1.18 Steep iris configuration with a closed angle

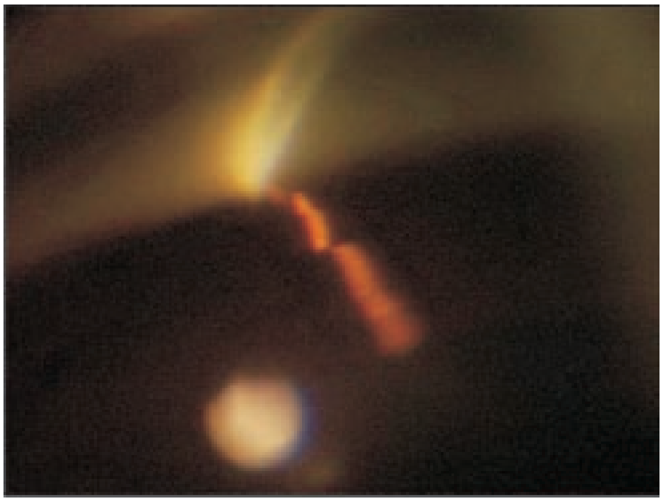


Fig 1.19 Sine wave configuration – Plateau Iris

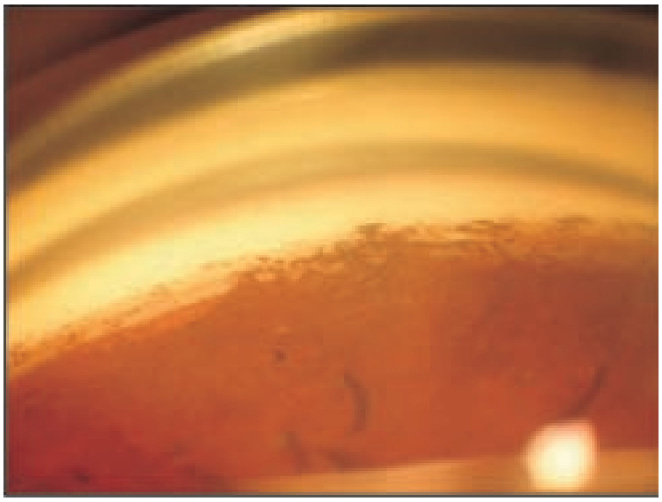


Fig 1.20 Peripheral Anterior Synechiae

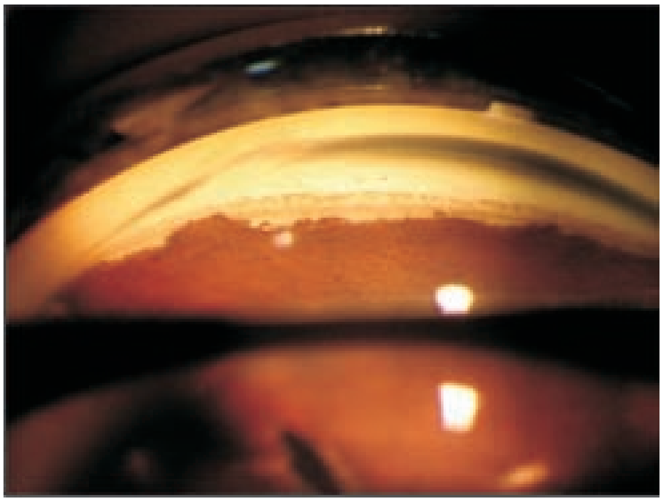


Fig 1.21 Broad based Peripheral Anterior Synechiae

Fig 1.22 Open Angle

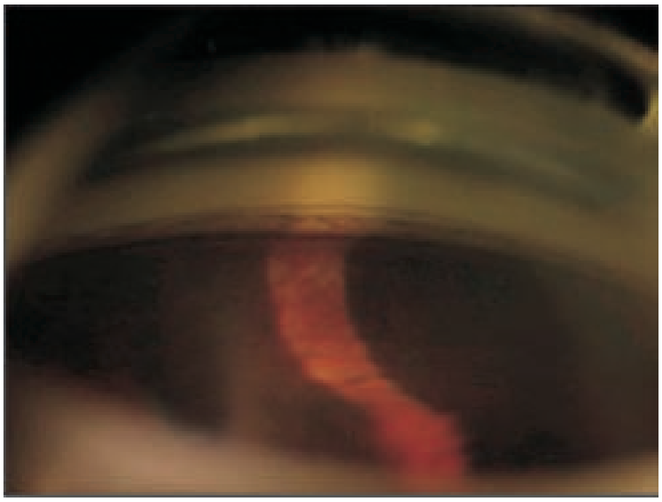


Fig 1.23 Pigment Dispersion Syndrome with Sampaolesi's line


Fig 1.24 Prominent Iris Processes

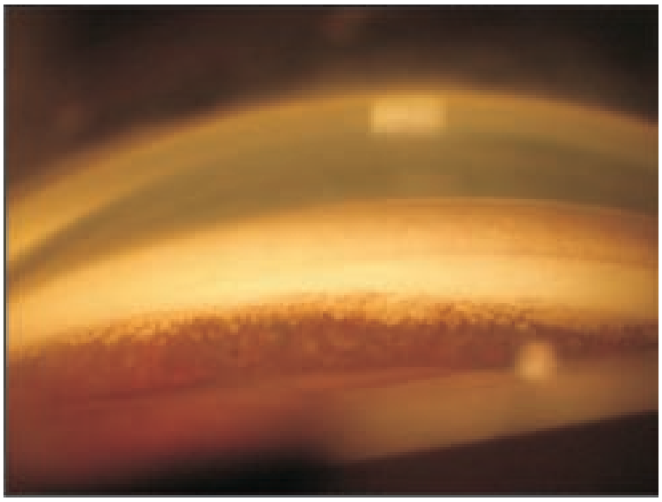

1.25 Anterior insertion of iris in Juvenile Glaucoma


Fig 1.26 Small iris stump seen in Aniridia


Fig 1.27 Irido-Corneal endothelial (ICE) syndrome

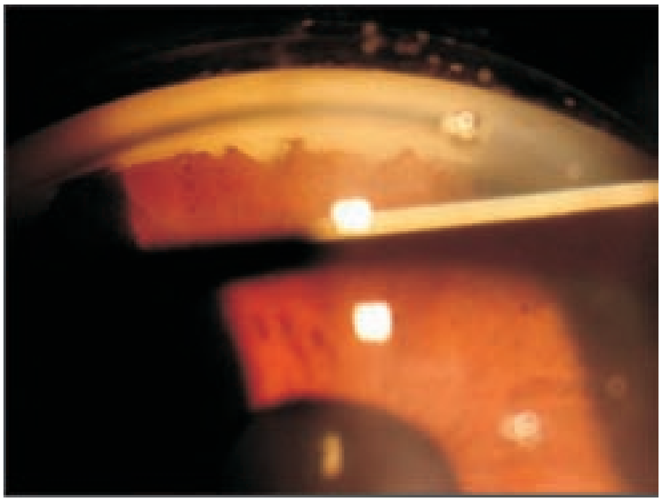


Fig 1.28 Anteriorly displaced Schwalbe's line with irido-corneal adhesions in Axenfeld Reiger syndrome

Fig 1.29 Angle Recession with widened ciliary body band

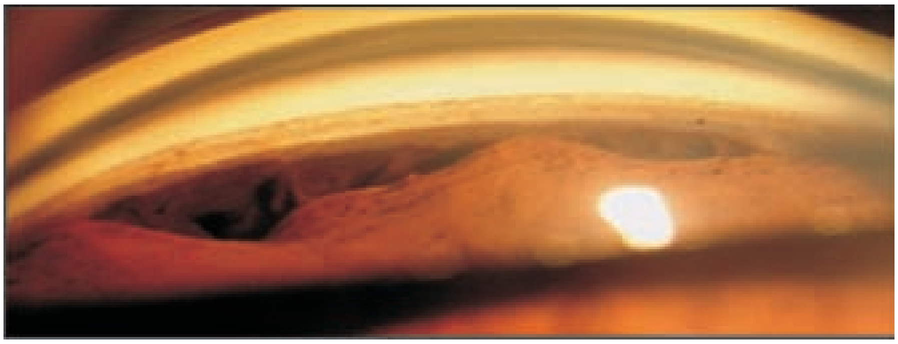


Fig 1.30 Iridodialysis

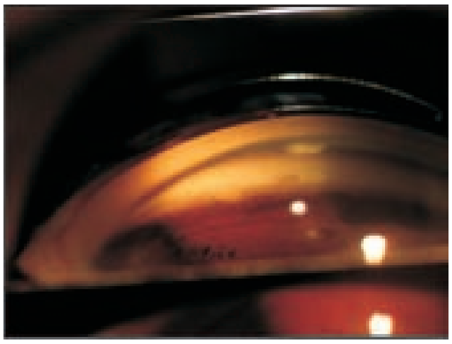


Fig 1.31 Nodules in the angle in a case of Sarcoidosis

Fig 1.32 Emulsified silicone oil in the angle

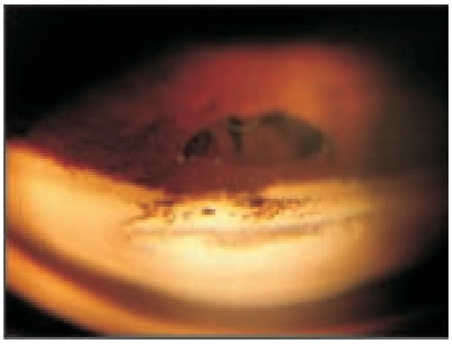


Fig 1.33 Internal ostium of Trabeculectomy

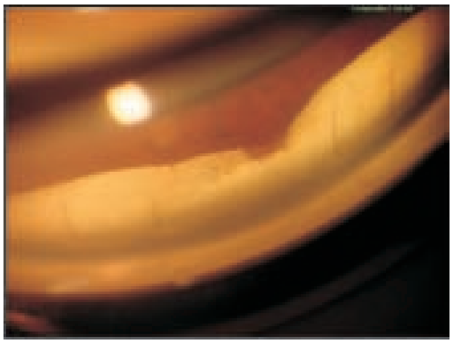


Fig 1.34 Trabeculectomy ostium blocked by iris

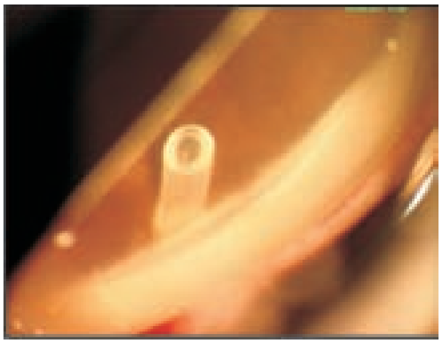


Fig 1.35 AGV tube in the angle

Suggested Reading

Dada T. Gonioscopy : A Text and Atlas. Jaypee Brothers Medical Publishers. 2013. New Delhi

Dada T. Gonioscopy DVD. All India Ophthalmological Society 2011.

Optic Disc Evaluation

OPTIC DISC EVALUATION

INTRODUCTION

A change in the appearance of the optic nerve can be the first finding in a glaucoma patient. Thus, stereoscopic view of the optic disc to recognize characteristic features of glaucomatous optic neuropathy is of extreme importance in glaucoma diagnosis and management. A variety of contact and non-contact lenses can be used for stereoscopic viewing of the fundus with the help of a slit lamp. Non contact lenses (like +60D, +78D, +90D) are more convenient than contact lenses and are widely used.

The optic disc has been considered to be invaluable in the interpretation of the automated perimetry and in assessing the impact of intraocular pressure.

Optic Disc Size, Shape, Neuroretinal Rim, Cup and Cup Disc Ratio :

Optic nerve Head (ONH) : A proper ONH examination can detect glaucomatous damage prior to visual field loss as reported by Quigley, who stated that 40% of axonal loss occurs prior to perimetric detection of glaucoma.

Optic Disc (OD) is the area on the fundus where axons from all over the retina converge and exit the eye. They are arranged in fascicles/bundles which are 1000 in number.

Glaucomatous Optic Neuropathy (GON) leads to the loss of axons which leads to the enlargement of the optic cup. The cup is only an indirect measure of the amount of neural tissue in ONH. It is misleading because large optic disc will have thin NRR but not less NRR. In glaucoma, the axonal loss is out of proportion to the decrease with age (loss of axons 4000-5000/year).
There are many characteristics on the optic disc which convey glaucomatous optic neuropathy, and these need to be assessed for every glaucoma evaluated.

SHAPE : In normal eyes, the average optic disc is slightly vertically oval. The longest diameter is 9% longer than horizontal.

Tilted discs tends to be more oval. It can be tilted in more than one axes. Tilted discs have a tendency for glaucoma and may be confused with a glaucomatous disc, hence need to differentiate it. Guffre introduced the papillary index which is a measure of the ovality of the disc wherein the largest disc diameter is divided by perpendicular to this value.

SIZE : The size of the disc varies with size of the eye. Thus for the same 1.2million optic nerve fibres to exit, the area occupied by the optic nerve fibres will be more in a small disc of a hypermetrope with crowding of nerve fibres, giving rise to a small cup. Thus in early glaucoma slight increase in cup size may still be discernable to the clinician unless he makes note of the small disc. Myopics have larger discs, where a large cup may be physiological.

Disc Diameter : Disc diameter has been found to be around 1.18-1.75 mm in various studies. It is dependent on various factors and ethnicity is one of them. In general, a small disc has a diameter of ≤1.3mm and >2mm is taken as large disc.

Disc Area : It has been found to range from 0.68 – 4.42mm^2, average being 2.42-2.56mm^2 on measurement with HRT, and 2.79mm2 on disc photos.

Optic Cup : is a passive reflection of the ON fibre loss. Traditionally, the Cup disc ratio (CDR) has been taken as a measure of glaucoma as propagated by Armaly since 1970's. The vertical CDR has more significance than the horizontal as the earliest fibres to be lost are at the superior and inferior pole. CDR> 0.5 is looked with suspicion and an asymmetry of >0.2 between the two eyes is considered glaucomatous.

Neuroretinal Rim (NRR) : The tissue between the cup and disc margins is called the neural rim and it represents the location of the axons. The axons in periphery of retina arch over and reach the superior/ inferior poles of the optic disc. They follow the ISNT rule (discussed later).

COLOUR :

The orange-pink appearance represents healthy, well perfused neuro-retinal tissue in a disc with a pale centre. There are many pathological conditions like advanced glaucoma, optic neuritis, arteritic or non-arteritic ischemic optic neuropathy, compressive lesion leading to a pale disc (loss of pink colour).

Cup Area had a stronger correlation with disc area than rim area, therefore the disc size is more important for cup area than rim area. Positive correlations has been found between the disc size and thickness of RNFL.

Confocal Scanning Laser Tomography (HRT) showed in healthy eyes that NRR area and OD diameter have a higher correlation with ONH configuration than age, sex/refractive error.

Disc patterns in Glaucomatous Optic Neuropathy :

i. Focal atrophy – inferior thinning, increased CDR, vertically selective loss of NR tissue in glaucoma in inferotemporal region and in superotemporal area to lesser extent leading to H:V decreased cup ratio.
ii. Concentric atrophy – unfolding starts temporally, then goes to superior and inferior poles, form of early glaucomatous damage. Compare other eye for symmetry. Study serial photographs for evidence of progressive damage.
iii. Deepening of cup – often associated with visibility of lamina cribrosa and laminar dot sign.
iv. Pallor cup discrepancy – in glaucomatous optic atrophy, the cup is generally larger than the area

of pallor. Pallor is a more important sign of neurological damage of optic nerve. Saucerisation, an early sign of glaucoma, refers to shallow cupping extending to the disc margin with the retention of central pale cup.

v. Advanced glaucoma cupping : essential loss of all neural rim tissue and all vessels bend at the disc margin leading to Bean Pot Cupping.

A systematic approach to disc assessment prevents many a glaucoma cases from being missed. Paying attention to the **5Rs** during optic disc examination is a concept created by Robert N Weinreb, Felipe Medeiros and Remo Susanna Jr and can be utilized to standardize the examination and documentation of the optic nerve and nerve fibre layer.[1]

Five Rules (5Rs) for Assessment of the Optic Disc in Glaucoma :

1. First R : Observe the scleral Ring to identify the limits of the optic disc and its size

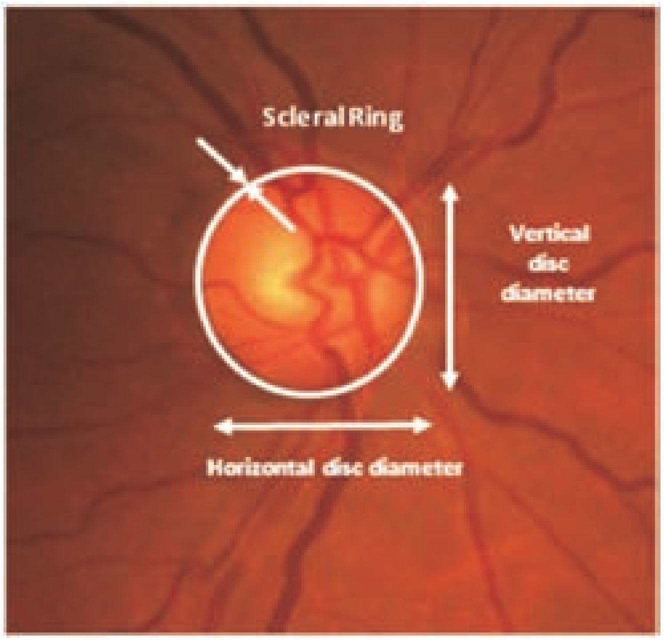


Figure 1a : Scleral Ring - inner edge of the Scleral Ring is observed to identify limits and size of the optic disc

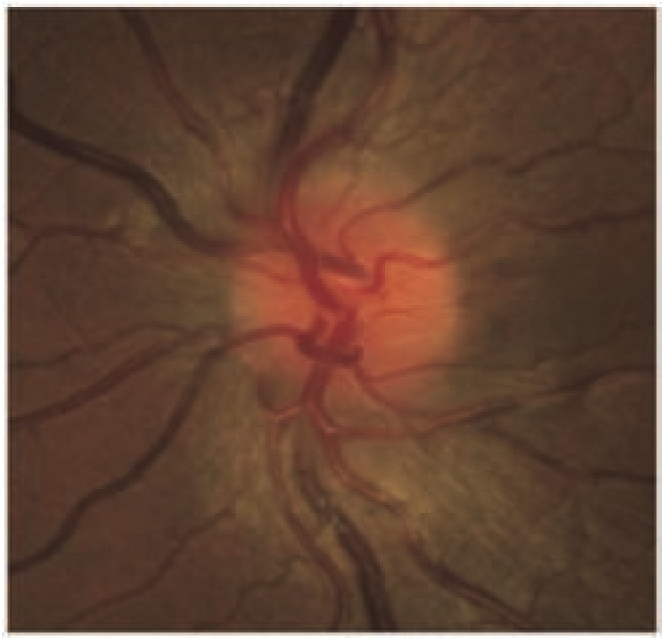


Figure 1b : Small optic disc with no cup

The inner edge of the Scleral Ring is observed to identify limits and size of the optic disc (Figure 1a). The normal optic disc is round or oval and pink in colour. Its diameter varies in size from 0.95 – 2.9mm, with the average dimensions being 1.9mm vertically and 1.7mm horizontally and is independent of age after the first decade of life. Disc size is related to race – it tends to be smaller in whites, intermediate among Asians, and largest among blacks.[2,3]

There are several helpful clinical tools in estimating disc size during routine examination. Larger the disc size, larger is the size of the cup. Figure 2c shows large discs with large cups (0.7-0.8:1 CDR, healthy neuro-retinal rim) in an individual suspected to have glaucoma. This individual had normal visual fields over several years and no evidence of retinal nerve head damage and just had large physiological cups. Small optic discs with virtually no cup deserve special attention (Figure 1b). Hence the earliest signs of glaucomatous progression may be more easily appreciated by evaluating the RNFL or peripapillary choroid. Even the development of a small cup in an eye with no previously documented cupping may indicate early damage in the crowded disc.

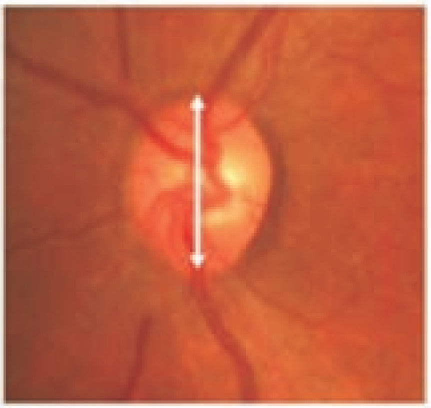


Figure 2a : Small disc, small cup

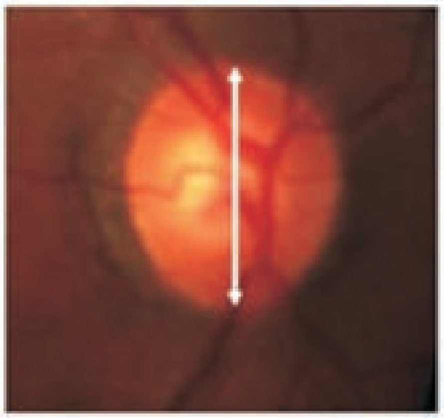


Figure 2b : Medium disc, 0.4:1 CDR

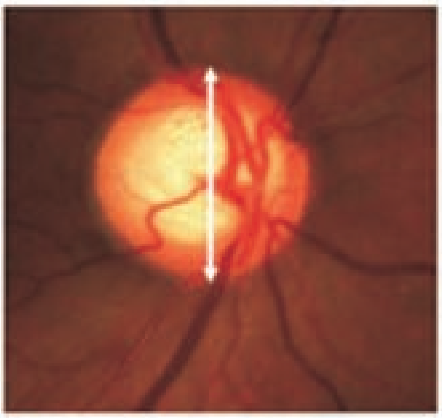


Figure 2c : Large disc, 0.8:1 CDR

Disc size can be estimated during

- **Direct Ophthalmoscope – Real, erect and magnified (15x) image:**
  - o Middle aperture of Welch-Allen direct ophthalmoscope illuminates a cone of 5 degree, and projects a circle of light onto the retina in eyes with a refractive error within ±4D of emmetropia with diameter of 1.5mm and an area of 1.8mm on the retina when it is held in the usual range (Figure 3).[4]
  - o For Heine's direct ophthalmoscopes with 2 spot sizes, the smaller one is utilized. The spot is aligned either over or adjacent to the optic disc and the size of the optic disc is compared with the size of the spot of light.

- **Slit lamp examination with Biconvex high aspheric lenses – Virtual, inverted and magnified image:**
  - o By adjusting the height of the slit beam to correspond with the margins of the disc and noting the reading from the graticule.
  - o The appropriate magnification factor must be multiplied to get correct measurement depending on the lens used (60Dx1, 78Dx1.1, 90Dx1.3) during examination

Along with the disc size, the vertical and horizontal cup disc diameter ratios (CDR) need to be documented as this is necessary for quantification of glaucomatous neuropathy. Armaly back in '70s introduced the idea of CDR, which is expressing the proportion of the disc occupied by the cup. Any vessel displacement, any sloping, depth of the cup also needs to be documented. However, the cup-disc ratio has its limitations as it is subject to a wide variability. A high CDR can be normal in a large disc whereas a low CDR may be glaucomatous if the disc is small (Figure 2 and 4). Margin of the cup is delineated by the bending of the disc

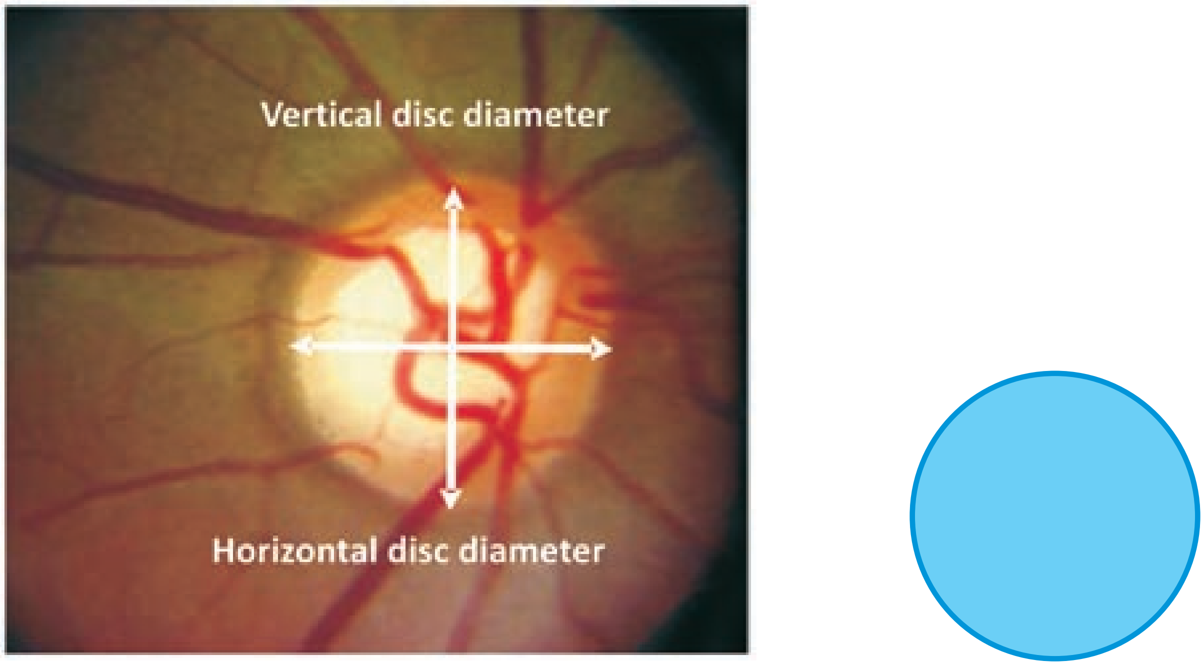


Figure 3 : Measurement of optic disc size with ophthalmoscope. Size of light spot = size of average optic disc

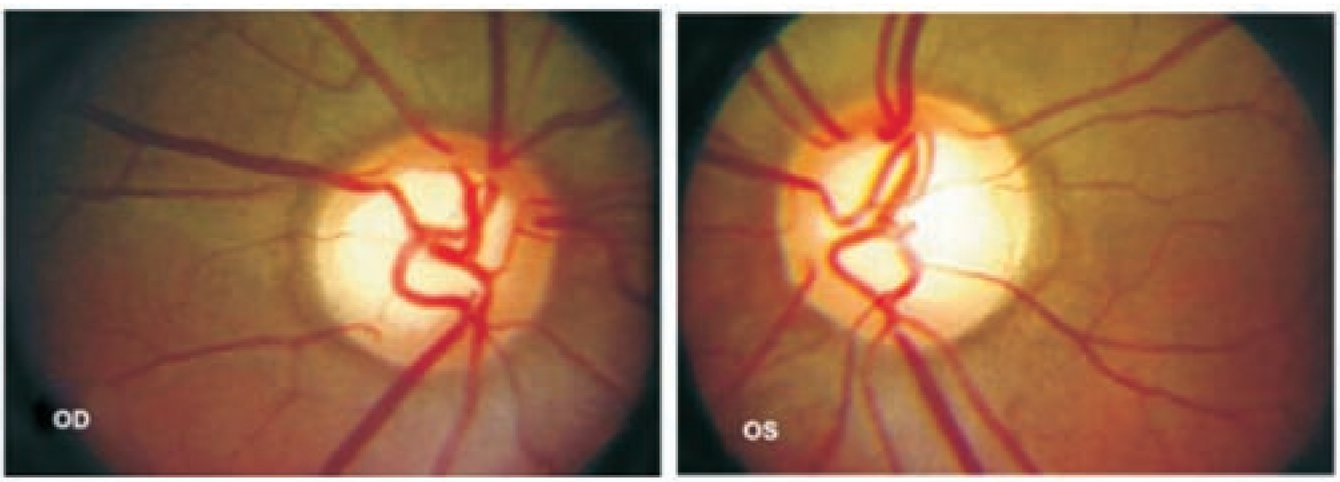


Figure 4 : Large disc with large cups suggestive of physiological cupping.

vessels. In general, CDR of 0.7 in an average sized or large disc should be viewed with suspicion. If there is asymmetry or CDR differs by more than 0.2 in both eyes of a patient, the possibility of glaucomatous damage should be considered (Figure 5), if other causes of asymmetry have been ruled out. Finally, there are clinical situations such as in high myopia or tilted optic discs in which it is difficult to evaluate optic disc size because of the imprecise definition of the scleral ring and optic disc margins (Figure 6).

An acquired pit of the optic nerve (APON) is a discrete, focal area of depression within the optic cup at the level of the lamina cribrosa (Figure 6b). It is an under-diagnosed sign of glaucoma damage due to its subtle appearance. Although it is relatively uncommon, the presence of APON is pathognomonic of glaucoma. APONs occur more frequently unilaterally, inferotemporally in 70-80% cases (superotemporally in rest) and in patients with normal-tension glaucoma (NTG). They often correspond to a deep, sharp-margined scotoma approaching or involving fixation. Given the location and progressive nature of the associated visual field defects, glaucoma patients and glaucoma suspects should be evaluated for this sign of localized optic nerve damage.

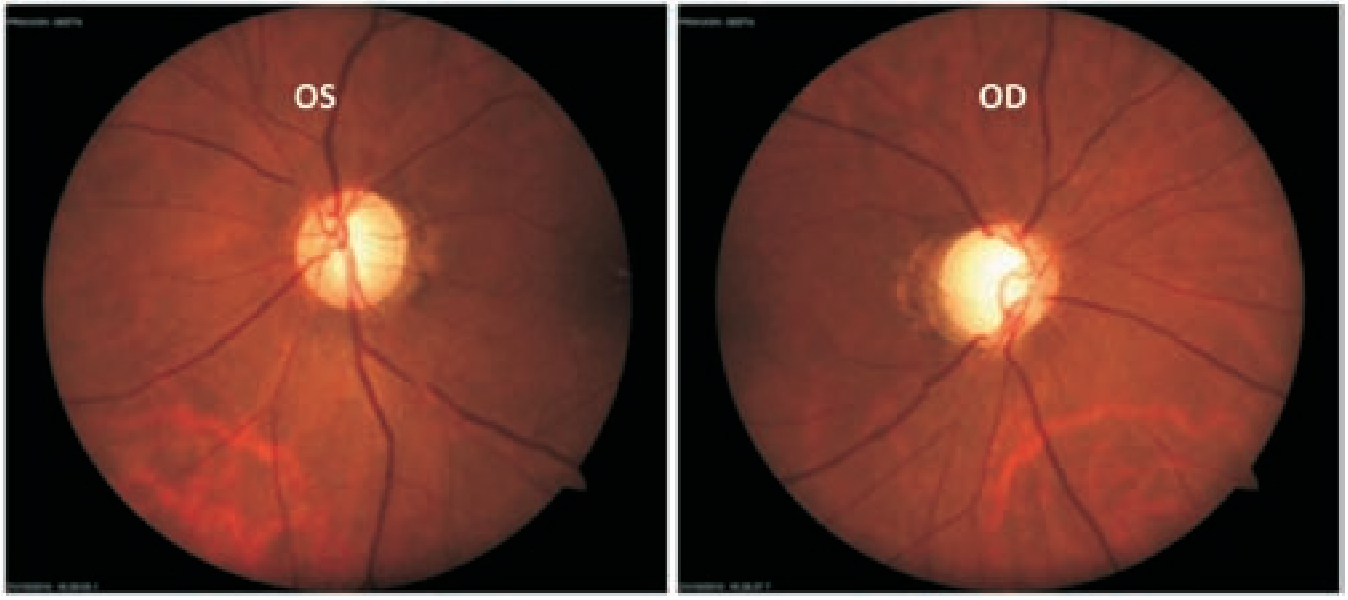


Figure 5 : Asymmetry in CDR>0.2 in both eyes of patient, highly suspicious of glaucomatous damage

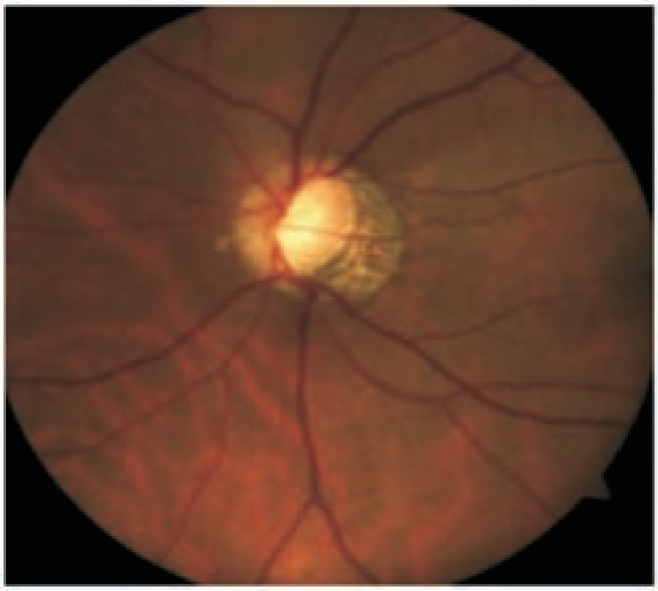


Figure 6a : Tilted disk : the disc margin is difficult to identify

Figure 6b : Acquired pit of the optic nerve (APON) located in superotemporal region. Observe the localised posterior ectasis of lamina cribrosa, leading to visualisation of its pores. Compare with inferior part of the cup where pores are not available.

2. Second R : Identify the size of the Rim

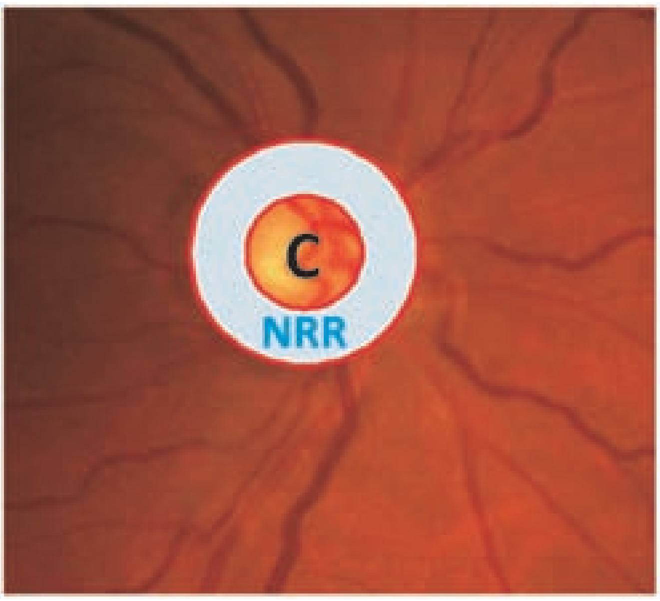


Figure 7a: Fundus photo of a normal right eye. C, cup: NRR, neuroretinal rim.

Figure 7b: Fundus photo of a normal right eye showing the ISNT Rule.

The area of the optic disc occupied by axons is called the Neuroretinal Rim (NRR) (Figure 7a). In the normal eye, the width of the NRR varies by quadrant and normally follows the ISNT rule, which was originally described by Jonas et al.[5] They calculated the rim thickness measurements of normal eyes using optic disc photographs. Normally the Inferior (I) rim is the thickest, followed by Superior (S), Nasal (N) and then Temporal (T) **(ISNT Rule)** (Figure 7b). An inferior or superior rim equal to or thinner than temporal rim is highly suspicious. The thinning may or may not extend to the edge of the disc. Nowadays, rim-disc ratio is considered to be more important than CDR. A rim-disc ratio of less than 0.1:1 in any area should be considered pathological.

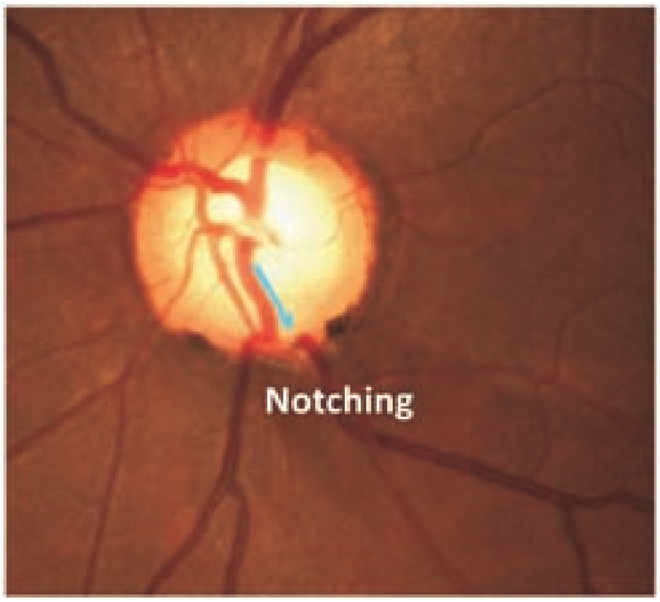


Figure 8a: Inferotemporal notching

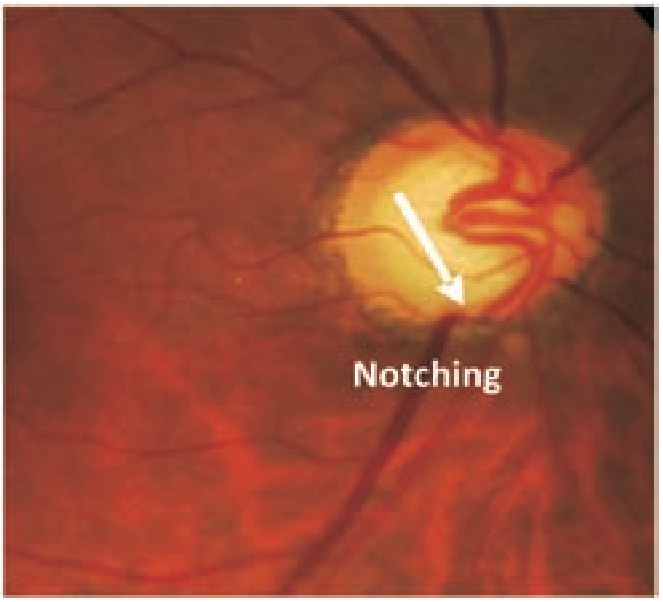


Figure 8b: Inferotemporal Notching

The thickness, colour and contour of neural rim should be compared in each of the four quadrants. Glaucomatous damage may be diffuse, focal or a combination. Diffuse damage results in symmetrical enlargement of the cup with generalized rim thinning while focal damage leads to localized loss of NRR, focal loss of NRR is called a notch which is highly suggestive of glaucoma and produces a corresponding functional field defect (Figure 8a,8b).

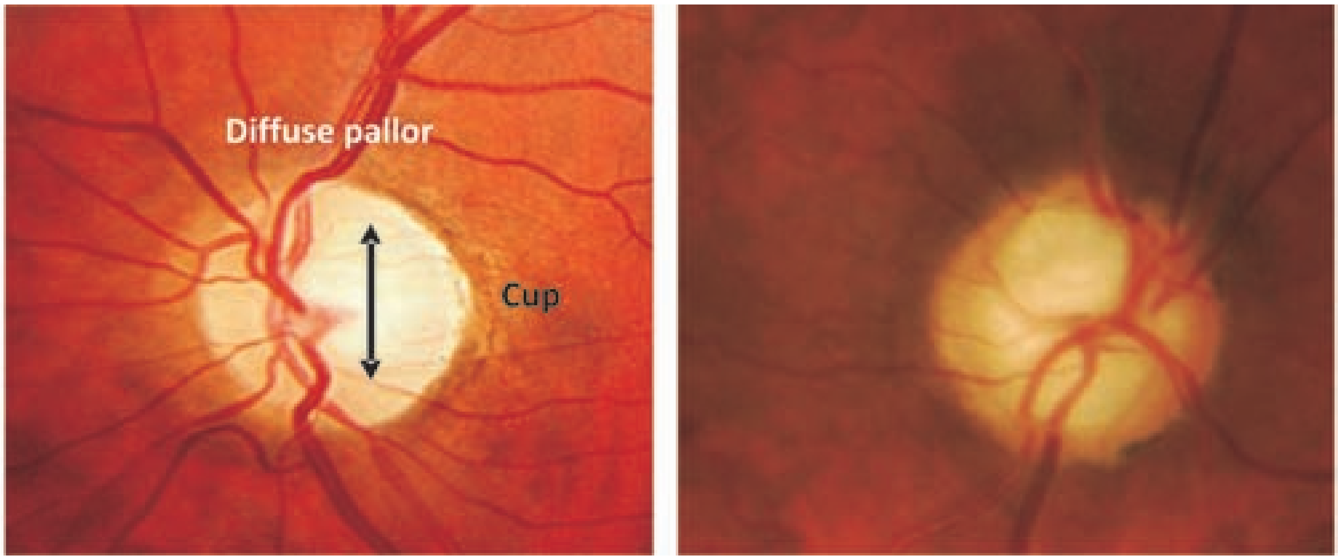


Figure 9 : Diffuse disc pallor suggestive of non-glaucomatous pathology

The normal pink colour of NRR may be pale (yellow, gray or white) due to atrophic tissue in glaucoma, some retinal pathologies, AION, chiasmal compression etc. If pallor is more than area of cupping (Figure 9a,9b), then causes other than glaucoma must be kept in mind.[6] Greenfield et al. have proposed the following criteria as suspicious for non-glaucomatous cupping in patients with pressures in the normal range: age less than 50 years, visual acuity less than 20/40, optic nerve pallor in excess of cupping, and vertically aligned visual field defects. If a patient has one or more of the Greenfield criteria, they should undergo neuroimaging. However, the absence of these criteria does not rule out the presence of non-glaucomatous cupping.

Several factors can interfere with interpretation of the neural rim width. A gray crescent in the ONH has been described, which typically is slate gray and located in the temporal or inferotemporal periphery of the neural rim (Figure 10).[13] It apparently represents a variation of the normal anatomy. However, mistaking the gray crescent for a peripapillary pigmented crescent could result in the physiologic neural rim's being misinterpreted as pathologically thin in that area.

Another source of error in interpreting the NRR is the ONH in myopia, in which the oblique insertion of the optic nerve may lead to distortion of the temporal neural rim from ophthalmoscopic view, Suggesting pathologic thinning of this tissue (Figure 11a). Rarely, Bergmeister's papilla - an atrophic partially elevated membrane is seen connected with the disc. It is the remnant of the embryological vascular system to the lens. It is usually an incidental finding and has no clinical significance. Absence of physiological cupping

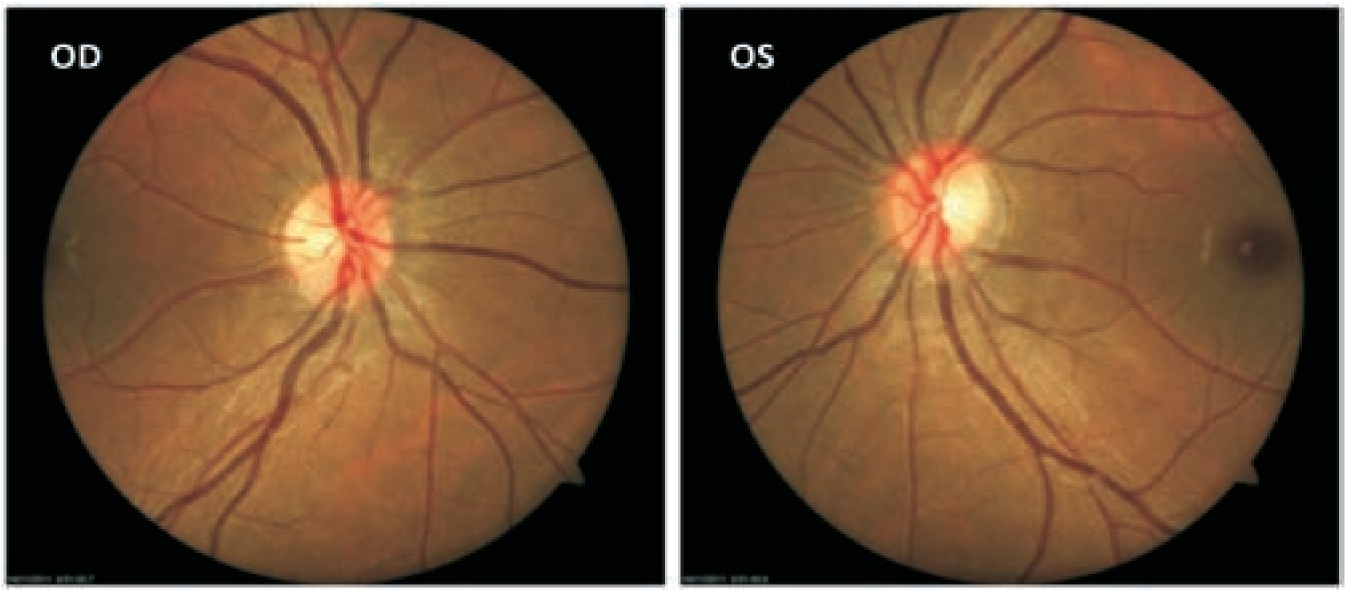


Figure 10 : A gray crescent in the ONH located in the temporal and inferotemporal periphery of the neural rim should not be mistaken as the neuro-retinal rim.

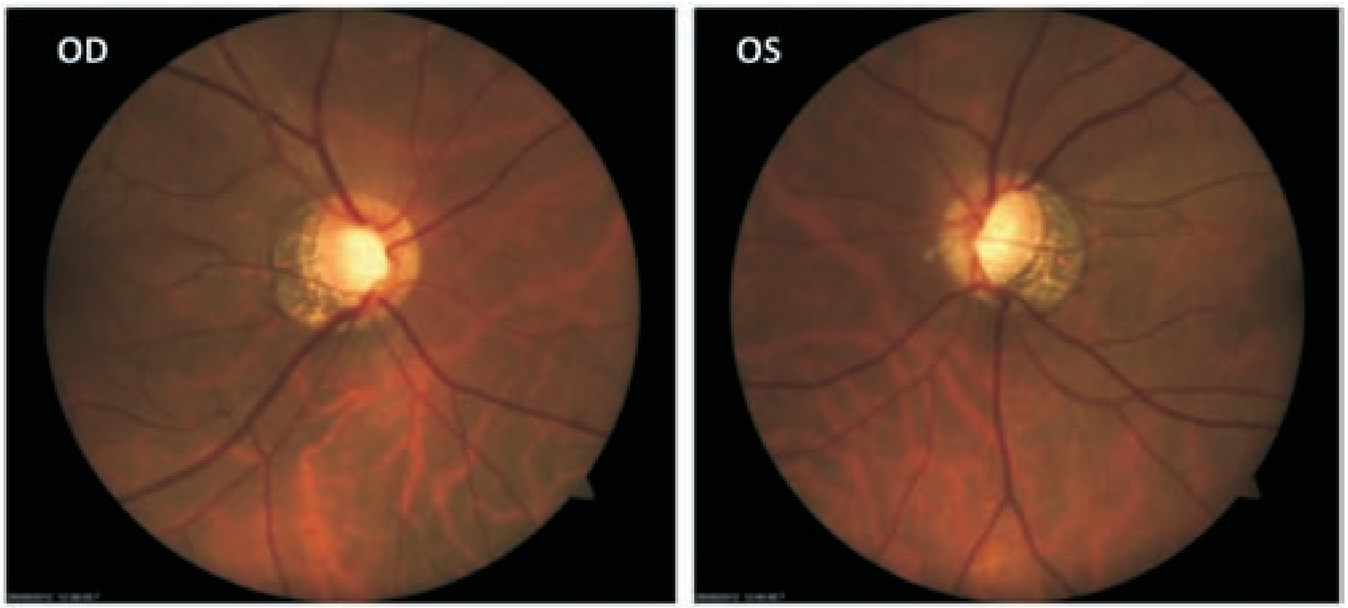


Figure 11a : Fundus photo of myopic disc showing oblique insertion of the optic nerve leading to distortion of the temporal neural rim from ophthalmoscopic view, suggesting pathologic thinning. A temporal peripapillary crescent, which may be confused with peripapillary pigmentary changes that are seen more frequently around some glaucomatous discs.

may be seen depending on the amount of regression. Therefore, asymmetry in the CDR of both eyes may be noted and mistaken for glaucoma by the beginner's.(Figure 11b)

It is often difficult to distinguish myopia from glaucoma based on a single disc evaluation and such patients should be followed over time to look for progression of structural damage which gives an indication of glaucomatous disease process. Recent advances in OCT technology allow for accurate imaging of even tilted myopic discs and are useful in this regard to pick up progression over time. Other features of highly myopic discs that may interfere with interpretation include a relatively large disc area; a shallower than usual rim which may mask the deepening of the cup in the glaucoma; and a temporal peripapillary crescent, which may be confused with peripapillary pigmentary changes that are seen more frequently around some glaucomatous discs (Figure 12). As well, the normalized databases for visual fields do not apply. Furthermore, other conditions such as myopic macular degeneration can complicate interpretation of visual fields.

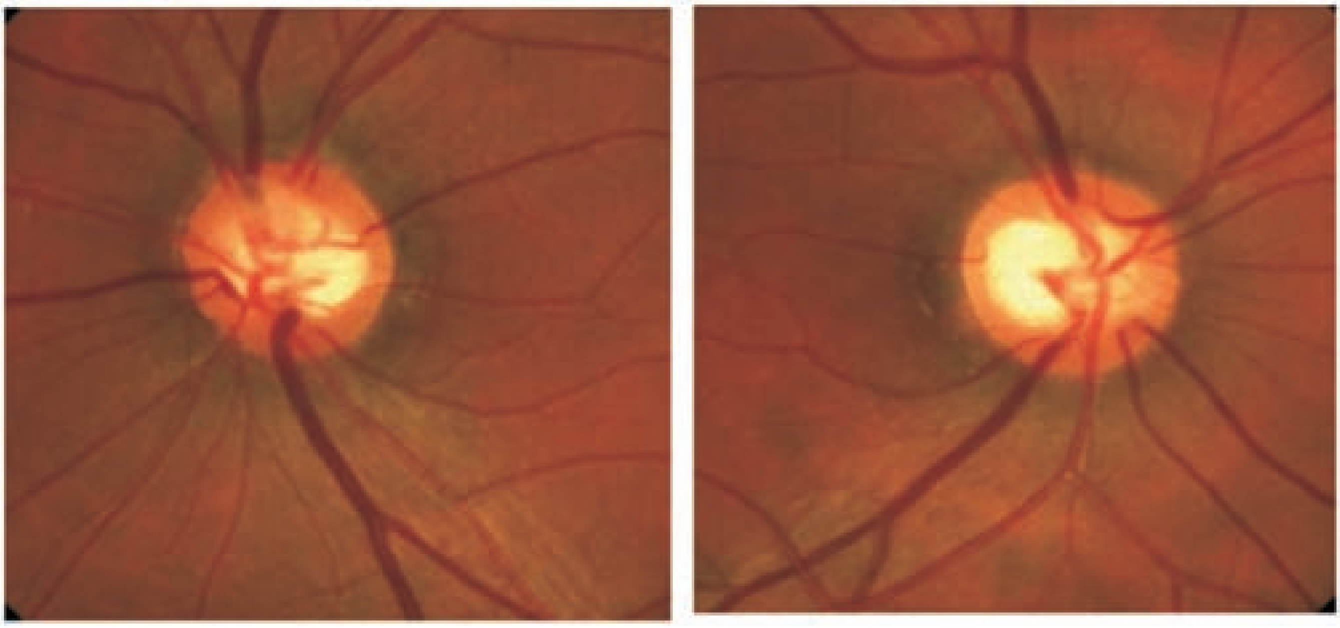


Figure 11 b : Fundus photo showing Bergmeister's papilla on the superonasal aspect of disc in the right eye , leading to asymmetry in the CDR of both eyes.

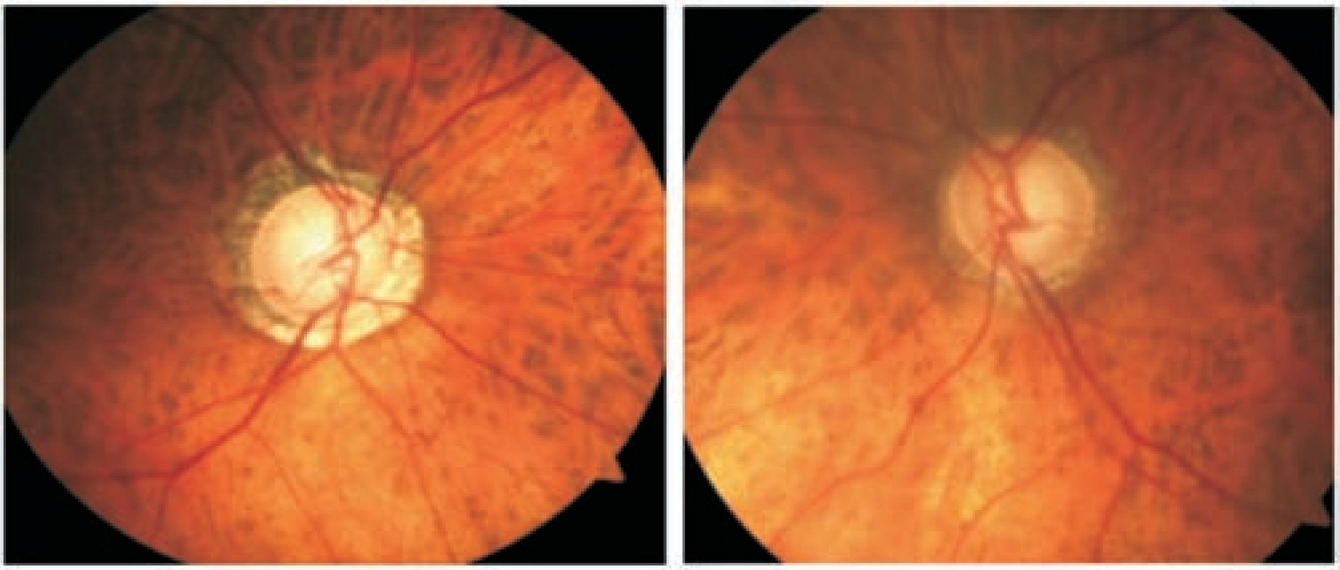


Figure 12 : Fundus photo of myopic disc with glaucoma showing relatively large disc area; a shallower than usual rim which may mask the deepening of the cup in the glaucoma; and an annular peripapillary crescent, more prominent temporally.

3. Third R : Examine the Retinal nerve fiber layer (RNFL) :

The RNFL corresponds to the nerve fibres passing from the photoreceptors over the retina as they course towards the optic disc. RNFL loss has been shown to precede glaucomatous visual field loss in patients of elevated intraocular pressure.[7] In healthy eyes, the RNFL appears slightly opaque with radially oriented striations, which has been likened to "horsehair" (Figure 13a).[8] Fibers of RNFL follow an arcuate pattern above and below the macula and are typically brighter at the superior and inferior arcuate bundles than the temporal and nasal bundles (Figure 13b).[8]

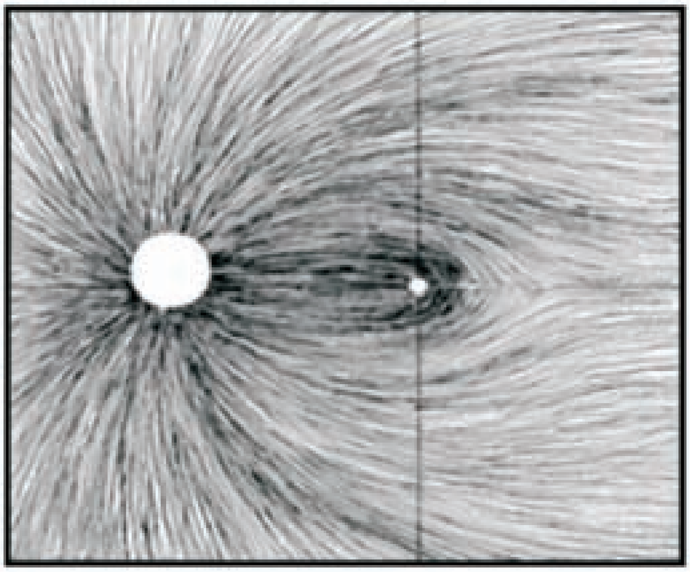


Figure 13 : Distribution of retinal nerve fibres. (a) Note the arching above and below the fovea of fibers temporal to the optic nerve head. (b) The RNFL in healthy eyes appears slightly opaque with radially oriented striations, typically brighter at the superior and inferior arcuate bundles than the temporal and nasal bundles.

Figure 14a : Normal RNFL with silvery striations

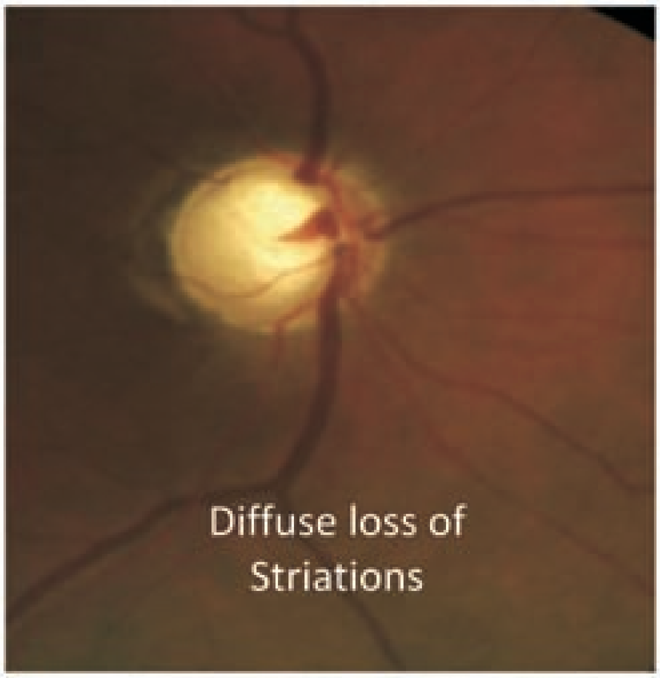


Figure 14b : Diffuse RNFL loss (Advanced glaucoma) - Loss of striate pattern with increased visibility of retinal vessel borders

RNFL examination is best performed using red-free green light through a dilated pupil. In affected areas, the normal silvery striations (Figure 14a) are lost and fundus appears darker and deeper in these areas. One has to look at striations, brightness, visibility of parapapillary retinal vessels and also for diffuse and localized RNFL loss (Figure 14b).

Slit defects may be physiological. Wedge shaped defects extending upto the disc margin are typical of glaucoma (Figure 15a-d). In the later stages of glaucoma, diffuse atrophy of RNFL is seen.

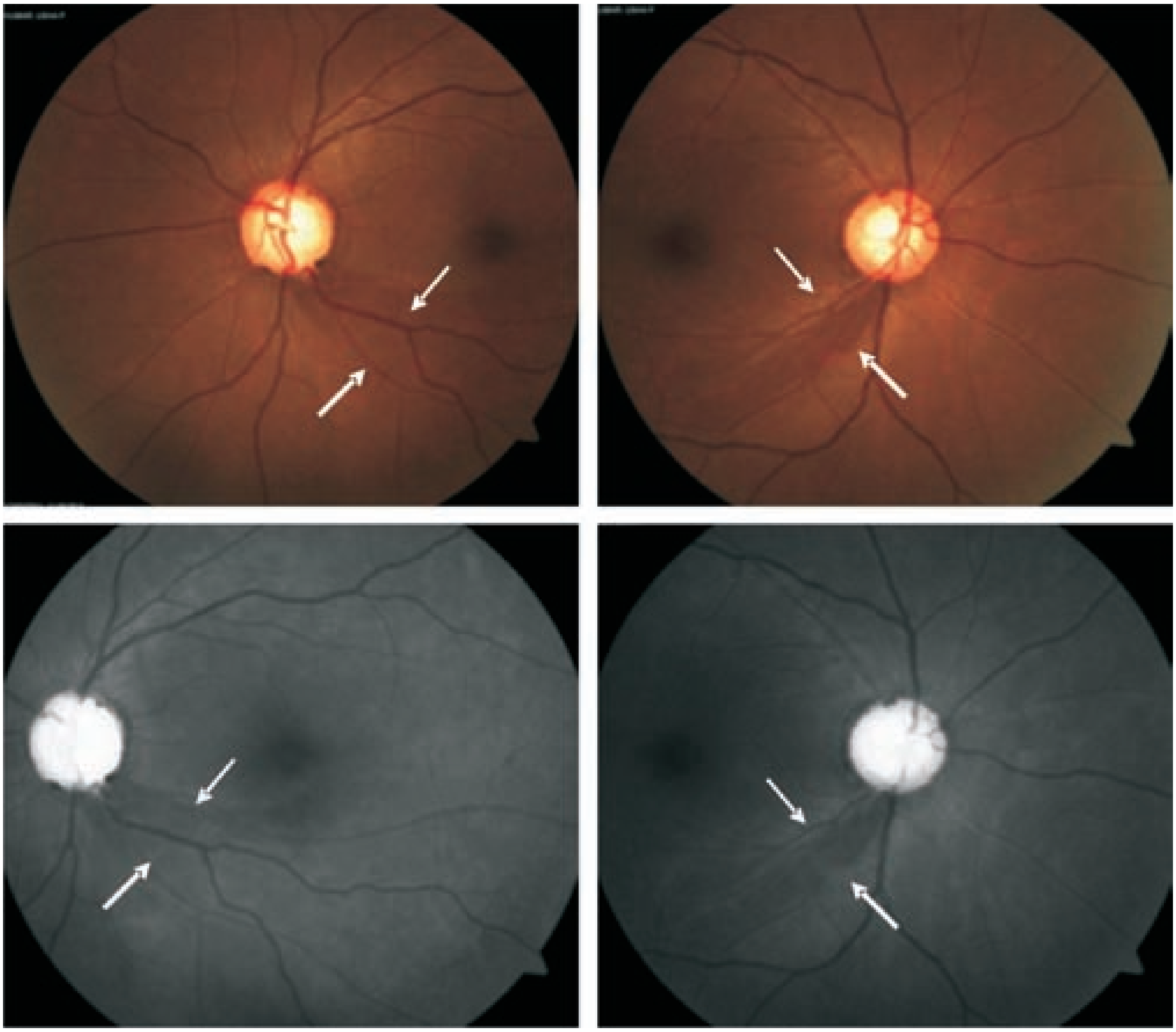


Figure 15 : Color (a,b) and Red Free (c,d) disc photographs show inferior RNFL wedge defect in both eyes.

4. Fourth R : Examine the Region of Peripapillary Atrophy (PPA) :

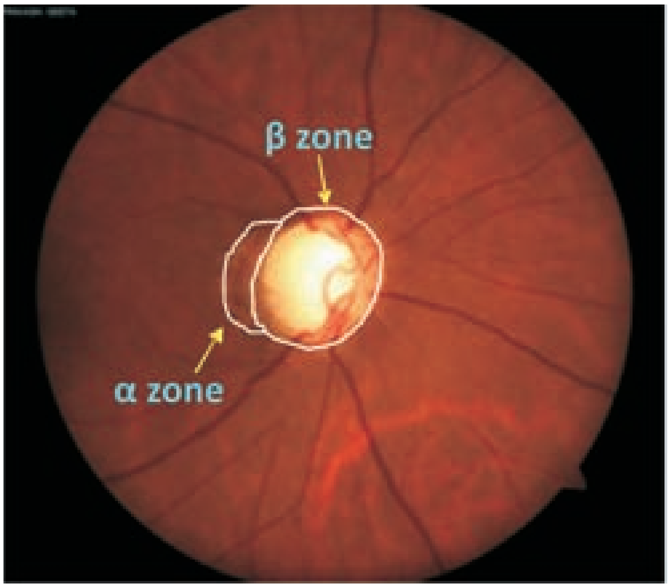


Figure 16a : Color photograph of disc showing peripapillary atrophy

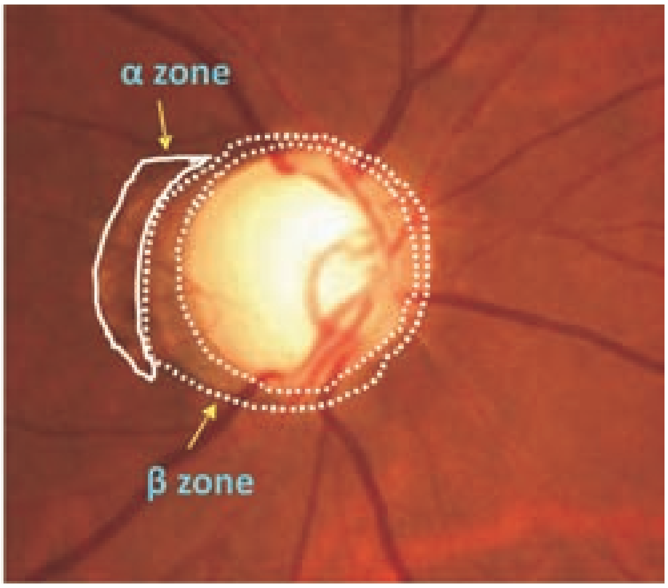


Figure 16b : Magnified view of the optic disc showing peripapillary atrophy

Peripapillary Atrophy (PPA) refers to the thinning, misalignment, irregularity, and degeneration of the retinal pigment epithelium, choriocapillaris, choroid and sclera just outside of the optic disc. PPA has an association with the development and progression of glaucoma.[6]

Evaluation of PPA aids in glaucoma assessment. Two distinct zones of atrophy – Alpha (α) and Beta (β) surround the optic disc (Figure 16).[9]

- Peripheral α zone
  - is an irregular hypo or hyper pigmented zone associated with chorioretinal thinning.
  - This zone is found in many normal eyes. Corresponds to relative scotoma
- Central β zone represents
  - This represents loss of Retinal Pigment Epithelium and choriocapillaries leaving intact choriodal vasculature.
  - β zone atrophy is seen more in glaucomatous eyes and increases with disease progression.
  - Width of beta zone inversely correlates with rim width at same area Larger beta zone à thinner rim (* Rarely occurs in the absence of zone α *Corresponds to absolute scotoma)

PPA may be focal or circumferential. Alpha and Beta zones have to be differentiated from crescents in myopic eyes and in eyes with tilted discs.

5. Fifth R : Look for Retinal and optic disc hemorrhages

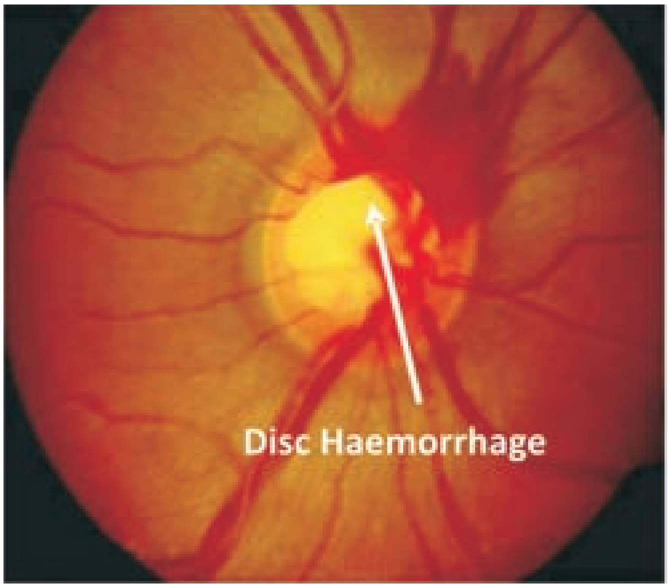


Figure 17a : Splinter ("Drance") haemorrhage in glaucomatous optic nerve.

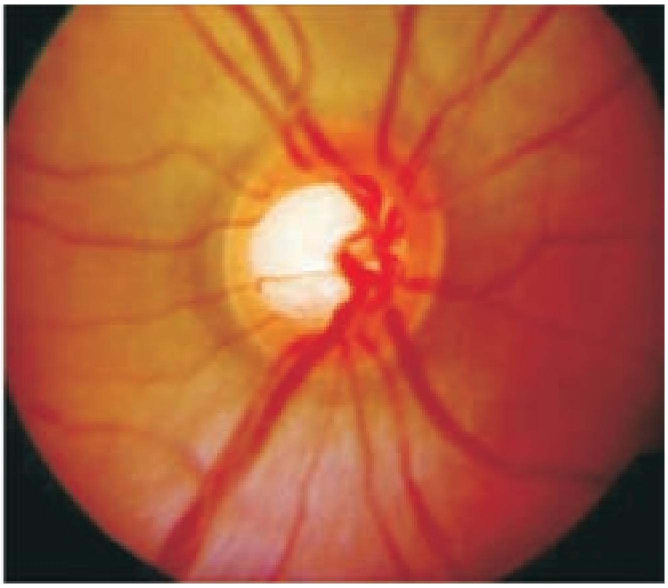


Figure 17b : Resolution of the splinter haemorrhage within 6months.

RNFL haemorrhages at the disc margin have been associated with increased risk of glaucoma progression, especially in average pressure glaucoma.[10] Disc haemorrhages are detected in about 4-7% of eyes with glaucoma.11 Optic disc haemorrhages (Drance haemorrhage) are usually splinter or flame shaped on the disc surface usually in superotemporal or inferotemporal rim (Figure 17a). More commonly seen in normal tension glaucoma, these haemorrhages are transient and last for usually 2-6 months (Figure 17b). Corresponding visual field defects may appear weeks to years later. Patients with disc haemorrhages are at a higher risk of developing glaucoma (OHTS).[12] Disc haemorrhages may occur rarely in normal eyes. Other causes such as PVD, trauma, hypertension and use of anti-coagulants like aspirin should be kept on mind. Detection of disc hemorrhages requires careful optic disc examination.

THE DISC DAMAGE LIKELIHOOD SCALE (DDLS) :

An enlarged cup disc ratio is undoubtedly linked with glaucomatous loss but the disadvantages of the CDR system (Armaly 1967) for diagnosing and quantifying glaucoma are the variation in cup sizes in the population and more importantly, the fact that the discs do not grow concentrically and eccentric cups may display localized notching. There may be significant intra and inter-observer error in this method.

To overcome these problems, the Disc Damage Likelihood Scale (DDLS) was brought forth by Dr George L Spaeth et al in 2002 to incorporate the effect of disc size and focal rim width into a clinical grading scale.[6] It is highly reproducible and does correlate strongly with the degree of field loss.

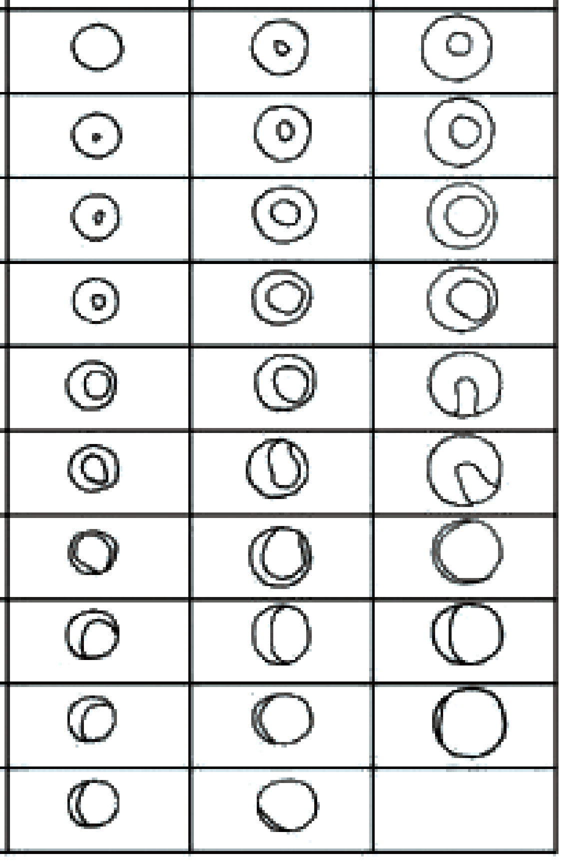
The DDLS is based on the radial width of the neuroretinal rim measured at its thinnest point. The unit of measurement is the rim/disc ratio, that is, the radial width of the rim compared to the diameter of the disc in the same axis. When there is no remaining rim, the rim/disc ratio is 0. The circumferential extent of rim absence (0 rim/disc ratio) is measured in degrees. Caution must be taken to differentiate the actual absence of the rim from sloping of the rim as, for example, can occur temporally in some patients with myopia. A sloping rim is not an absent rim. Because rim width is a function of disc size, disc size must be evaluated before attributing a DDLS stage.

The rim is defined as the width between the outer edge of the disc and the inner edge of the rim, this inner edge being the position where the surface of the disc starts to bend posteriorly towards the lamina. There are 10 DDLS Stages. The DDLS relies on the optic nerve as a direct indicator of the disease. As the scale divides glaucomatous progression into 10 stages, it can monitor disease progression better.

DDLS Scoring Chart (Spaeth et al) :

THE DISC DAMAGE LIKELIHOOD SCALE

	Narrowest width of rim (rim/disc ratio)					Examples	
DDLS Stage	For Small Disc <1.50 mm	For Average Size Disc 1.50-2.00 mm	For Large Disc >2.00 mm	DDLS Stage	1.25 mm optic nerve	1.75 mm optic nerve	2.25 mm optic nerve
1	.5 or more	.4 or more	.3 or more	0a			
2	.4 to .49	.3 to .39	.2 to .29	0b			
3	.3 to .39	.2 to .29	.1 to .19	1			
4	.2 to .29	.1 to .19	less than .1	2			
5	.1 to .19	less than .1	0 for less than 45°	3			
6	less than .1	0 for less than 45°	0 for 46° to 90°	4			
7	0 for less than 45°	0 for 46° to 90°	0 for 91° to 180°	5			
8	0 for 46° to 90°	0 for 91° to 180°	0 for 181° to 270°	6			
9	0 for 91° to 180°	0 for 181° to 270°	0 for more than 270°	7a			
10	0 for more than 180°	0 for more than 270°		7b			



DDLS scores of 1 -3 are rarely associated with glaucomatous field loss. Any disc graded stage 5 or higher is unhealthy. It will almost always be pathologic, although it may not be glaucomatous. Damage from glaucoma will usually be infero or superotemporal. Some individuals are born with DDLS 3, whereas others begin with DDLS 1 discs. For this reason, noting that a person has a DDLS 3 optic disc indicates that it is reasonably healthy and that there is no field loss. This score is not proof that the disc's health has not worsened, however, because it could have been a stage 1 or 2 in the past.

CATEGORIZATION

The DDLS allows you to quantify the amount of damage that the optic nerve has sustained. Visual field loss usually will not occur before stage 5. The differentiation between very early and no damage is important, because a neuroretinal rim that has already narrowed is likely to become narrower still, whereas an undamaged rim is far more likely to remain stable. One may choose to defer treatment and observe closely patients with optic nerves of stages 0 – 5, because the consequences of treatment may outweigh those of nontreatment. Unless glaucomatous progression has stabilized (eg, in cases of inactive glaucoma secondary to trauma or corticosteroids), a DDLS score of 6 – 10 strongly supports aggressive treatment.

MONITORING

The stability of a patient's glaucoma is often best determined by evaluating the optic disc. The DDLS Scores may be recorded on patient's chart every time the fundus is examined, i.e.; at every visit when assessment is being made whether their glaucoma is stable, improving, or deteriorating (Figure 18). The stage of disease is graded considering the amount of disc damage estimated by DDLS. The optic discs may be graded in three zones: green, yellow or red. In the green zone, which comprises DDLS of 1–4, the patients do not have definite damage. When a patient is in the yellow zone (with a DDLS of 5–7), the optic nerve is definitely damaged, but the person may still be asymptomatic. It is certain that the optic disc is not normal. Finally, when a person is already in the red zone (with a DDLS of 8, 9 or 10), that is, the person already has a disability. The patient may have decreased quality of life or impaired ability to perform the daily activities.

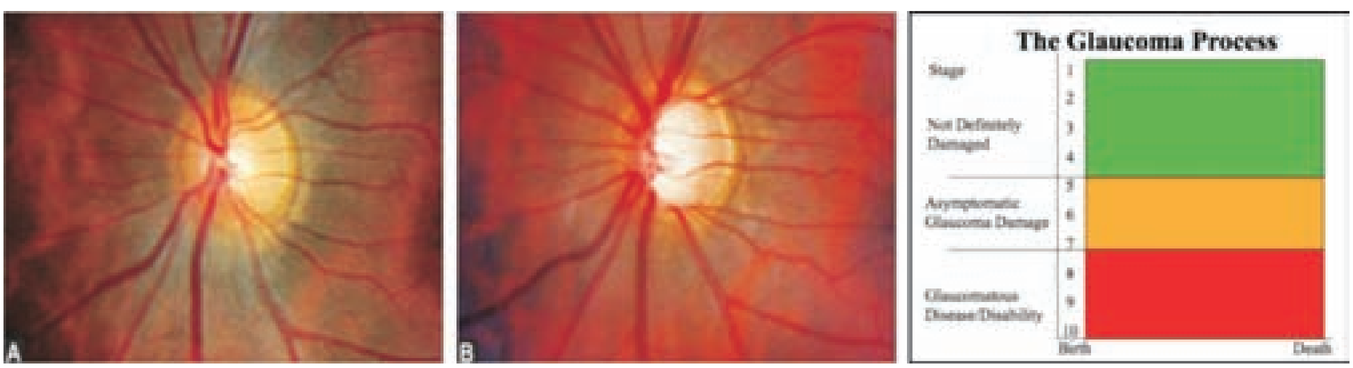


Figure 18a,b & c : showing progression of glaucomatous optic neuropathy on serial follow ups

Correlation of optic disc and visual field

It is very important to correlate optic disc findings with the visual field of patients as it helps to tide over diffult and confusing siuations and also helps to confirm the diagnosis. A few examples are given in Figure 19-21.

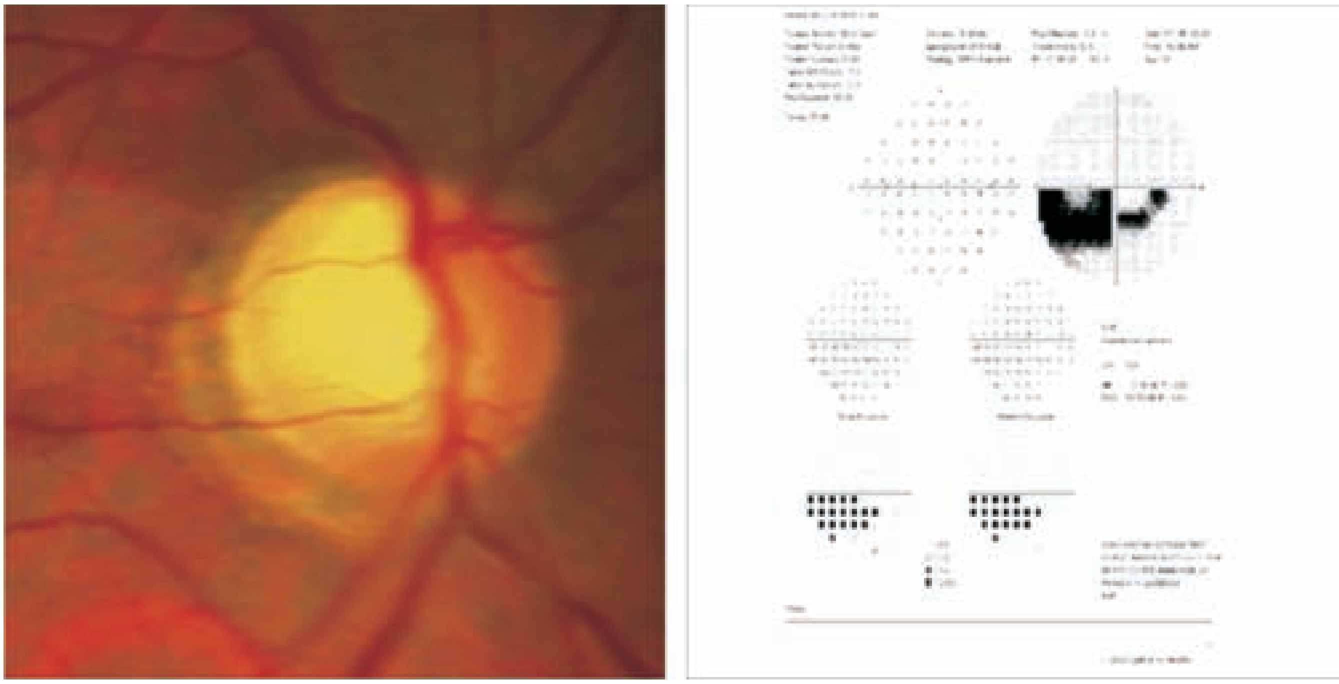


Figure 19 : Disc photograph showing superotemporal notching and superior NRR thinning, correspondingly HVF shows inferior arcuate scotoma

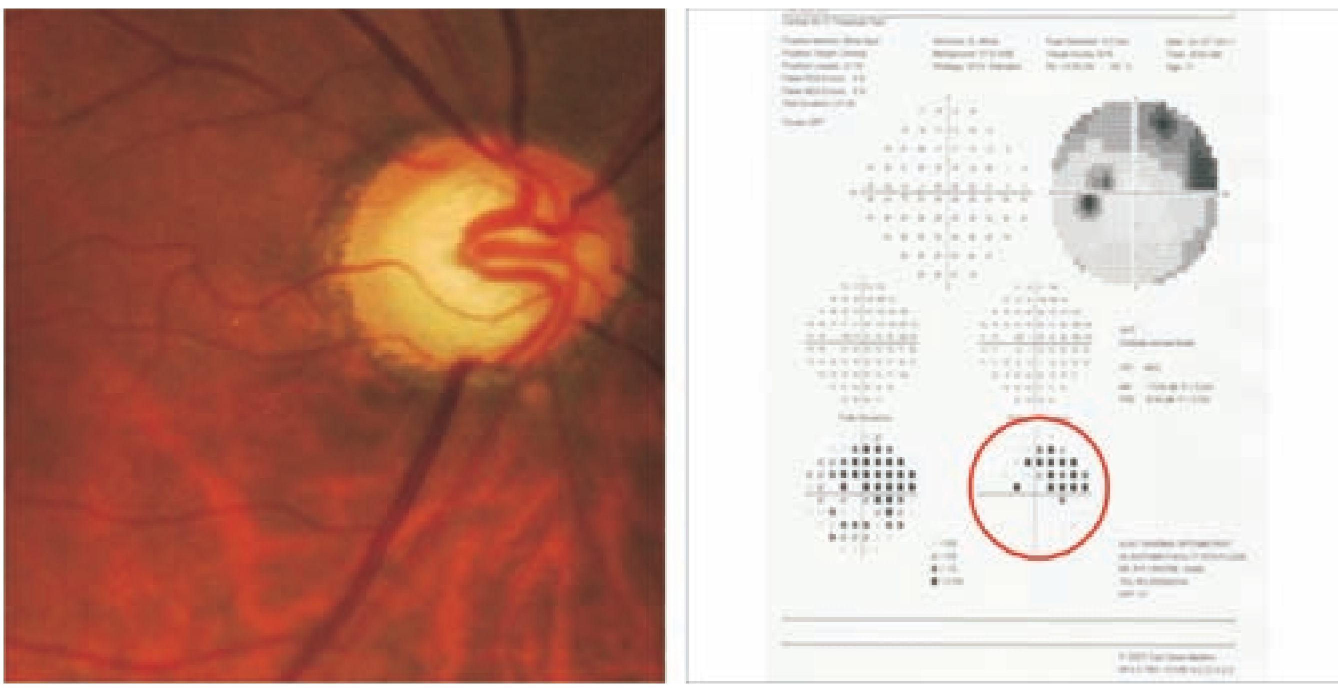


Figure20 : Disc photograph showing inferotemporal notching and inferior NRR thinning, correspondingly HVF shows superior arcuate scotoma.

Figure21 : Disc photograph showing shallow cups with NRR pallor (pallor>cupping). HVF shows scotoma respecting the vertical meridian, indicating a neuro-ophthalmic etiology.

Documentation of optic disc findings

All the findings on the optic nerve should be documented. Labeled hand drawn diagrams are very helpful, and should be done as far as possible in the out patient records with cooment on the size of the disc, pallor if any, notching and the vertical cup-disc diameter ratio. Fundus photographs is another good way of documentation, although the illumination and shine of the photo can change some parameters- this should be kept in mind. Both colour and red free photographs should be taken at baseline and during follow up visits on a 6 monthly or yearly basis.

How to describe a disc ?

Remember a simple 3C's rule for describing any optic disc – Contour, Colour, Cup. You should comment on each of these three findings in general and then come to specifics of a glaucomatous disc with the 5Rs. For example see the disc below :

So, we describe the given disc as – an average sized disc with inferotemporal notching of NRR, with VCDR of 0.7:1 with IT RNFL wedge defect.

- Ring – average sized disc
- Rim – NRR - Inferotemporal (IT) notching
- RNFL – IT wedge defect
- Peripapillary atrophy - not distinctly visible
- Haemmorhage - Absent

Disc Photos of different cup sizes (Figure 22 a-l) :

A series of disc photos showing various disc sizes and cupping, in increasing order of cupping (vertical cup disc diameter ratio).

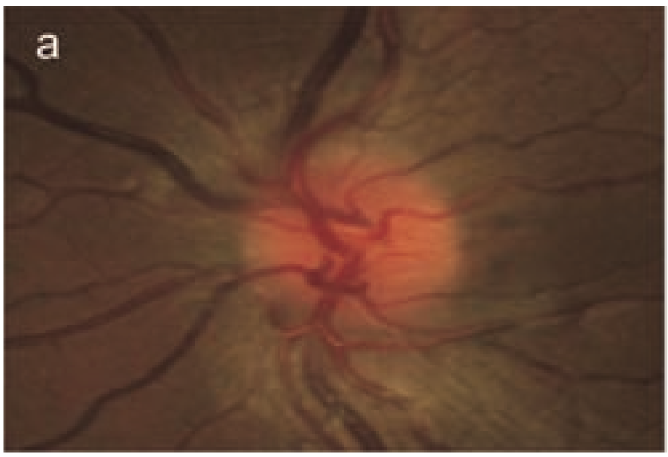


Figure 22a: Small sized cupless disc

Figure 22b: Average sized cupless disc

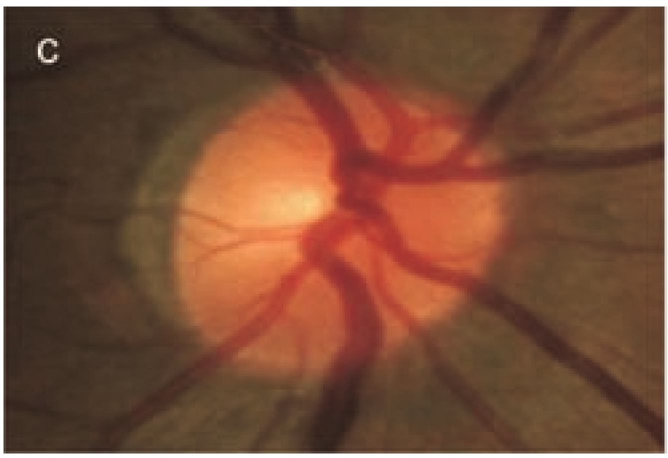


Figure 22c:Average sized tilted disc(mild), with CDR of 0.1:1 with temporal crescent

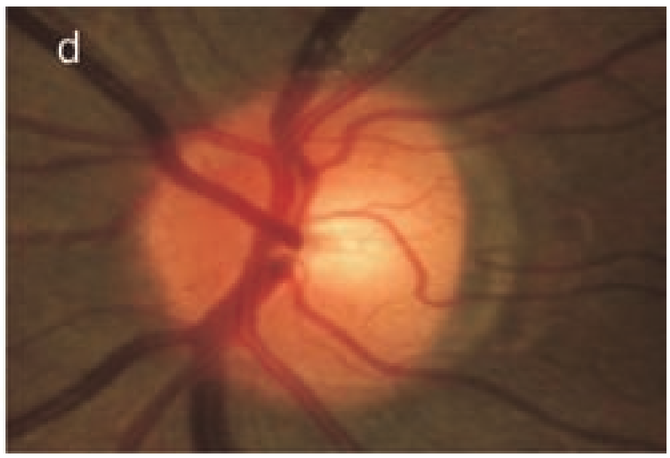


Figure 22d Average sized disc, with CDR of 0.2:1 with temporal crescent

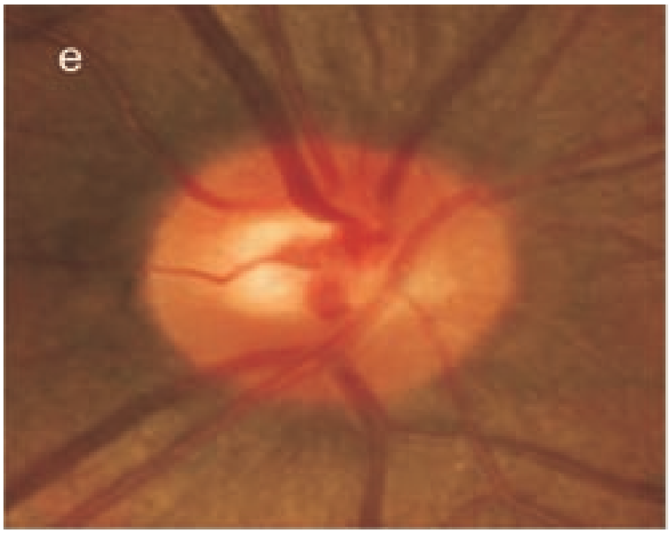


Figure 22e :Average sized disc, with CDR of0.3:1

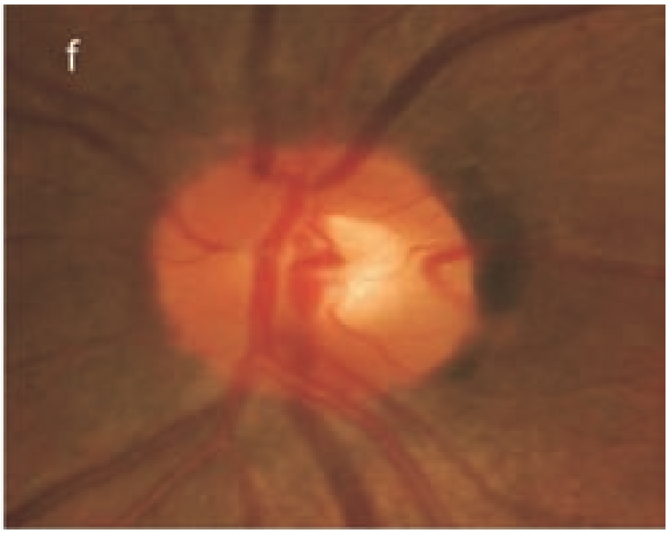


Figure 22f :Average sized disc, with CDR of0.4:1

Figure 22g :Average sized disc, with CDR of0.5:1

Figure 22h:Average sized disc, with CDR of 0.6:1

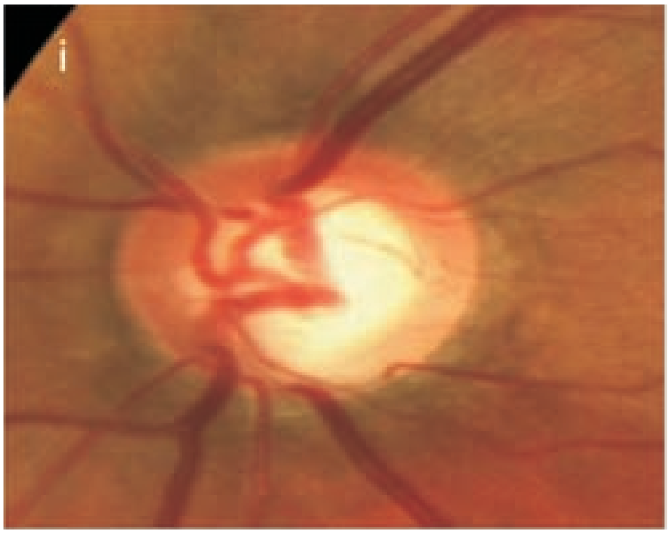


Figure 22i :Average sized disc, with CDR of0.7:1 with infero-temporal notching

Figure 22j:Large sized disc, with CDR of 0.8:1 with significant thinning of superior NRR violating the ISNT rule

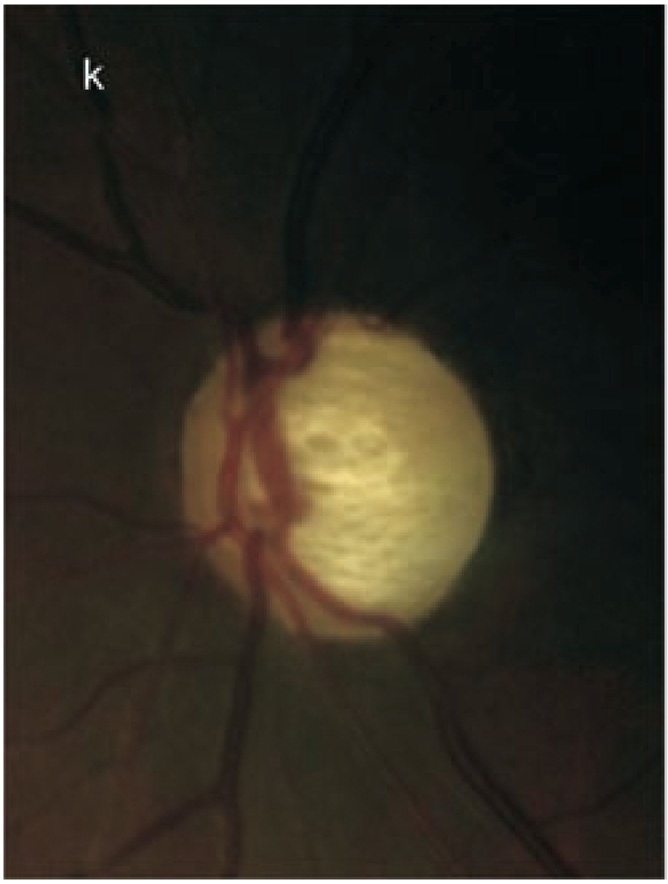


Figure 22k :Average sized disc, with near total cupping with laminar dot sign (superior very thin rim of NRR present)

Figure 22l. Average sized disc, with total cupping (bean pot fundus) with bayonetting and nasalisation of vessels with laminar dot sign with peripapillary atrophy

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Standard Automated Perimetry

AUTOMATED PERIMETRY

The visual field is defined as the space that one eye can see while steadily fixating on a target. Visual field analysis is an important part of ophthalmic and neurological examination. Perimetry has been vital in glaucoma management particularly in diagnosis and also to monitor the progression of glaucoma.

Basic Perimetry Techniques

Kinetic vs. Static perimetry

Traquair's description of the visual field as a three dimensional hill island of vision in a sea of darkness helps us in understanding the two basic strategies of perimetry testing. Testing along the X-Y axis (kinetic testing) determines location in the visual field while testing in the vertical Z axis as is done during static testing can detect the depth of a visual field defect.

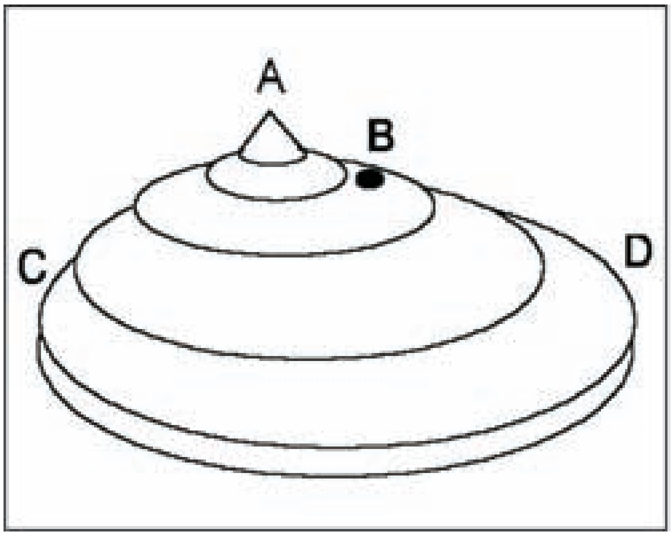


Fig. 1: Traquair's island of vision with blind spot B

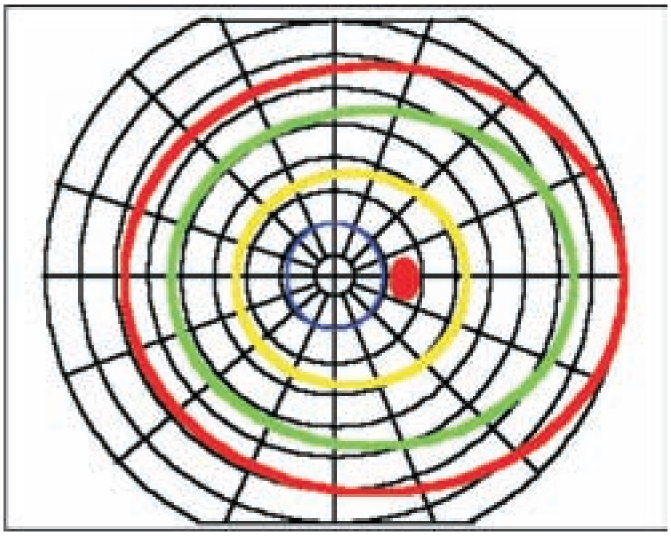


Fig. 2: Isopter patterns with Goldmann perimeter

In kinetic perimetry stimuli of varying sizes and/or brightness are moved from non seeing to seeing area and the limits of the visual field are mapped in isopters. An isopter forms the border that connects the threshold points of a given stimulus. Using different stimulus sizes many such isopters can be found. The shape of such isopters is ovoid.

In static perimetry which is now employed in all automated perimeters a fixed size stimulus is varied in brightness in different locations in the visual field and the threshold is determined for each tested point. Threshold is the dimmest target that the patient can see at a test location. The obtained threshold value (expressed in decibels or dB) may vary within 1-2 dB when tested twice during a field test (fluctuation). This is because the island hill of vision is considered to be an island of quivering jelly and not of solid rock.

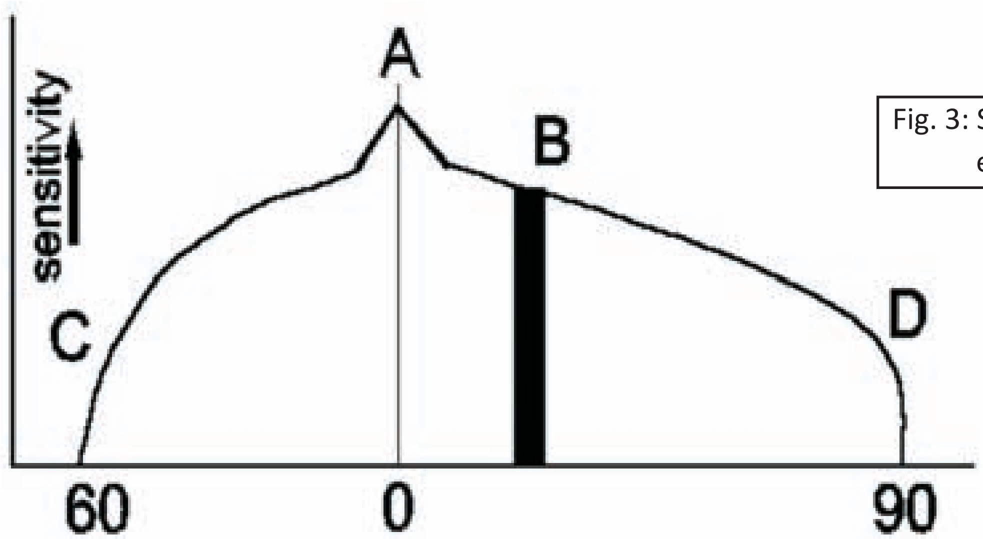


Fig. 3: Static threshold testing to estimate sensitivity

The disadvantages of manual kinetic perimetry include

1. Skilled technician is needed
2. Kinetic tests are mostly suprathreshold and subtle changes may be overlooked
3. Isopter patterns may be artistic depending on the testing technician and statistical analysis is difficult
4. Results may not be reproducible and comparable across various centres

The advantages of the older kinetic techniques are that most practitioners were familiar with the isopter patterns and that the testing equipment was relatively inexpensive and easy to maintain.

There are several automated perimeters now available – these include the Humphrey field analyzer (HFA), Octopus, Oculus, Opto, Dicon and Synemed etc. Of these the most popular ones are the HFA (Carl Zeiss) and the Octopus (Interzeag – Haag Streit).

Basic Terminology

Differential light sensitivity (DLS) – The ability of the visual system to detect a difference in contrast between two areas of different contrast forms the basis for perimetry. For a strict definition of DLS certain test conditions have to be fixed.

The parameters are

- background luminance (by International standards this is set to 31.4 apostilbs)
- background color of white (yellow in Blue on yellow perimetry),
- stimulus size 4 mm diameter corresponding to Goldmann size III,
- stimulus color white (blue in BY perimetry)
- exposure time (100 milliseconds in Octopus perimeters and 200 ms in Humphrey machines).

Apostilbs (asb) – it is a measure of differential light threshold and is measured in units of brightness per unit area eg. candelas/square metre.

Decibels – it is the logarithmic representation of brightness and inversely proportional to asb (Asb = 1/dB). This implies that the higher the dB value the dimmer the stimulus and vice versa. The brightest stimulus that the machine can produce is 0 dB (in HFA 0dB = 10000 asb while in Octopus 0dB = 1000 asb)

The ***threshold*** is the estimated luminance (brightness) of the test stimulus which has a 50% detection rate for a given set of test parameters at a given retinal location or test point. The normal values obtained are compared with age matched normal values in different test locations on the visual field.

Threshold strategy and bracketing – the stimulus luminance is varied up and down in steps (staircasing or bracketing) to find the luminance value (threshold) that is perceived by the patient with a probability of 50%. The program then goes on to present a series of brighter or dimmer stimuli at all test locations in random order while the computer keeps track of the responses. Testing starts from a luminance level which is derived from preliminary results obtained within the same examination at adjacent test locations. The local threshold is then first determined in 4 dB steps and then 2 dB steps. Testing usually starts in four primary anchor points at the age corrected normal value minus 4 dB followed by an increase in stimulus luminance when the patient does not see the first stimulus. Once the threshold is crossed the procedure is reversed in steps of 4-2-1 dB steps in Octopus (fig.4) and 4-2 dB steps in HFA machines. For a full threshold (HFA) or Normal (Octopus) strategy about 4- 6 stimuli are needed to determine the threshold value at a given test location. This process has been considerably shortened by the use of Swedish interactive threshold algorithm (SITA) and Tendency oriented perimetry (TOP) programmes.

Stimulus source – there are 3 ways to generate a stimulus. One is to project a light source using filters and mirrors (Goldmann). A second method is to embed light emitting diodes (LED) in the surface of the bowl and turn them on or off when needed. The current method employed is to randomly project stimuli of varying brightness on to a dimly lit hemi bowl (HFA) or use a direct projection system with a pseudo-infinite target (Octopus).

Fixation is vital for perimetry. Monitoring systems include Heijl Krakau's method of blind spot monitoring, gaze tracking, forehead sensors and CCTV with infrared camera.

Practical Perimetry – How to do a visual field test ?

Calibration – The calibration of background and target is done automatically and is usually reviewed periodically by a service engineer.

Testing conditions – the perimeter should preferably be placed in a dimly lit room with no visual or auditory distractions.

Refraction – The full near correction has to be placed in the holder for HFA perimeters while near correction is not needed for Octopus machines. High refractive errors (more than 4 diopters) are best corrected with contact lenses. When refractive correction is used only thin rim trial lenses should be used and near vision is corrected only for the Cupola perimeters (HFA and Octopus 101).

Pupil size – the pupil size is now automatically measured by the modern perimeters and indicated in the printouts. The minimum pupil size required is 3.5 mm. Miotic pupils may be dilated for field examination. A repeat field test must preferably be done with the same pupil size every time.

Data entry – all basic patient information such as ID no, birth date, visual acuity must be entered. The age is vital as all comparisons of the patients' test results are done with age matched normal data.

Patient positioning – one eye is occluded flush to the nose but not protruding to occlude vision of the viewing eye. The buzzer is placed in the patient's hand. The chair height is adjusted and the patient is positioned comfortably with the chin touching the chin rest and forehead touching the forehead band. The lens holder is placed as close to the eye as possible without touching the eyelashes. If the patient does not need a lens the lens holder may be flipped away.

Instructions to patients – Patients must be encouraged to steadily view the fixation target and asked to press the buzzer when the stimulus is seen. Some of the stimuli may be bright and easily seen while some may be dim. Even dimly perceived stimuli should be responded to by the patient. After pressing the buzzer the patient is instructed to blink as viewing the fixation target without blinking is very uncomfortable. The fixation target can be changed if the patient has no central vision. The approximate test duration for a full threshold test is about 10 minutes while with Swedish interactive threshold algorithm (SITA) and TOP it can be as short as 1-3 minutes. Many patients appreciate the presence of a perimetrist nearby and therefore a patient must not be left alone once the test commences. The occluder should be applied in such a way that the patient feels comfortable. After completing the test in one eye the occluder is removed and the lights may be turned on for a short while to allow the occluded eye to recover from its dark adapted state before it is tested.

Program selection

Extent of field – Most often it is sufficient to test the central 24 or 30 degrees of the visual field in patients undergoing glaucoma evaluation. This central region is where majority of retinal ganglion cells are located. In the HFA these are termed as 24-2 or 30-2 tests. The test points are located 6 degrees apart. Peripheral visual fields are tested only rarely in clinical practice. In the Octopus (direct projection type) perimeters the peripheral field cannot be tested.

The G1 program of the Octopus perimeter is a unique program in which the central testing grid accentuates the nasal step and has a higher resolution in the paracentral area (2.8 degrees). It is also possible to perform the test in phases and stages in the Octopus.

In advanced glaucoma it is useful and sufficient to test the central 10 (10-2) or 5 degrees (Macula program) alone.

Testing strategies

Suprathreshold – This method of testing is not used in common clinical practice. In a suprathreshold examination each stimulus presented is intense enough to be easily seen by normal subjects. The same level (brightness) stimulus is used across the entire visual field and the patient respose are recorded as 'seen' or 'not seen'. This type of testing is sometimes used for rapid screening of large populations (eg Motor vehicle tests etc).

Threshold related – In this strategy also all stimuli used for testing are suprathreshold but the stimulus brightness varies in different test locations. In other words the stimulus intensity at a given point is related to the expected normal threshold but is brighter and the contour of the hill of vision is respected. The usual threshold related tests use stimuli about 5dB brighter than the expected normal threshold. This type of testing is considered to be a coarse form of field-testing and is not used in common clinical practice.

Full threshold – During threshold examination the machine estimates the visual sensitivity at each tested point. This is done by a staircase or repetitive bracketing strategy as described earlier in this chapter. From a clinician's perspective a full threshold test is the most useful test a field machine can perform. It is however tedious for the patient and may take 10-15 minutes per eye. It has now been replaced by faster strategies such as SITA and TOP.

SITA and TOP - SITA in the HFA and TOP in the Octopus work by using patient responses and the timing of responses to customize the test for each patient. They reduce the test time by almost half without affecting the diagnostic capability. Threshold estimation is not done at all points and by the use of artificial intelligence; several test values are obtained by interpolation of adjacent points. In HFA SITA tests can be performed as either ***SITA standard*** (preferred by most clinicians) or ***SITA Fast*** (used for rapid screening). The Dynamic strategy in Octopus machines is a test procedure with varying step sizes and one threshold crossing. The steps are small in regions of normal sensitivity and larger in locations, which are depressed. This reduces the test duration significantly.

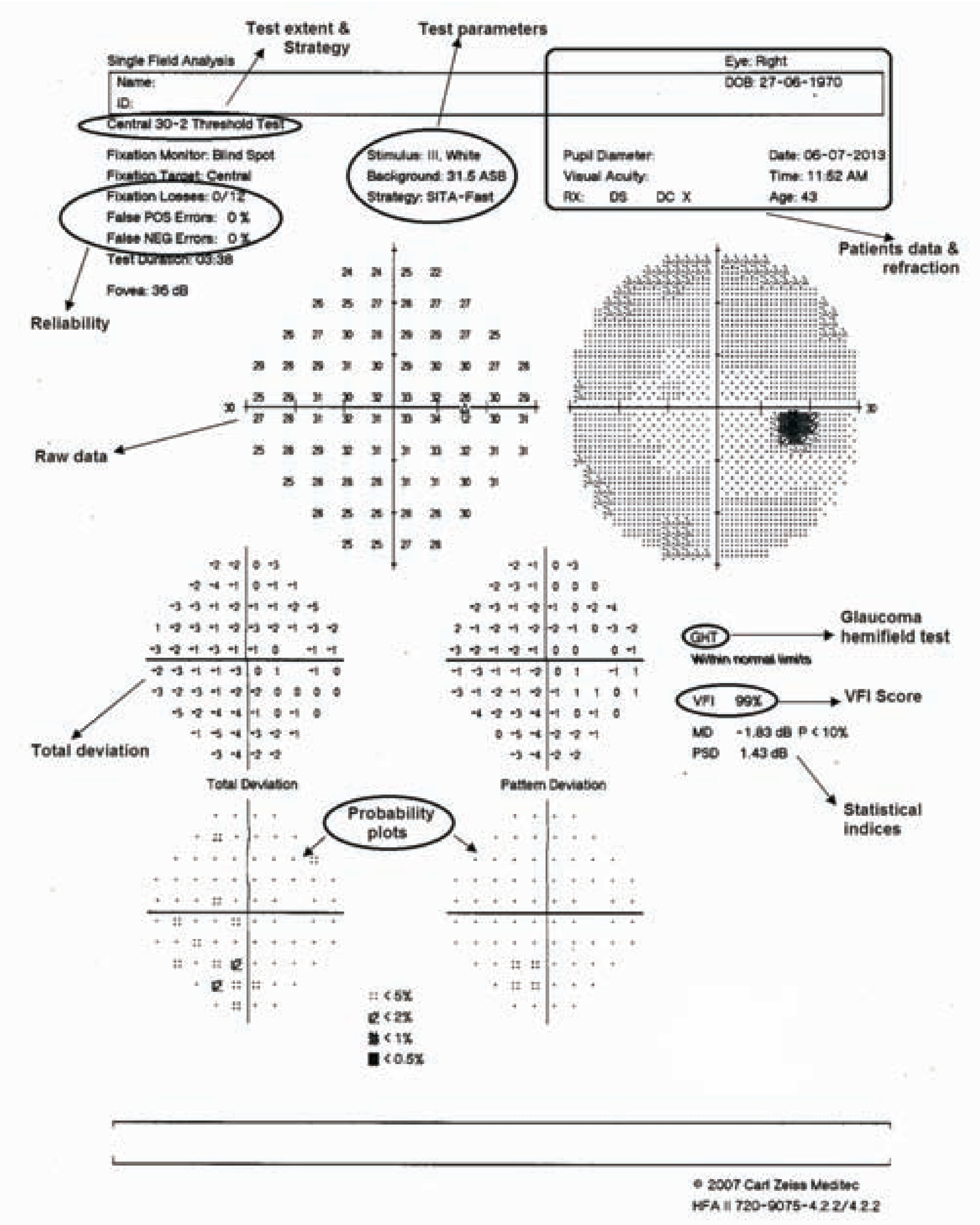
Goldmann Kinetic Perimetry (GKP) software in Octopus 900 series perimeters – this offers a full 90-degree field spherical cupola perimeter combining automatic static and manual kinetic perimetry. It employs the same Goldmann standard stimulus sizes, filter settings and draws isopters in colors. The Goldmann Kinetic Perimetry option is particularly useful in very advanced glaucoma where standard testing may not provide any useful data.

Flicker perimetry in Octopus machines– In this method the Critical fusion frequency (CFF) is measured (instead of DLS) in different locations of the visual field. Several studies have shown the value of CFF perimetry in glaucoma especially in earlier detection of disease and is particularly useful in detecting glaucomatous field defects in the presence of coexisting cataract.

Pulsar perimetry in the new Octopus 600 machine combines Contrast sensitivity with flicker testing and may detect field changes earlier than standard testing.

Stepwise interpretation of single visual field data –

The Ten Step Method (Fig.4)



Step 1 – Look at the patient data. Check if the name, age, ID number and refraction data are entered correctly. The visual acuity will also correlate with the foveal threshold (foveal threshold is estimated in HFA machines). Also verify if the pupil size was measured and is adequate (min size is 3.5 mm).

Step 2 – Examination data – this gives information about the strategy (full threshold/SITA in HFA and Normal/TOP in Octopus) and extent of field tested.

Step 3 – Reliability – The percentage of fixation losses, false positive and false negative responses indicate reliability. An unreliable field test should be repeated. A high percentage of FP may indicate a trigger-happy patient while false negatives indicate an inattentive patient. False negatives are commonly observed with advanced field loss and do not mean that the patient was inattentive. Reliability of a field test depends on various factors including proper patient instruction and location of the blind spot on initial perimetric testing (if the blind spot is wrongly located at the start of the test fixation loss cannot be tested accurately by the blind spot monitoring method)

Step 4- Gray scale – The grey scale in the printout gives us a general impression of the tested visual field. It can be used to describe the damage to the patient or relatives. To develop a grey scale printout, interpolated threshold values are assigned to locations between test points and threshold sensitivities are combined into groups of 5 dB in width so that the range from 1-40 dB is assigned to 8 levels of grey. Hence subtle or early defects may not be seen in the gray scale and such defects are better observed in the probability plots.

Step 5 – Total and pattern deviation including probability plots (termed comparisons and corrected comparisons in Octopus printouts) – The total deviation is the difference between patient's measured thresholds and the age matched normal value at each tested location. The total deviation plot has a table of numeric values which represent the actual difference and below it is shown a probability plot. The symbols in the probability plot indicate the statistical significance of each measured deviation. A key to the probability plot is shown below. For example a test location with the symbol < 1% means that fewer than 1% of reliable normal fields in the age related database have a low sensitivity.
The pattern deviation adjusts for generalized depression due to cataracts or refractive errors and helps to expose a localized scotoma. There is a probability plot below the pattern deviation.

Step 6 – Look at the Numeric or raw data display (called Values in Octopus printouts) – It is useful to now view the decibel threshold sensitivities at each test location. Any abnormal points seen in the total and pattern deviation plots can be looked at in more detail.

Step 7 – Global indices or statistical indices –The four main indices are

- Mean deviation or mean defect (in Octopus) signifies overall or average severity of field loss. MD represents the average difference between normal age corrected sensitivity values and the measured values at all test locations. A normal field should have MD of 0 dB. In the HFA worsening of the field is associated with negative MD values while in the Octopus MD values become positive with increasing defects.

- Visual field index (VFI) – VFI is an index seen in newer HFA machines. It is similar to MD and is expressed as a percentage. It is said to be more resistant to field changes due to cataract and after cataract surgery.
- Pattern standard deviation (loss variance in Octopus) is an index of the degree to which the numbers in the total deviation plot differ from each other. Probability (P) values are assigned when PSD exceeds that found in 90% of normals.
- Short term fluctuation – It is the standard deviation of multiple measurements of threshold within a test session at 10 standard locations and weighted according to the variance of the normal population. SF is usually 1-2 dB in normal reliable fields. SF is not derived in SITA in order to shorten the test time.
- Corrected pattern deviation (corrected loss variance in Octopus) – this index is obtained from PSD by correcting for SF i.e CPSD = PSD – SF. The CPSD or CLV is useful in identifying a local scotoma.

Step 8 – Glaucoma hemifield test (HFA) or Bebie curve (Octopus) – The GHT compares 5 zones in the upper hemifield with mirror image locations in the lower hemifield. These zones are in the areas where glaucomatous defects are most likely to be seen. A score is assigned to each zone based on percentile deviations in the pattern deviation plot of points. The difference in scores between the upper and lower zones is compared with age related normal. 5 possible messages appear – Outside normal limits, borderline, generalized reduction, abnormally high sensitivity and within normal limits.

Step 9 – Is the test report abnormal? - The minimum criteria for abnormality are (Anderson's criteria)

- The localized defect should be a cluster (in an expected location such as the arcuate or paracentral area) of at least 3 or more points which have sensitivities occurring in less than 5% of the population and one of which has a sensitivity occurring in less than 1% of the population. Test locations surrounding the blind spot are to be ignored in this analyses.
- The PSD has a value that occurs in less than 5% of the population.
- The Glaucoma hemifield test (GHT) is abnormal.

In the Octopus printouts of a reliable field (reliability factor should not exceed 15) an MD value more than 2 or LV more than 6 can be considered as criteria for abnormality.

Step 10 – Does the report correlate clinically – Interpretation of a visual field report must be supported by clinical findings (optic disc changes/nerve fiber layer defects in glaucoma). A typical field defect should correlate with corresponding disc/NFL defects. It is well known that the converse is not true – ie standard automated white on white perimetry (SAP) may be normal even if a NFL defect has been noted on clinical examination. This is because structural changes occur earlier than functional changes.

Typical glaucomatous field defects

- Asymmetrical across horizontal midline
- Field defects located 5-25 degrees from fixation (mid periphery)

- Cluster of depressed points
- Reproducible and not due to other pathology (macular lesions etc)

A field test done for the first time should not be considered as a diagnostic test for decision making because most patients have a learning curve and do better on repetitive testing. A second or even a third test should be taken as a baseline from which all subsequent tests can be compared.

Severity of field changes (HODAPP classification)

Early glaucoma

- MD < - 6 dB
- Less than 18 points depressed below the 5% probability level and less than 10 points below the p < 1% level
- No severely depressed points (< 15 dB) in the central 5 degrees

Moderate glaucoma

- MD < - 12 dB
- Less than 37 points below 5% probability level and less than 20 points below p < 1% level
- No absolute deficit in the central 5 degrees
- Only one hemifield with sensitivity of < 15 dB in the central 5 degrees

Severe glaucoma

- MD > - 12 dB
- More than 37 points below p < 5 % or more than 20 points below the p < 1 % level
- Absolute deficit (0dB) in central 5 degrees
- Sensitivity < 15 dB in the central 5 degrees in both hemifields

Other types of perimetry

Blue on yellow perimetry or Short wavelength automated perimetry (SWAP) and Frequency doubling perimetry (FDP) may detect glaucomatous field defects earlier than SAP. The increased sensitivity of these tests is however accompanied by reduced specificity. SWAP detects damage in the koniocellular pathway and FDP detects damage in the magnocellular pathway. SWAP is more variable than SAP and may predict the future development of SAP defects. It is a slower test and is difficult to administer in the presence of significant cataract. SITA program for SWAP is now available. The newer version of FDP machine is called Matrix (Carl Zeiss).

Evaluation of Progression in Glaucoma

Glaucoma is a progressive disease and therefore visual fields evaluation and detecting progression of visual field changes is of fundamental importance. Detecting progression in a chronic and slowly progressive disease like glaucoma is difficult. In following visual fields in glaucoma patients, it is often difficult to differentiate between normal short-term and long-term fluctuations and true disease progression. Due to variability, a new change on a visual field needs to be confirmed on repeat testing.

Fluctuation versus Progression

The main problem in deciding whether or not a glaucoma patient's visual field loss is progressing is to separate true progression from changes due to variability or fluctuation between tests. Fluctuation is defined as the variability in the response to the same stimulus that is not due to true disease progression. As visual fields testing is a subjective examination, variable responses may be obtained each time the test is performed (inter-test or long-term fluctuations) or during the same test (intra-test or short-term fluctuations). Fluctuation varies among patients and among sectors in the same visual field, and increases with severity of disease. To detect true progression, one has to evaluate whether the observed change exceeds the expected fluctuation in the tested area.

Visual field progression in glaucoma may be seen as:

(1) Development of a new defect
(2) Deepening or enlargement of a preexisting defect
(3) Diffuse loss of sensitivity (less common)

Most often progression is identified as a deepening of a preexisting scotoma (as shown by various research studies), along with enlargement of the scotoma. In a study evaluating visual field progression in glaucoma, most cases showed deepening (86%) or enlargement (23%) of a previous scotoma, while none of the eyes developed new visual field defects in previously normal areas. This highlights the importance of evaluating areas adjacent to existing scotomas when searching for visual field progression. However, these adjacent areas are also known to exhibit larger degrees of fluctuation, which makes identification of true progression more difficult. Diffuse sensitivity loss may also represent glaucoma progression, although it is usually accompanied by new defects or worsening of previous focal defects. Progressive diffuse loss should raise the suspicion of cataract progression and must be correlated with clinical examination.

The Humphrey field analyzer (HFA) has statistical software, STATPAC, which is capable of analyzing a single visual field for abnormalities or a series of fields for progression. The Single Field Analysis provides a printout of a single visual field with most detailed information about that test. In the Overview printout, several visual fields are arranged chronologically on the same page for the ease of comparison. The Change Analysis printout provides a chronologic box plot analysis, the time course of the four global indices (only MD and PSD in SITA), and the linear regression analysis of MD.

How frequently should Visual fields be done to assess Glaucoma Progression

Most glaucoma patients under treatment will have slow rate of progression over the years, but there are those few who will have rapid progression rates. Published rates for mean deviation (MD) deterioration in glaucoma patients have varied and depend on individual susceptibility, severity of disease, and treatment strategies. One should perform enough visual fields at the beginning of follow-up in order to detect cases that present with fast progression rates. It has been suggested that six visual field examinations be done in the first 2 years, in order to rule out aggressive disease and to establish a consistent baseline. Subsequently, the frequency of testing may be reduced to once or twice yearly as long as no change is detected. At any time during follow-up that a change is identified on the visual field, one should not wait another year to proceed with a confirmatory test, but instead the frequency of examinations should again be increased in order to confirm or exclude progression.

Event and Trend based Analyses

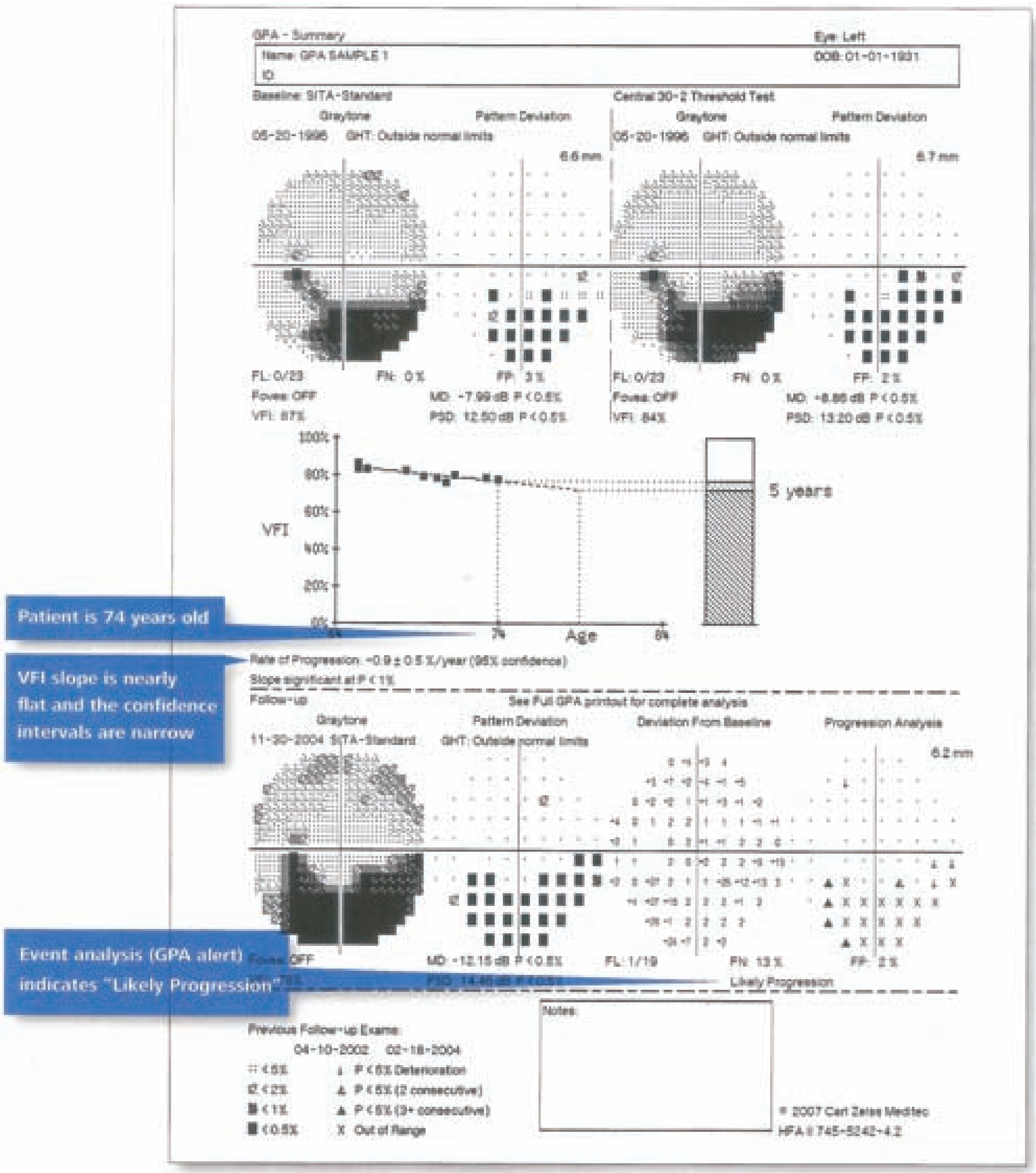
There are two main approaches to analyze progression -- event-based and trend-based analyses. The first approach compares the current examination with a previous one (usually the baseline test). If the results are significantly worse on the follow-up examination, progression is indicated. This is called event-based analysis. In the second approach, instead of only comparing a few tests, one looks for progressive change by analyzing all the tests available in a specific period of time. This is called trend-based analysis, as a trend in the values is plotted over time, and observing the slope or decline of the regression line can assess significant deterioration. Besides evaluating whether progression has occurred, trend-based analysis also allows an estimation of the rate of progression. It is well known that some patients deteriorate faster than others, and estimating each individual's rate of progression may help decide aggressiveness of treatment and the response to treatment.

The older software version is the Glaucoma Change Probability (GCP) software. The GCP performs individual comparisons of each visual field point on follow-up examinations with a set of baseline fields. Progression is flagged if two or more adjacent points within adjacent to an existing scotoma show significant deterioration confirmed on two consecutive tests. The GCP performs individualized analysis of the sectors in the visual field; however, as it is based on the total deviation plot, it is affected by diffuse media opacities such as cataract.

The new Guided Progression Analysis (GPA) software was developed to overcome the limitations mentioned above. Both the GCP and the GPA are event based analyses, but the GPA has following advantages when compared with the GCP.

- The GPA is based on the pattern deviation plot, as opposed to the total deviation plot used by the GCP. Therefore, the GPA evaluates progression adjusted for diffuse effects.
- The GPA runs not only on SITA tests, but also accepts full-threshold tests for the baseline pair (the GCP did not), which is convenient as some patients with long-term follow-up have been tested with the full-threshold strategy during early follow-ups.

As detection of new or progressing visual field defects is performed by comparison to the baseline, it is imperative to have reliable baseline examinations. The software automatically selects the first two available examinations as the baseline tests. However, one can override this automatic selection to a more suitable time-point (e.g., change in therapy after progression), or to reject fields that are unreliable due to initial learning effects (which could reduce the sensitivity to detect progression). The GPA software then compares each follow-up test to the average of the baseline tests. It identifies points that show change greater than the expected variability (at the 95% significance level), as determined by previous studies with stable glaucoma patient.



If significant change is detected in at least three points, and is repeated in the same points over two consecutive follow-up tests, then the GPA software will flag the last examination as Possible Progression. If the same three or more points have significant change detected and repeated in three consecutive follow-up tests, the GPA software will flag the last examination as Likely Progression (Fig.5)

The latest version of the Humphrey field analyzer provides the **visual field index (VFI)** and VFI progression plot. The VFI is a newly developed index that is proposed to evaluate the rate of progression. The aim of this analysis is not to detect progression, which can be done with the GPA, but to provide valuable information on the rate of deterioration. ***The VFI is calculated as the percentage of normal visual field, after adjustment for age. Therefore, a VFI of 100% represents a completely normal visual field, while a VFI of 0% represents a perimetrically blind visual field***. The VFI is shown on the GPA printout both as a percent value for each individual examination and as a trend analysis, plotted against age. While the MD is based only on the total deviation map, and thus is largely affected by cataract, the VFI is based both on the pattern deviation and the total deviation probability maps. The former (pattern deviation) helps in the identification of possibly progressing points, and the latter (total deviation) is used for the actual calculation of change of the total deviation value. In addition, the VFI algorithm gives weightage for different locations, giving more weight to the central points. The final VFI score is the mean of all weighted scores. For glaucoma patients with worsening cataract, however, the VFI showed a slower rate of progression than the MD, which would be a more accurate representation of the actual rate of

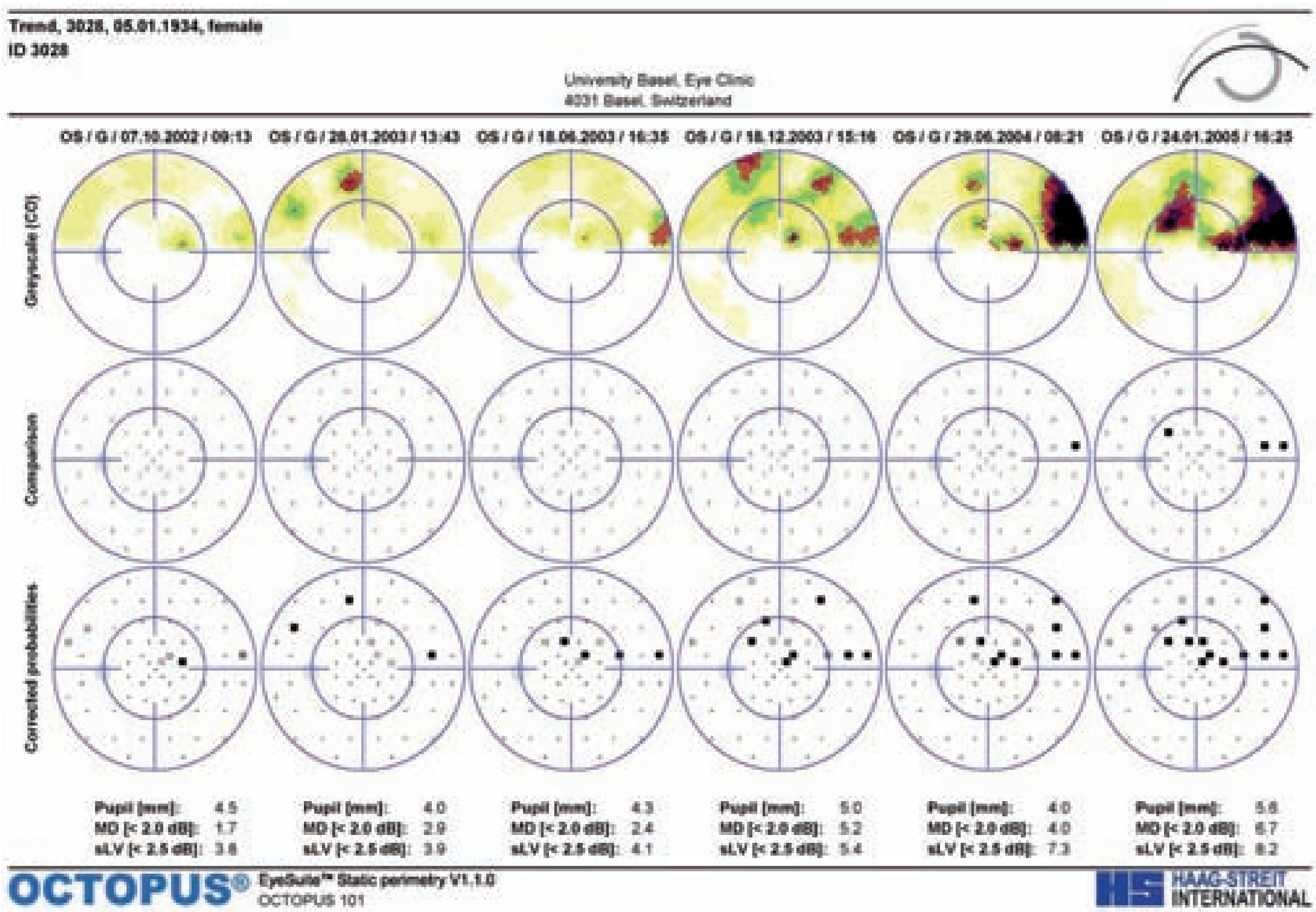


Fig. 6a (Overview Analysis)

glaucoma progression. Conversely, for glaucoma patients who had cataract surgery during follow-up, improvement in media clarity masked glaucoma progression when assessed by the MD. It did not happen when assessment was performed with the VFI. The VFI also provides an estimate of the visual field loss that will occur in the next 5 years, assuming that the same rate of progression is maintained. This is valuable for the treating ophthalmologist as it estimates the number of years that a patient has before advancing to blindness. A summary of the progression of visual field loss analysis is presented in the (Fig. 6) below.

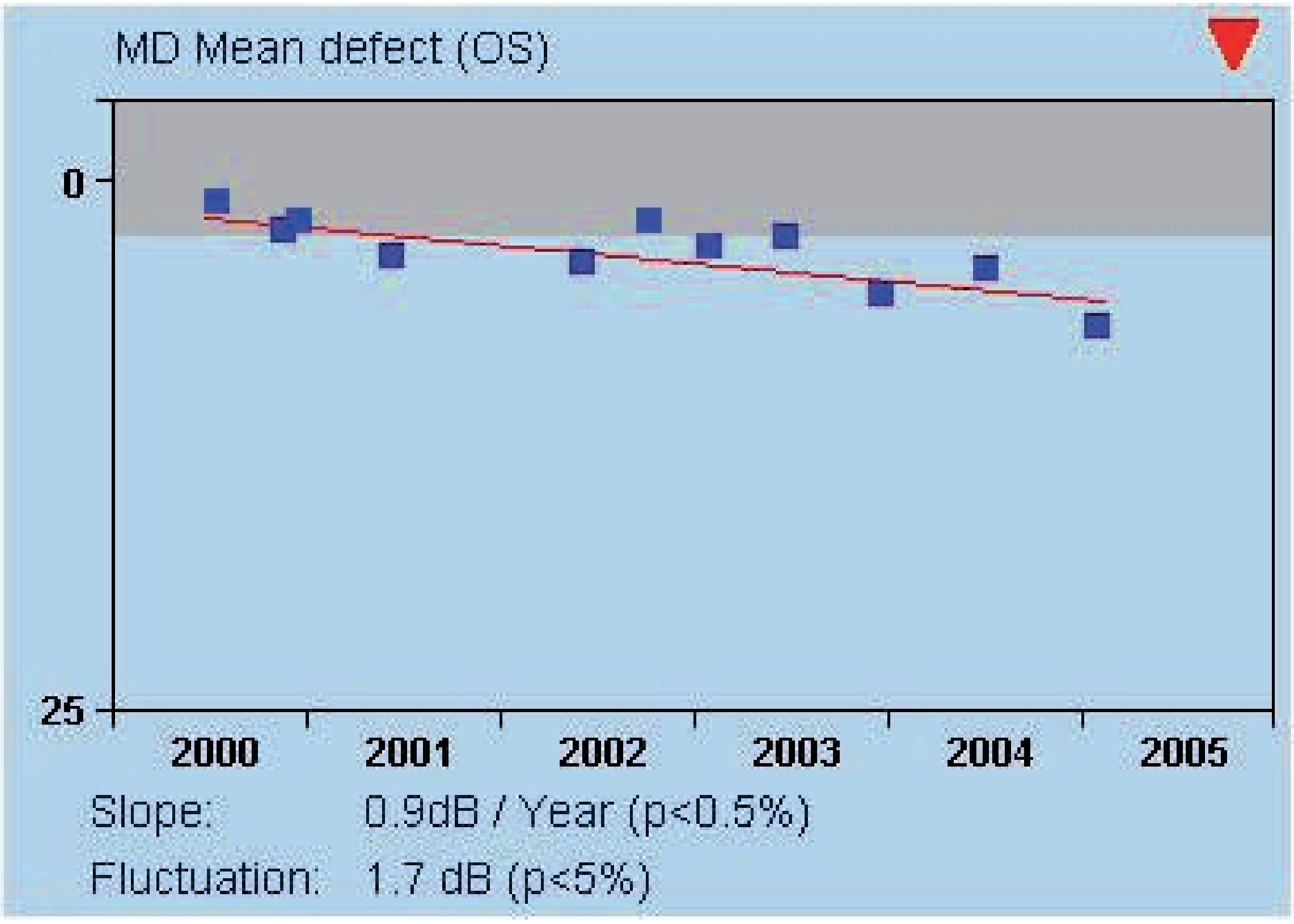


Fig. 6b : Progression of visual field damage-Trend Analysis

Progression analysis using Octopus Eyesuite Perimetry

The Octopus Eyesuite software provides a number of useful analyses such as:

1. The Overview analysis provides an overview of all previous examinations to show and look for changes (Fig.6a).
2. It can also provide bilateral viewing as a two on one report.
3. Trend analysis of the Mean defect (MD) helps to calculate the rate of progression per year including the probability level and Fluctuation (Fig.6b)

4. The trend graph also shows areas for normal range (gray band), impaired (15 dB) and legal blindness (25 dB).
5. A red icon arrow will be displayed when significant worsening is noted
6. Trends can also be shown for SLV, DD, Cluster analysis and Polar graphs.

Table 1.1: Summary of progression analyses available in HFA

Tool used	Index used for analysis	Analysis	Progression
Mean deviation (MD) plotted against time	Mean deviation	Plots MD values over time	•Remember Mean D viation: Minus is bad. • Pattern standard deviation: Plus is bad. Decrease in MD over time
Glaucoma change probability	Total deviation	Compares individual field points at follow-up to baseline	Two or more adjacent points in or next to an existing scotoma show a significant deterioration on two consecutive tests
Guided progression analysis	Pattern deviation	Compares each follow-up tests to the average of the two baseline tests; identifies points that show change at the 95% significance level	•Possible progression = significant change in at least three points that is repeated over two consecutive tests; •likely progression = significant change in a least three points that is repeated over three consecutive tests.
Visual field index	Mean deviation and pattern deviation	Provides information on the rate of progression; gives more weight to central visual field points	Provides an estimate of additional field loss that will occur over the next 5 years given a steady rate of deterioration

Frequently Asked Questions For Perimetry

What is visual field ?

Visual field is at all that space or area that is seen by a steadily fixating eye. It is described as an island or hill of vision surrounded by a sea of darkness (Traquair). It is a three-dimensional structure and extends 60^{O} nasally, 90^{O} temporally, 50^{O} superiorly and 70^{O} inferiorly. The acuity of vision is sharpest at the top of the hill (corresponds to the fovea) and then decreases progressively to the periphery with nasal slope steeper than temporal.

What is Perimetry ?

Perimetry is used to describe the measurement of the visual field (Gr.Peri: around / Gr.Metrein : to measure). Perimetry is vital in glaucoma management including its diagnosis and monitoring progression. Perimeters have evolved from Bjerrum screen (1856), Lister's Arc perimeter and Goldman manual kinetic perimeter to its present state of the art fast, quick and accurate automated perimeters such as Humphery Field analyzer (HFA) (Carl Zesis), Octopus (Interzaag-Haag Streit), Oculus, Dicon, Synemed and Kowa. The most commonly used perimeters in India are HFA and Octopus.

What is a Scotoma ?

Scotoma is a defect in the visual field – an absolute scotoma represents total loss of vision in which even the brightest and largest target cannot be perceived. A relative scotoma is a region of partial visual loss with which some of the stimuli may be seen while some are not. A scotoma may have sloping edges, i.e. an absolute scotoma may be surrounded by a relative scotoma.

What is the extent of field tested ?

In glaucoma it is usually sufficient to test the central 30 or 24 degrees (called 30-2, 24-2 in HFA or G1 program in Octopus machines). In the 30-2 test 76 points in grid pattern which are 6 degrees apart are tested in the central 30 degrees while in the 24-2 tests 54 points are examined. The 10-2 program tests 68 points 2 degrees apart in the central 10 degrees and the macula program examines 16 points which are 2 degrees apart in the central five degrees. In advanced glaucoma it is useful to do the 10-2 or macula program to check for split fixation. G1X of the Octopus tests 59 locations in the central field which are concentrated in the central, arcuate and nasal midperiphery. The M2X tests 45 locations in the central 4 degrees which are 0.7 degrees apart.

What are Kinetic and Static Strategies and what is an Isopter?

Traquair's description of the visual field as a three-dimensional hill island of vision in a sea of darkness helps us in understanding the two basic strategies of perimetry testing. Testing along the X-Y axis (kinetic testing) determines location in the visual field while testing in the vertical Z axis as is done during static testing can detect the depth of a visual field defect. In kinetic perimetry stimuli of varying sizes and / or brightness are moved from nonseeing to seeing area and limits of the visual field are mapped in isopters. An isopter forms the border that connects the threshold points of a given stimulus. Using different stimulus sizes many such isopters can be found. The shape of such isopters is ovoid.

What is threshold and how is it estimated ?

In static perimetry which is now employed in all automated perimeters a fixed size stimulus is varied in brightness in different locations in the visual field and the threshold is determined for each tested point. Threshold is the dimmest target that the patient can see at a test location. The obtained threshold value (expressed in decibels or dB) may vary within 1-2 dB when tested during a field test (fluctuation).

What is SITA ?

Threshold determination at each point of the visual field is time consuming and may fatigue the patient. Newer techniques such as Swedish interactive threshold algorithm (SITA) in the HFA are based on the fact that a response at one location has implications not only for that tested location but for neighbouring points. Tendency oriented perimetry (TOP) in Octopus machines is similar to SITA wherein it analyses the location where the stimulus is presented and assesses the threshold of the four neighbouring locations by interpolation.

Automated static threshold strategy of the central visual field using SITA or TOP is now the preferred for testing visual fields in glaucoma.

How is Reliability estimated ?

The percentage of fixation losses (more than 20%), false positive and false negative responses (exceeding 1/3) indicate unreliable, field test should be repeated. Also a test done for the first time should not be considered as baseline test because most patients have a learning curve and do better on repetitive testing. A second or even a third test should be taken as a baseline from which all subsequent tests can be compared.

What is Total and Pattern Deviation (Termed Comparisons and Corrected Comparisons in Octopus Printouts)?

The total deviation is the difference between patient's measured thresholds and the age matched normal value at each tested location. The total deviation plot has a table of numeric values which represent the actual difference and below it is shown a probability plot. The symbols in the probability plot indicate the statistical significance of each measured deviation. A key to the probability plot is shown below. For example, a test location with the symbol < 1% means that less than 1 % of reliable normal fields in the age related database have low sensitivity.

The pattern deviation adjusts for generalized depression due to cataracts or refractive errors and helps to expose a localized scotoma. There is a probability plot below the pattern deviation.

What are Global Indices or Statistical Indices ?

The four main indices are:

- (MD) Mean deviation (mean defect in Octopus) which signifies overall or average severity of field loss.
- (PSD) Pattern standard deviation (loss variance in Octopus) is an index of the degree to which the numbers in the total deviation plot differ from each other. 'P' values are assigned to if PSD exceeds

that found in 90% of normals.

- (SF) Short term fluctuation– It is the standard deviation of multiple measurements of threshold within a test session at 10 standard locations and weighted according to the variance of the normal population. SF is usually 1-2 dB in normal reliable fields. SF is not derived in SITA in order to shorten the test time.
- (CPSD) Corrected pattern deviation (corrected loss variance in Octopus - this index is obtained from PSD by correcting for SF, i.e. CPSD = PSD – SF. The CPSD or CLV is useful in identifying a local scotoma.

What is Glaucoma Hemifield Rest (GHT), Defect or Bebie Curve (Octopus) ?

The GHT compares 5 zones in the upper hemifield with mirror image locations in the lower hemifield. These zones are in the areas where glaucomatous defects are most likely to be seen. A score is assigned to each zone based on percentile deviations in the pattern deviation plot of points. The difference in scores between the upper and lower zones is compared with age-related normal. Five possible messages appear –Outside normal limits, borderline, generalized reduction, abnormally high sensitivity and within normal limits.

Defect curve or Bebie curve – The defect curve is derived by ranking all tested points (59 points in the G1 test) and plotting them in a curve with the least deviated points to the left and most deviated points to the right of the curve. The normal range is shown with the confidence limits.

What is Anderson's Criteria ?

The criteria for abnormality in hemifield area (HFA) are (Anderson's criteria)

- The localized defect should be a cluster (in an expected location such as the arcuate or paracentral area) of at least 3 or more non-edge points which have sensitivities occurring in less than 1% of the population.
- The CPSD or PSD has a value that occurs in less than 5 % of the population.
- The glaucoma hemifield test is abnormal.

In the Octopus printouts of a reliable field (reliability factor should not exceed 15) a MD value more than 2 or LV value more than 6 can be considered as criteria for abnormality.

What are the TYPICAL FIELD DEFECTS IN GLAUCOMA ?

- Follow an arcuate pattern corresponding to the pattern of nerve fiber bundle loss.
- Asymmetrical across horizontal midline.
- Located in mid-periphery in early to moderate cases.
- 5^{o}-25^{o} from fixation.
- Should be reproducible.
- Not attributable to other pathology
- Usually clustered or localized in neighboring test points.
- Defect should correlate with the appearance of the optic nerve head.
- Do not affect visual acuity except in advanced glaucomatous optic atrophy or due to the presence of coexistent cataract.

How often fields should be performed?

It is generally advisable to obtain at least 2 reliable visual fields to establish a baseline before commencing definitive therapy – in other words the field defect must be reproducible. Follow-up fields are performed on the basis of degree of risk of developing glaucoma. Glaucoma suspects and relatives of glaucoma patients may be tested once every year. In compliant patients with good IOP control and stable glaucoma the visual field may be tested every 6 months. Glaucoma patients with unstable high IOP or other risk factors for progression may be subjected to testing every 3-4 months.

How to assess Progression ?

Assessing visual field progression: Progression can be judged by viewing reliable individual single field printouts obtained over a period of time. Another method would be to obtain an 'overview' print in which up to 16 previously tested visual fields can be shown in single printout without any statistical interpretation. For statistical analysis one may use the recently available progression analysis software such as GPA in HFA machines or Eyesuite in Octopus perimeters.

What are common pitfalls noted during field testing ?

- There is a learning curve in a patient undergoing visual field testing especially with the first few tests – so the baseline should be established after the first few tests.
- Miotic pupils (pupil size should be at least 3 mm) and cataracts can cause generalized depression. Cataract and high refractive errors (more than 6 dioptres) can cause diffuse field loss which is usually determined by the total deviation plot. In patients with high refractive errors visual field test should be performed with contact lenses to avoid the artifacts associated with trial lenses.
- Trial lenses used for perimetry must be full aperture lenses and must be properly centred.
- The patient should also be properly positioned on the chin rest with forehead touching the forehead band.
- Unexplained or atypical visual field defects must raise the suspicion of a nonglaucomatous cause for the defect.
- A visual field is a subjective test. It is important for the technician / perimetrist to encourage and monitor the patient throughout the test.

Which perimeter should I use ?

We use perimetry in glaucoma for two reasons. One is to diagnose or rule out glaucoma and the second is to detect if the disease is progressing. Since automated perimetry detects visual field defects based on comparison of the subject's threshold with that of an age matched control the role of the normative database in the machine is critical. Progression is detected based on appropriate software available in the device. While choosing a perimeter the normative database and progression softwares are of paramount importance. Currently the Humphrey and Octopus perimeters are known to have large databases and are most reliable ones.

What should I use, 30-2 or 24-2 strategy?

The 30-2 takes 1-2 minutes longer to perform than a 24-2 therefore many busy practices use it as a default test for glaucoma. However, it does test more of the field than the 24-2. One strategy could be to use the 30-2 for the initial test and if the peripheral points are not involved use the 24-2 for follow up. For neurological disease 30-2 testing is advisable. The 10-2 test is used to assess the central ten degrees of the visual field in greater details (points 2 degrees apart are tested). A 10-2 is usually asked when paracentral points are involved so that we can look for changes next to fixation and follow up the central points in greater detail.

Which program should we use to detect glaucoma-SITA Fast or SITA Standard ?

SITA Fast is significantly quicker than SITA Standard since it tests the field in slightly less detail. Since SITA Fast testing is associated with greater test re-test variability in most situations SITA Standard is preferred. However in younger patients or those experienced with perimetric testing the SITA FAST can be used as also in suspected neurological disease.

I have been using the Full threshold progam for a patient and have switched to SITA recently. Why are the defect patterns different ?

Both the Full Threshold and SITA programs use different strategies for testing and have different normative databases. The SITA programs usually detect shallower defects. This can result in different visual field defect patterns.

How should I select baseline fields for assessing progression ?

The baseline fields should be reliable and reproducible. Both fields should show similar visual field defects. The baseline should be re- done in case of major changes that could influence threshold values(e.g: Cataract surgery, YAG capsulotomy, laser PRP) or a major change in disease management (e.g: Trabeculectomy).

What sort of corrective lenses should be used? Can we use trial frame lenses ?

Full aperture lenses should be used for testing since other lenses can produce testing artifacts. Care should be taken to place the lenses as close to the eye as possible to reduce the risks of lens rim artifacts.

Should perimetry be done with a dilated pupil or an undilated pupil ?

Perimetry can be done with an undilated pupil (provided it is at least 3 mm in size). In case of significant lens changes dilatation may be required. Dilatation can cause a minor decrease in recorded thresholds. While looking for progression it is important to keep this in mind.

Can we do perimtery after contact procedures such as applanation tonometry, gonioscopy, etc ?

Threshold estimation can be affected by corneal changes associated with repeated contact procedures in addition to increased patient discomfort associated with these changes. If the central cornea shows SPK,s it is better to defer perimetry to another visit.

When can I use a Size V stimulus?

The size V stimulus can be used in advanced disease where most points are showing very low threshold values with a size III stimulus. The size V stimulus can be used with either 30-2, 24-2 or10-2 testing.

However there will be no access to the normative database or the SITA testing strategies. The Guided Progression analysis will also not be available. The sensitivity range will be extended and patients can be followed up by comparing threshold values across serial visual fields.

How do I test people with macular disease ?

Those with macular disease find it difficult to fixate on the central fixation target and can be asked to look in the centre of the four fixation targets of the large/small diamond.

Can we compare threshold values between an Octopus and Humphrey perimeter ?

Threshold values between both perimeters cannot be directly compared.

Which is the more important – False positives or false negatives ?

High false negatives can sometimes be seen in glaucoma patients because of short term fluctuation in visual field thresholds during the test. Abnormal False positives are more likely to represent test unreliability.

What is the role of FDP and SWAP ?

Both the FDP and SWAP had been reported to pick up disease earlier than standard white on white perimetry. However, recent evidence suggests that SWAP does not offer any additional benefit over conventional white on white perimetry. FDP has shown good performance as a screening device to detect disease but because of its large stimulus size follow up to detect progression is difficult. The FDP Matrix uses a smaller stimulus size and corresponds more closely to white on white defect patterns but progression data is currently unavailable. The SWAP test takes longer to do (Except SITA SWAP which is quick). It is also more difficult to perform and results are unreliable in the presence of cataractous lens changes.

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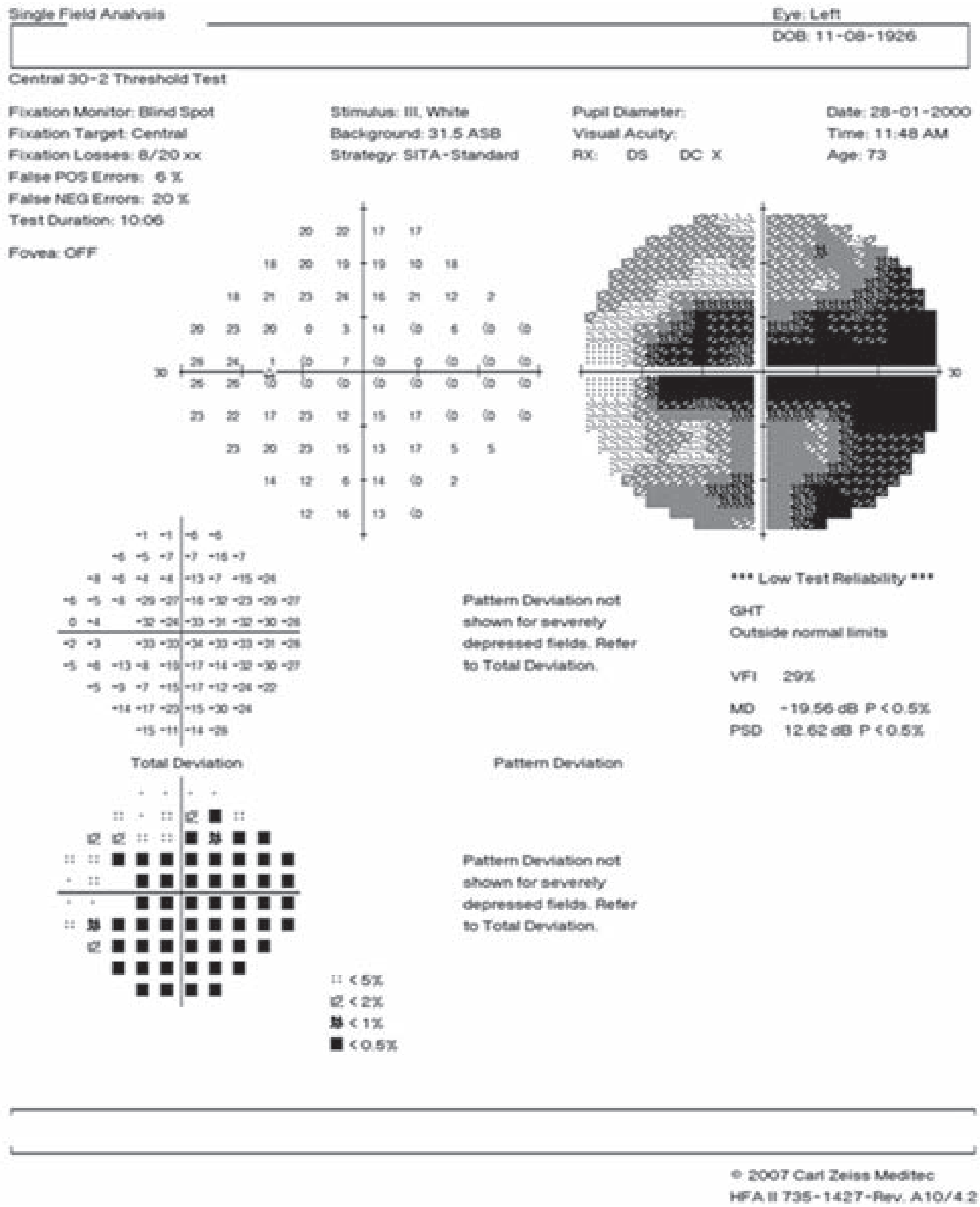
Atlas of Visual Fields

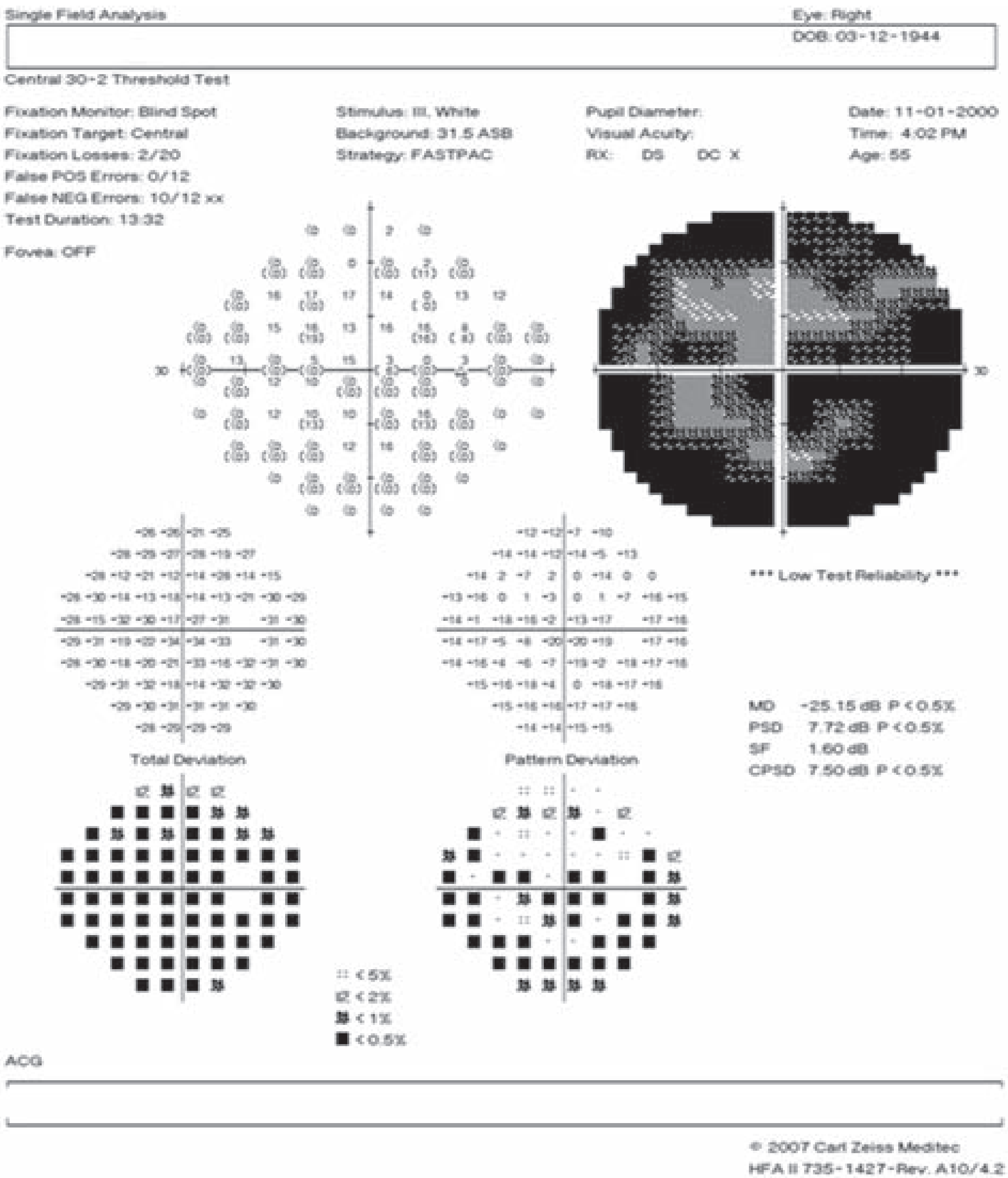
Case 1



Reliability Indices – show high fixation losses (xx) and high false negative errors, suggestive of an unreliable field. It may be due to learning curve, fatigue of patient or lack of interest.

When fixation losses are > 20%, it is bracketed (xx).

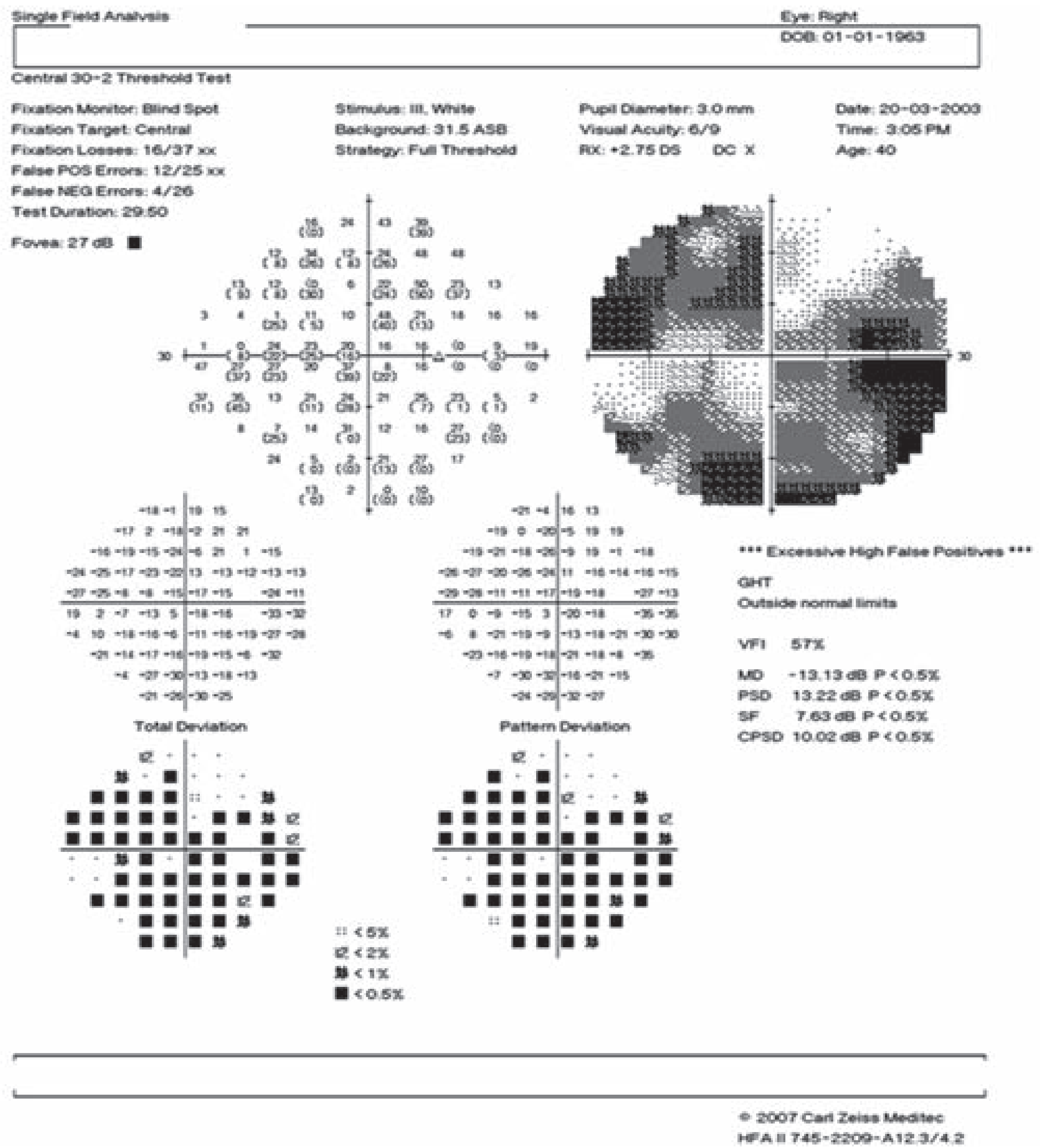
Case 2



Reliability Indices – show high false negative errors (xx), suggestive of an unreliable field. If the patient does not respond when a point previously thresholded is retested with a brighter stimulus, a false negative error is recorded. A high false negative score may indicate a fatigued patient, inattentive patient, or a malingerer, but may also be seen commonly in reliable patients who have genuine significant visual field loss.

When false negative errors are > 33%, it is bracketed (xx).

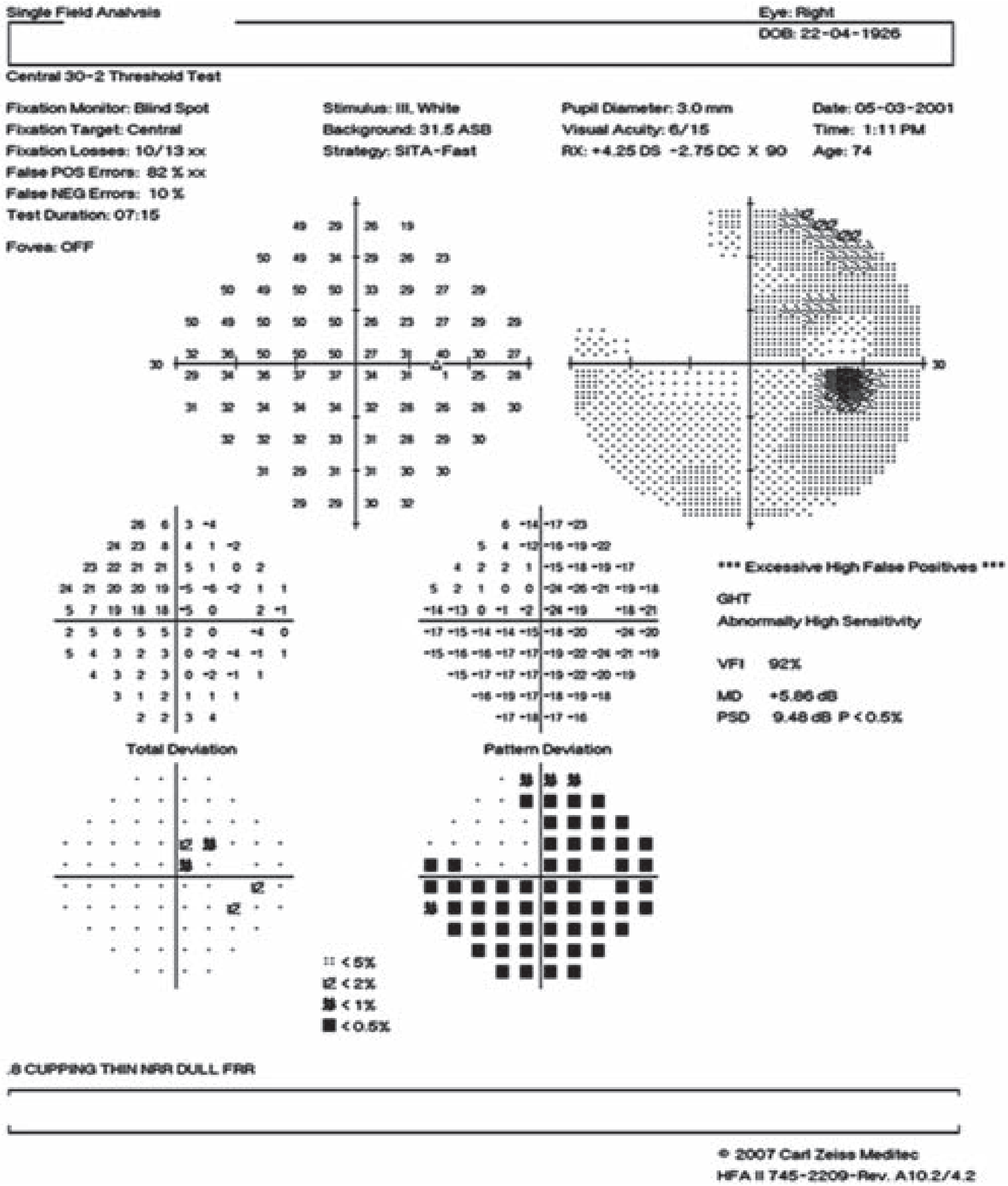
Case 3 (A)



Reliability Indices – show excessive false positive responses. The patient pushed the response button repeatedly when no stimulus was projected, to produce what is known as "trigger – happy" test results. Measured sensitivities are abnormally high at several points resulting in white patches on the gray scale printout and high positive deviations in the numerical total deviation map. The frequency of false positive errors is high, as is the rate of fixation losses.

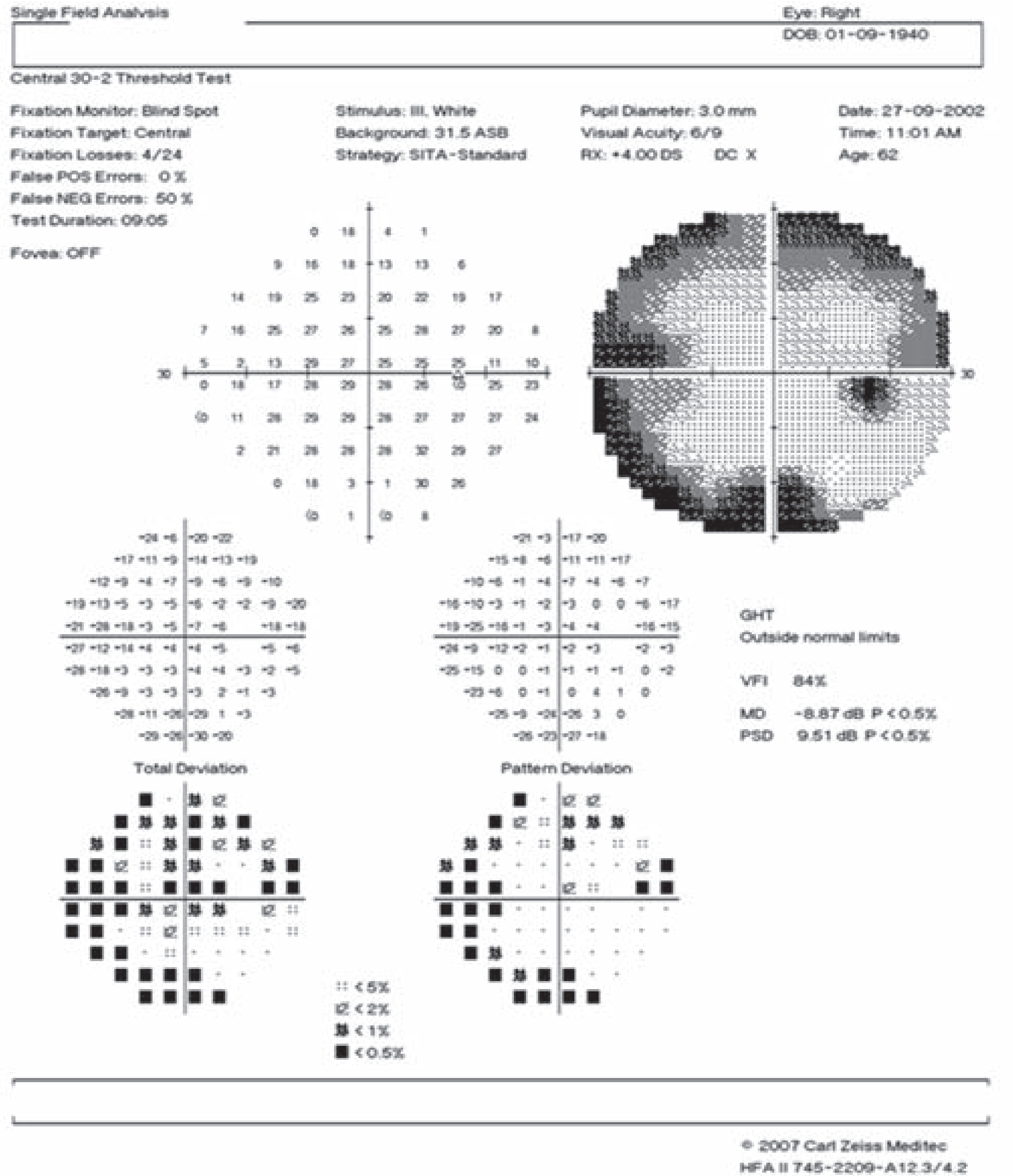
When false positive errors are > 33%, it is bracketed (xx)

Case 3 (B)



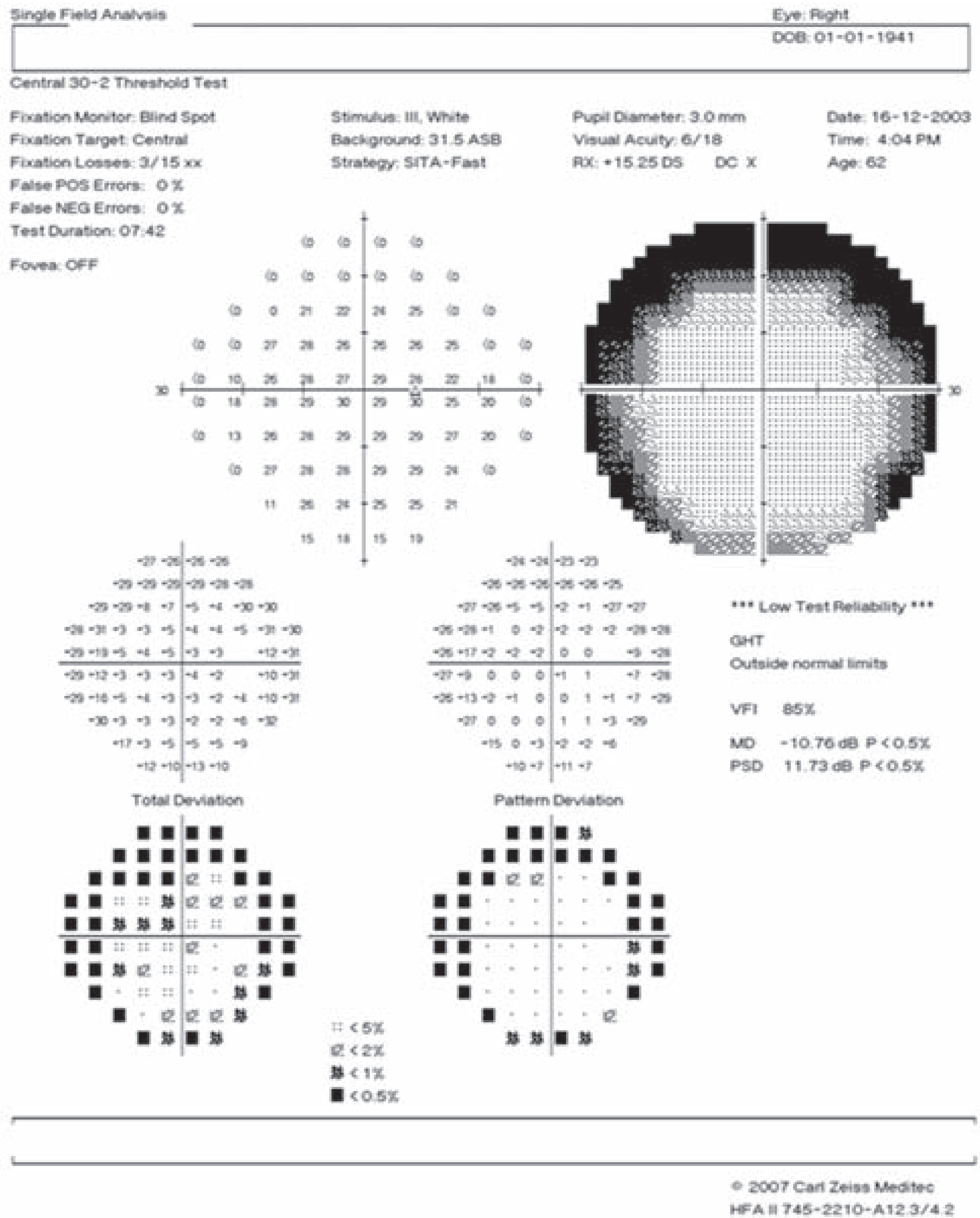
Reliability indices - Another trigger happy patient with high false positive error and fixation losses. The GHT message is "Abnormally high sensitivity" resulting in white patches on the gray scale printout and high positive deviations in the numerical total deviation map. The pattern deviation probability map indicates many abnormal points that are absent in the total deviation probability plots.

Case 4



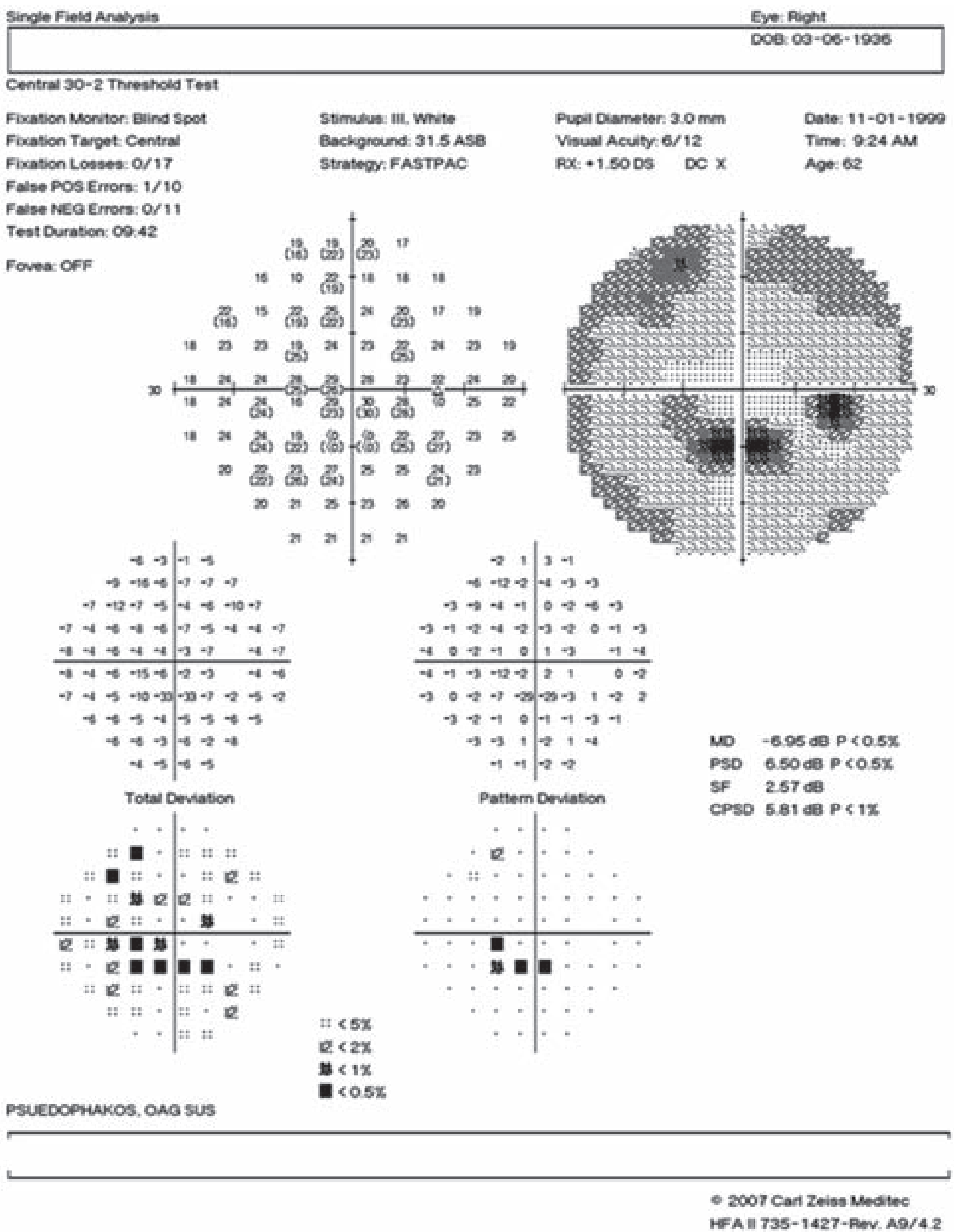
An example of a field of an untrained person showing mid peripheral field loss with clover leaf pattern on the grayscale. It occurred because the patient stopped paying attention shortly after testing began. Note the high false negative errors in the field. Patchy reduction of sensitivity in clusters towards the edge is typical.

Case 5



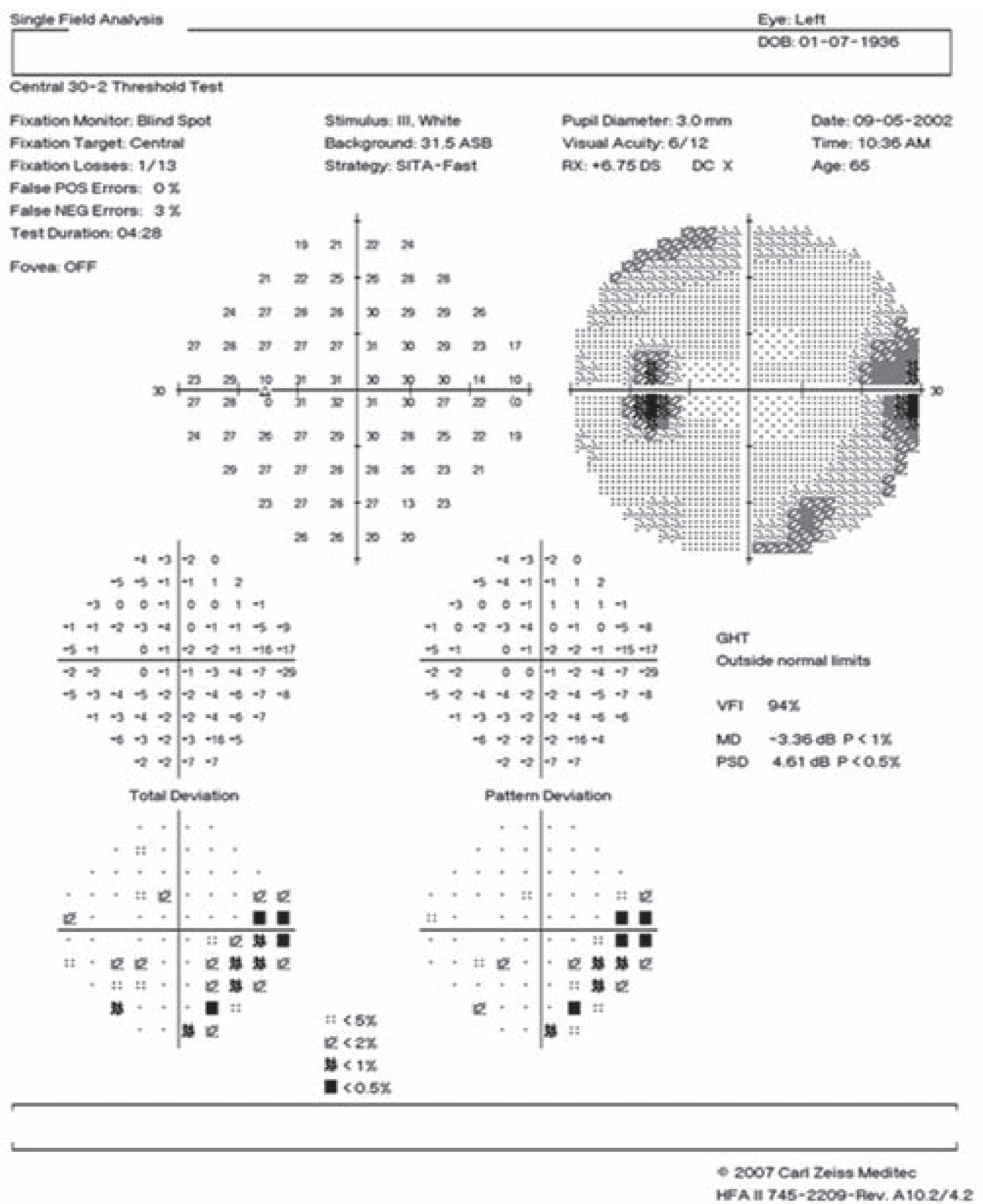
Edge Defect : The trial lens artifact associated with use of a +15.25 D sphere corrective lens demonstrates the importance of carefully maintaining the alignment of the patient during the test, especially when using strongly positive lenses.

Case 6



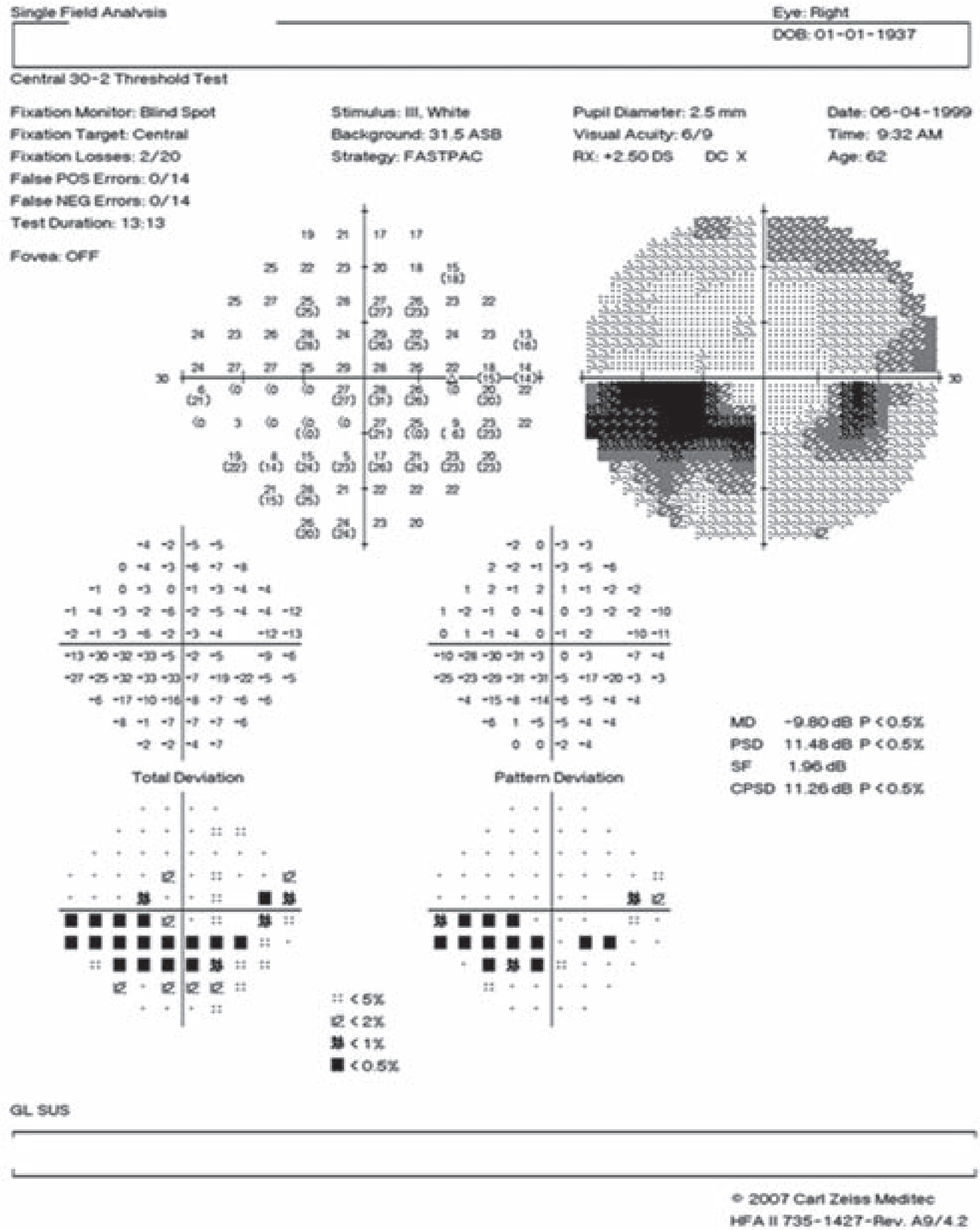
HVF 30-2 showing paracentral scotoma in a glaucoma patient having superotemporal notching.

Case 7



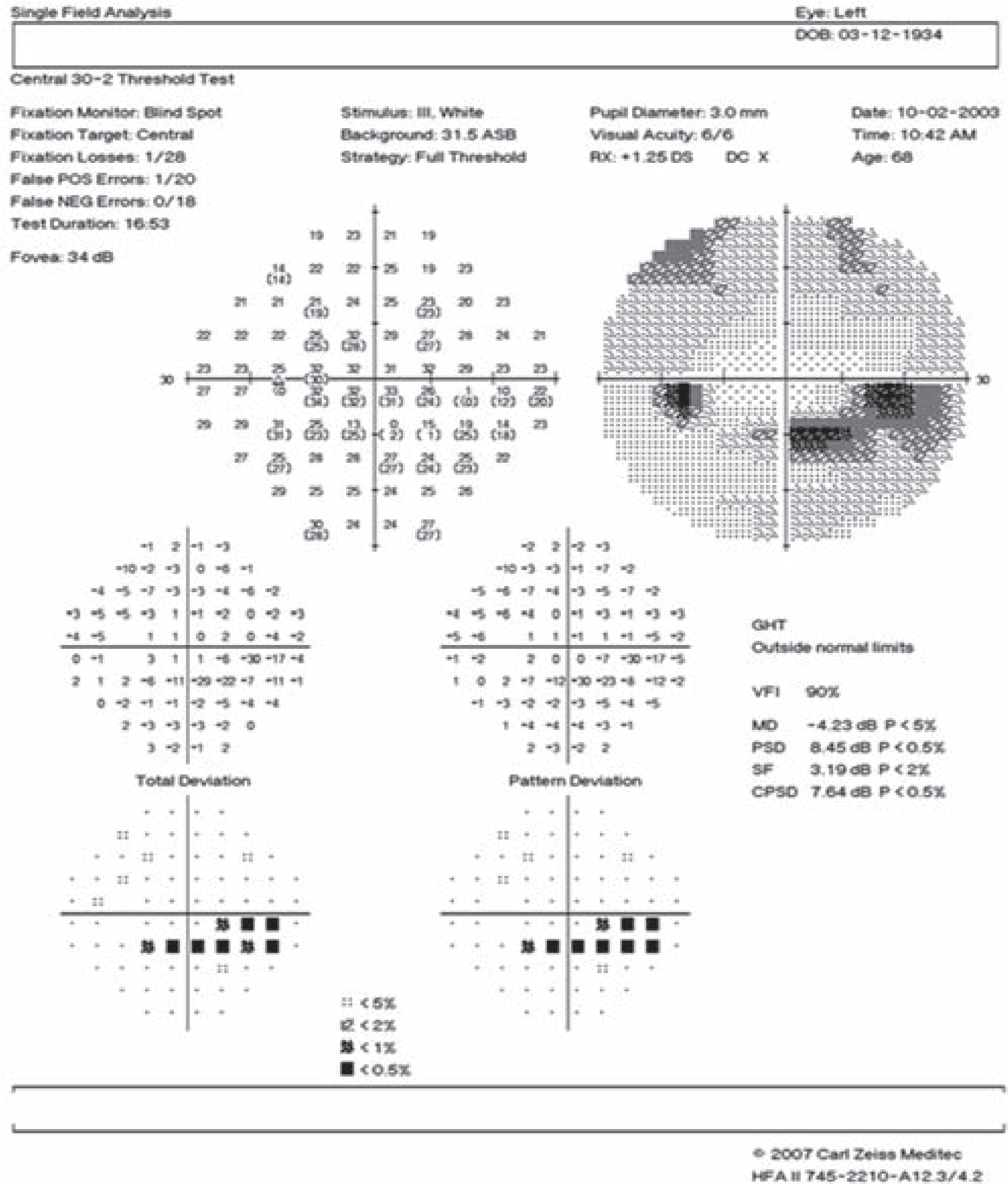
Inferior nasal step extending back to the blind spot. GHT indicates that the finding is outside normal limit.

Case 8



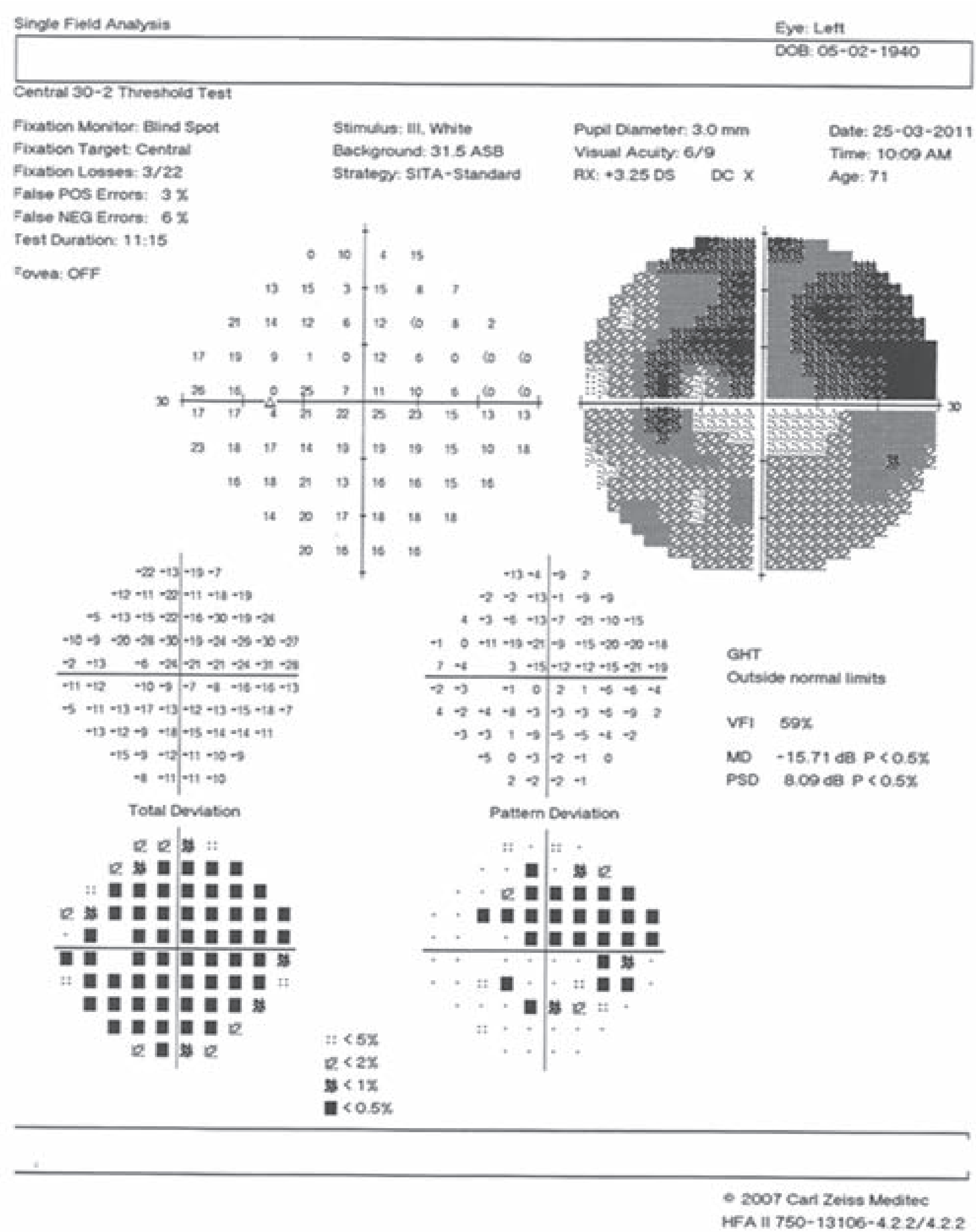
Another patient showing inferior nasal step extending further to the blind spot.

Case 9



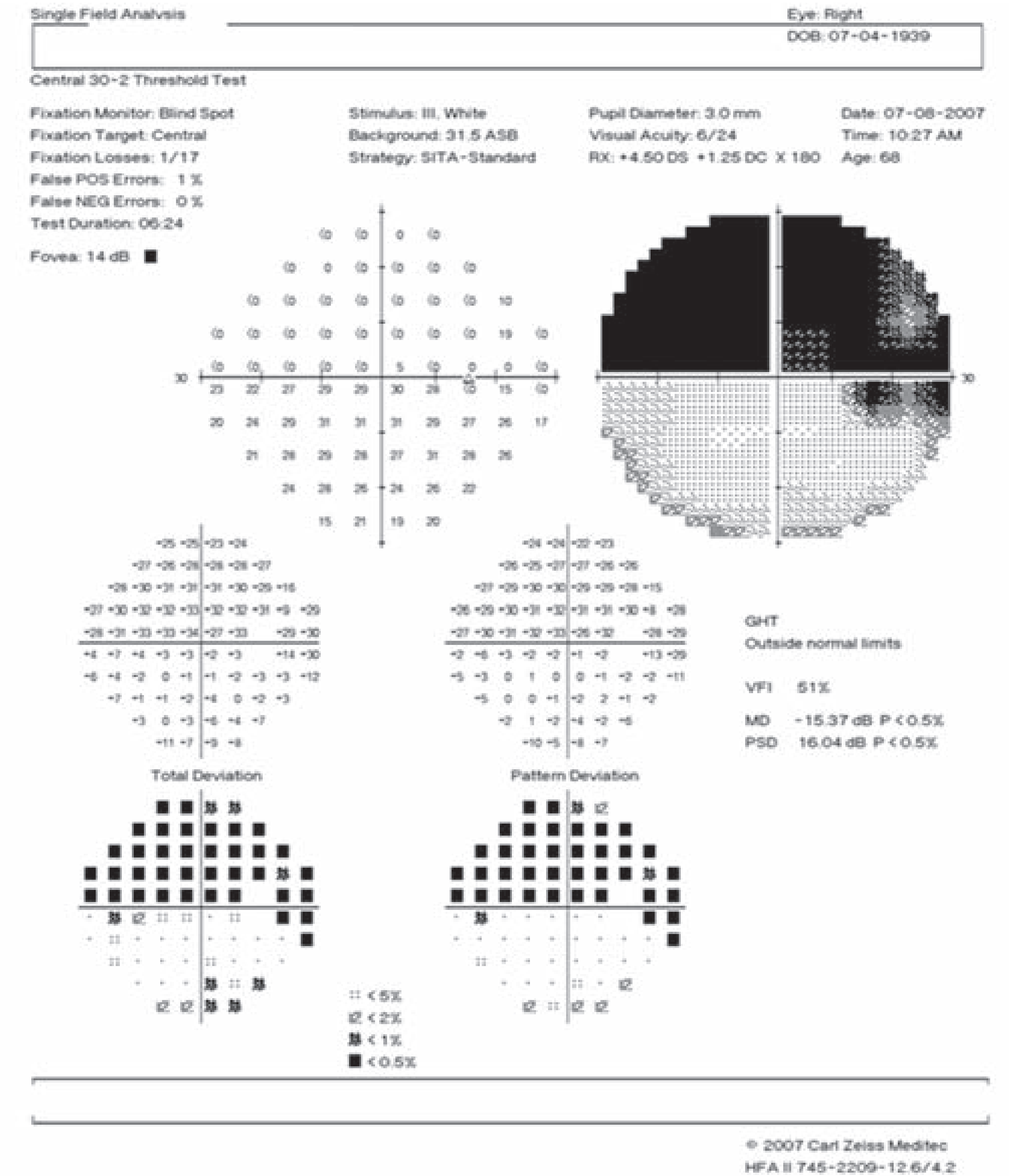
The arcuate nature of the defect is evident. Although it comes close to fixation from the nasal side, the visual acuity is normal. Note the characteristic features: the defect clearly emanates from the physiological blind spot, it becomes broader as it arcs over the point of fixation into the nasal field, and it comes closer to the foveal point from the nasal side than it does from the temporal side. GHT is outside normal limits.

Case 10



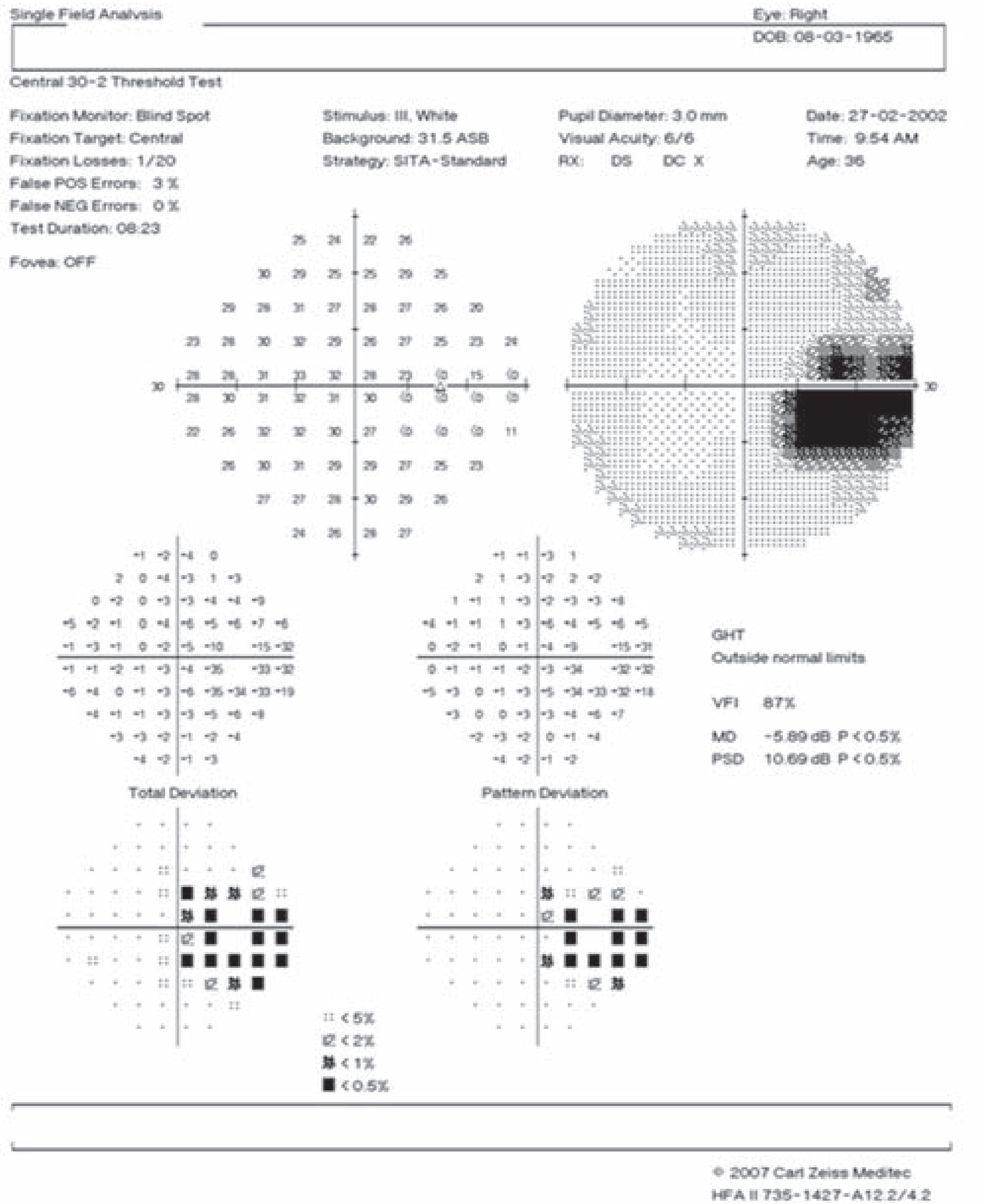
Biarcuate scotoma that impinges on fixation.

Case 11



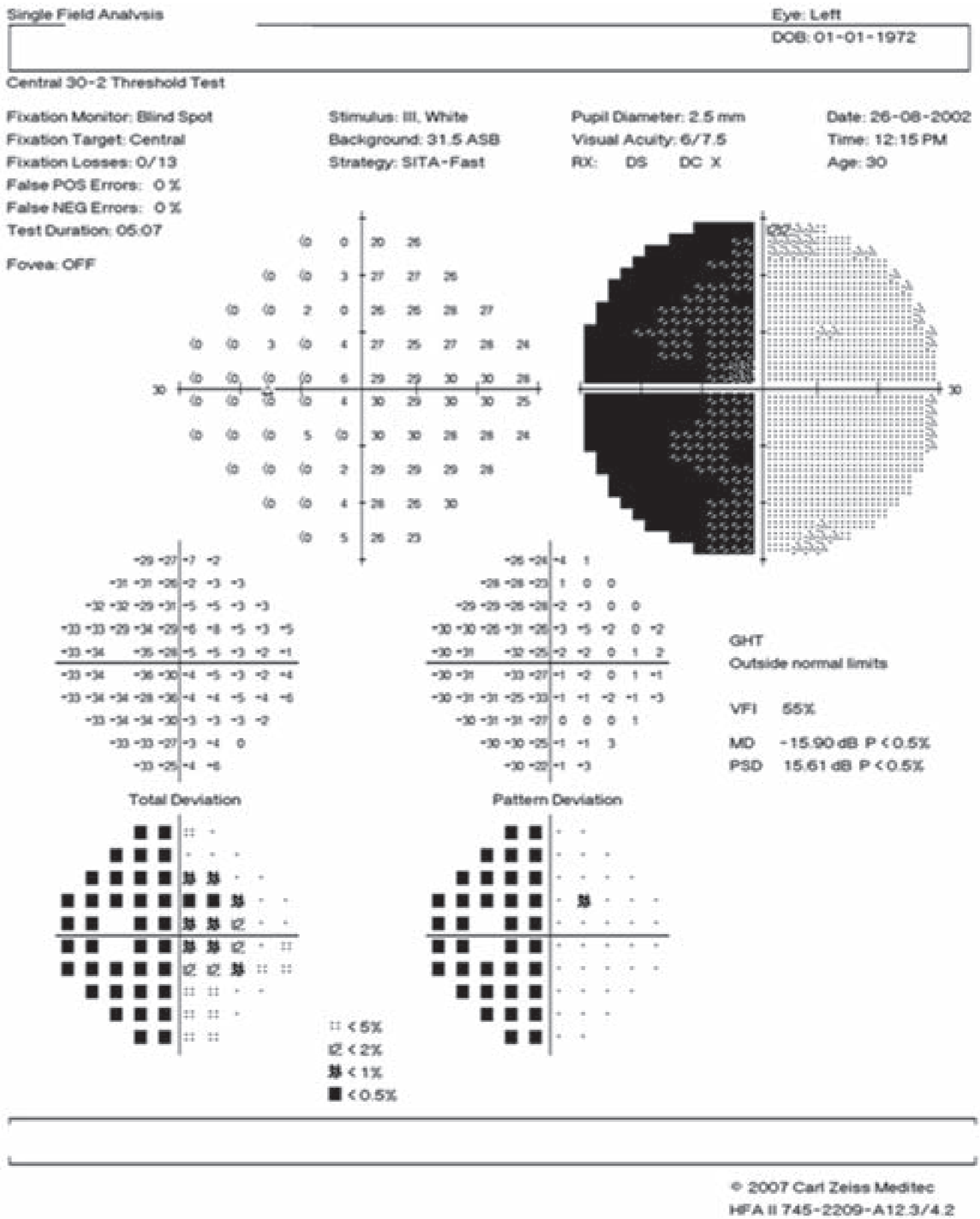
Acute ischemic optic neuropathy with typical altitudinal field defect. The patient was a 68 yr old male who suddenly perceived shadow in the upper field four days before presenting. Ophthalmoscopy showed a swollen disc with some haemorrhages, and generalised arteriolar constriction.

Case 12



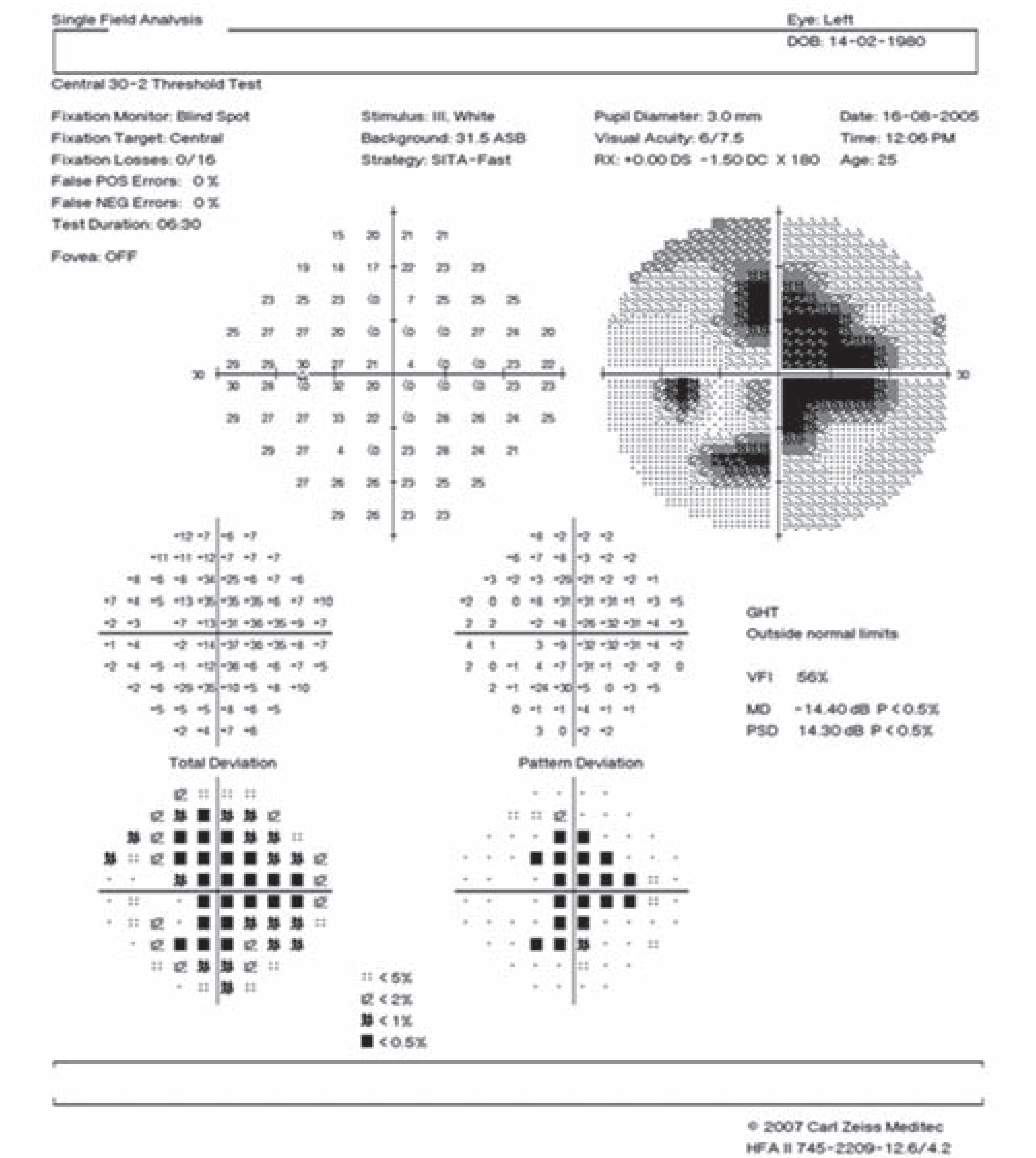
Enlarged blind spot caused by optic disc edema in a 36 yr old female with benign intracranial hypertension. Points around the blind spot show significantly depressed sensitivity values.

Case 13



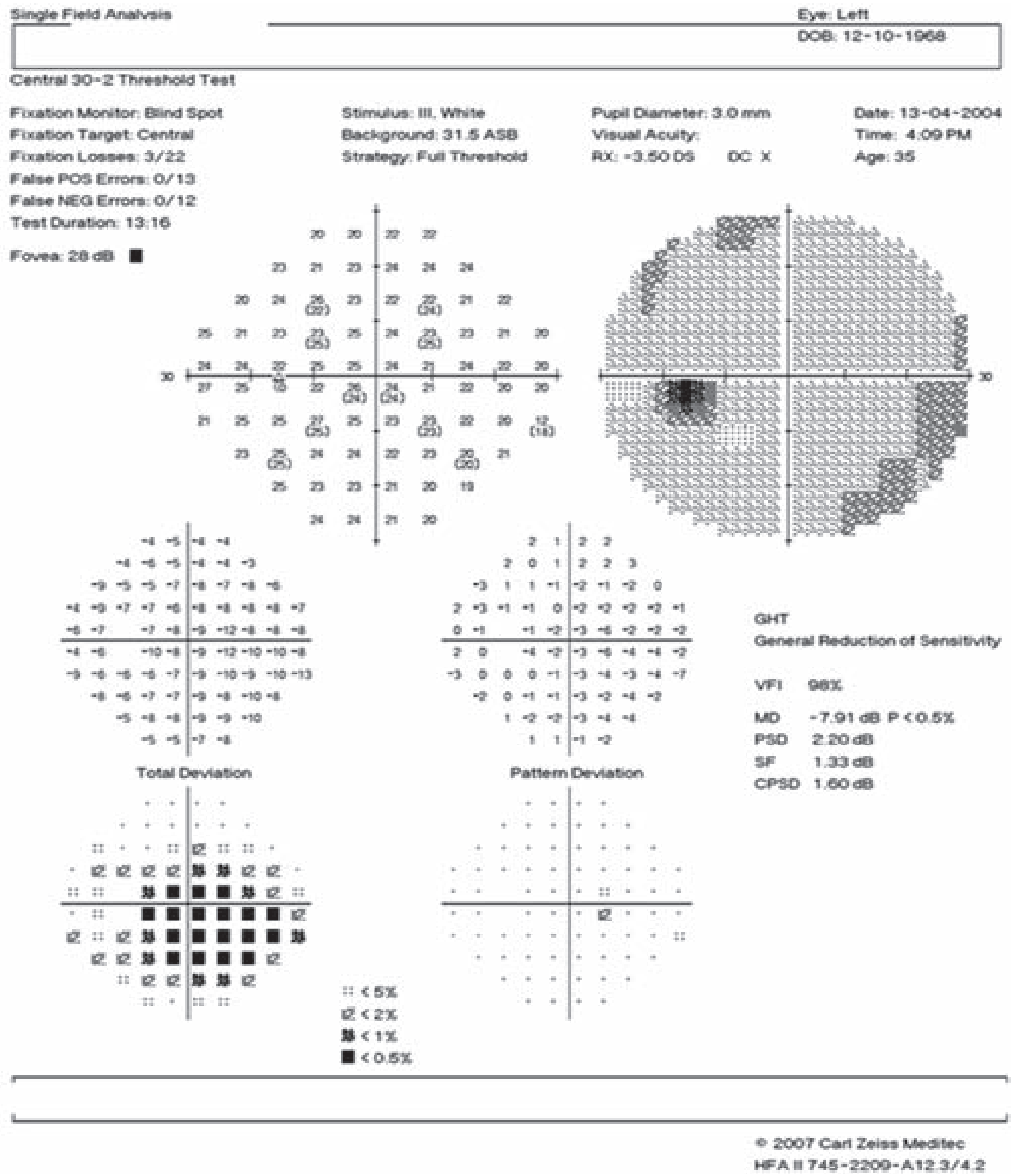
Thirty year old woman with nearly complete bitemporal hemianopia secondary to cystic pituitary adenoma. Patient noticed reduction in vision for six months prior to presenting for treatment.

Case 14



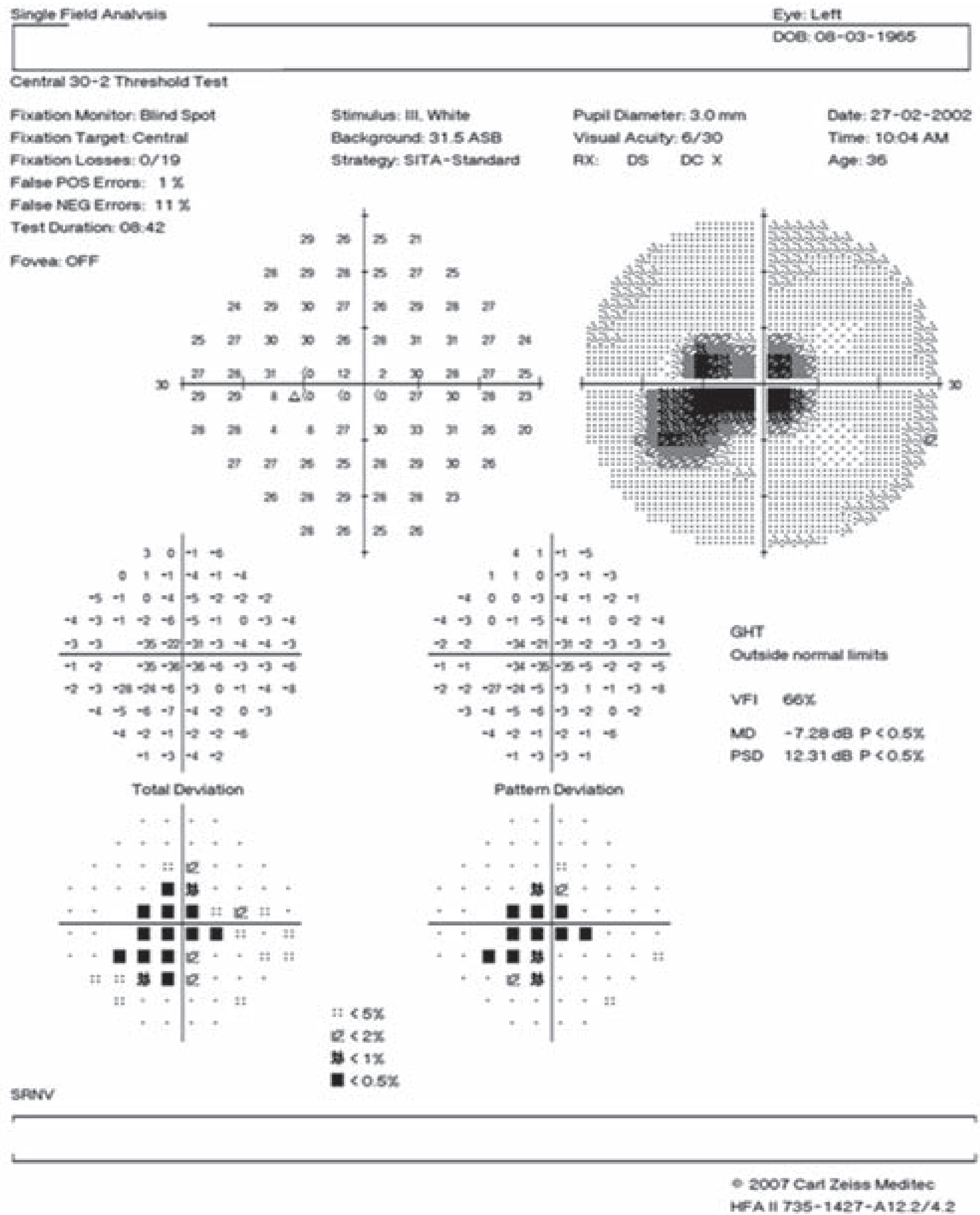
Cataract and macular disease: The entire field is depressed, but the sensitivity in the center is less (0 to 20 dB) than elsewhere (20 to 30 dB). Compare these figures with examples of cataract alone or a blurred image from refractive error, in which the reduction from normal values may be greatest at the centre but actual threshold sensitivity is no worse at centre than elsewhere. Severe macular disease does produce obvious, large scotoma, as in this example; however mild macular disease –enough to affect acuity to mild but noticeable degree – may produce equivocal findings.

Case 15



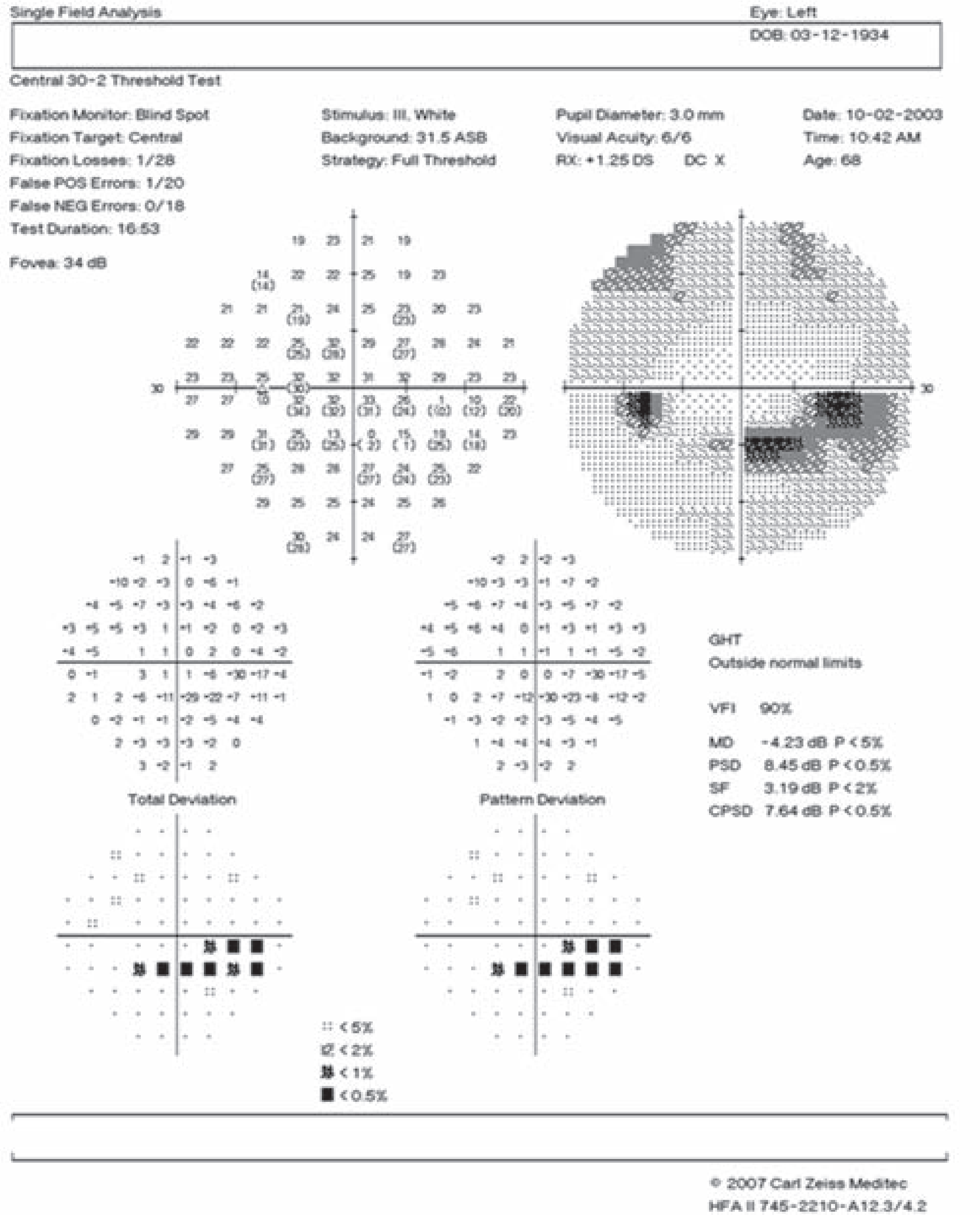
Visual field of a patient with cataract. While the total deviation plots indicate significant field loss, the pattern deviation plots filter away the generalized depression resulting from the cataract and shows there is no localized field loss. The hemifield analysis did not yield significant or even borderline asymmetry of the upper and lower regions but only a generalised reduction of sensitivity.

Case 16



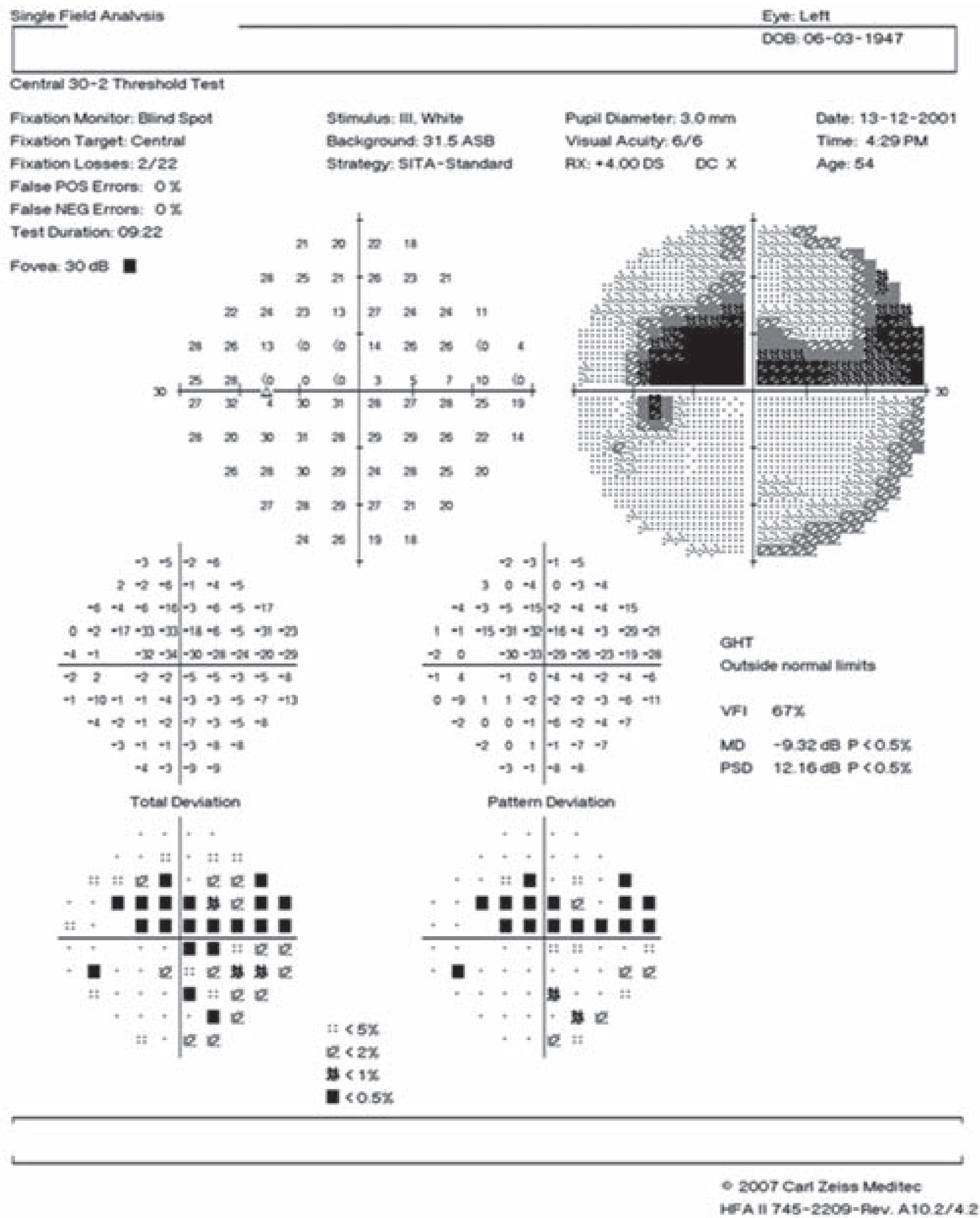
Central scotoma – may be due to retinal disease or non-glaucomatous optic neuropathies. This is a case of Subretinal Neovascular membrane (SRNVM).

Case 17



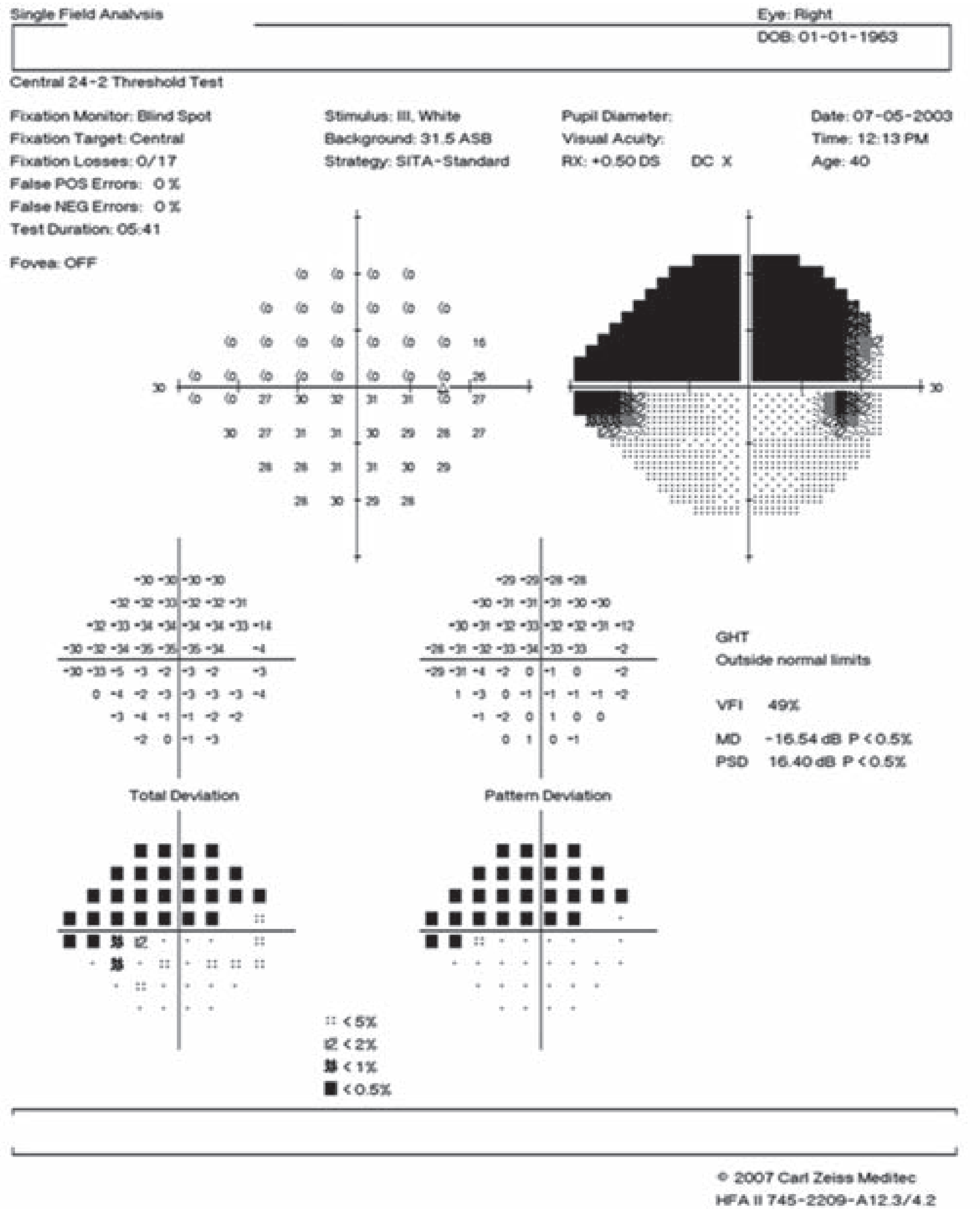
Early glaucomatous field loss – as per the Hoddap-Parish-Anderson criteria. MD< -6dB.

Case 18



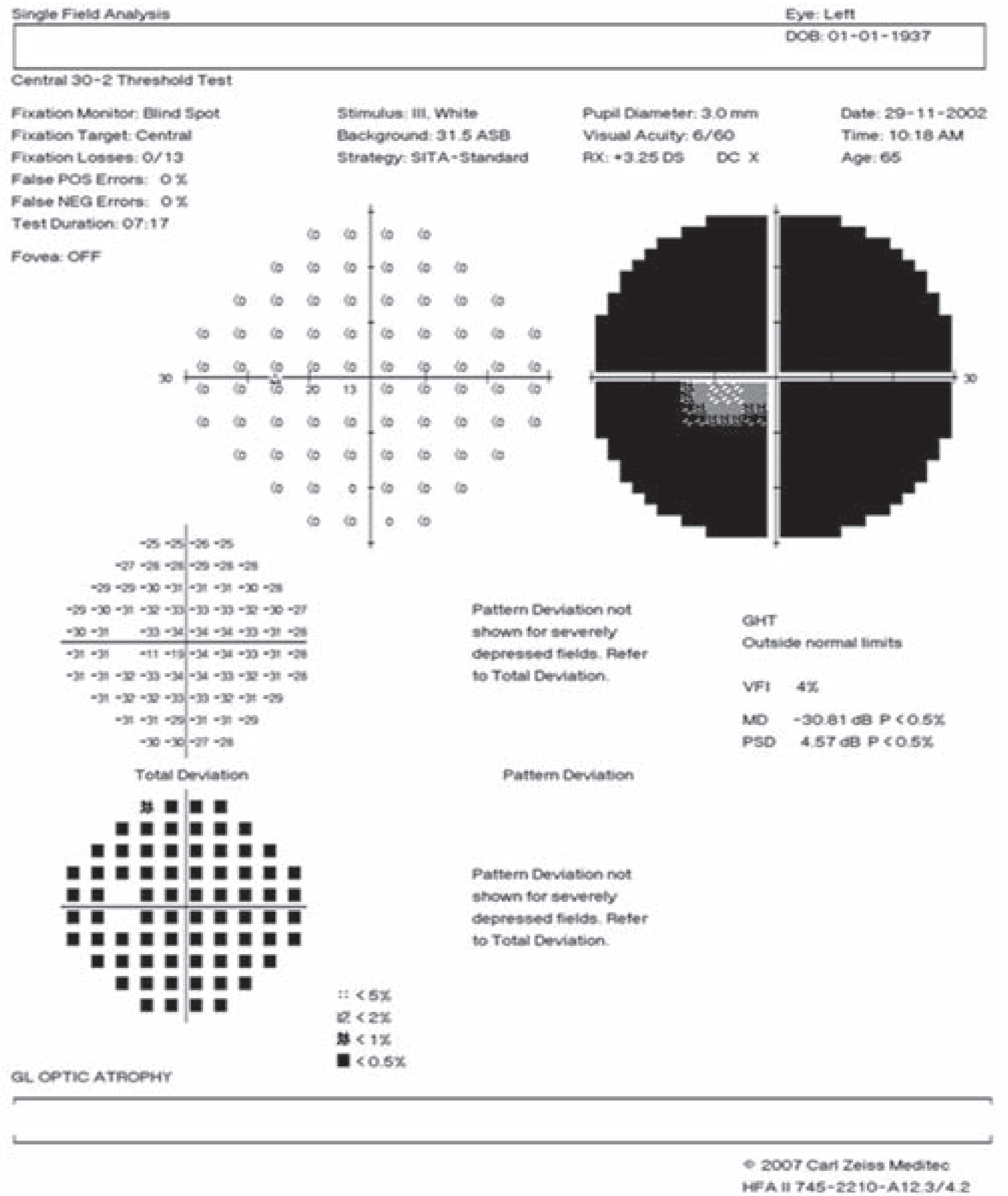
Moderate glaucomatous field loss – as per the Hoddap-Parish-Anderson criteria. MD is - 6 dB to < -12dB.

Case 19



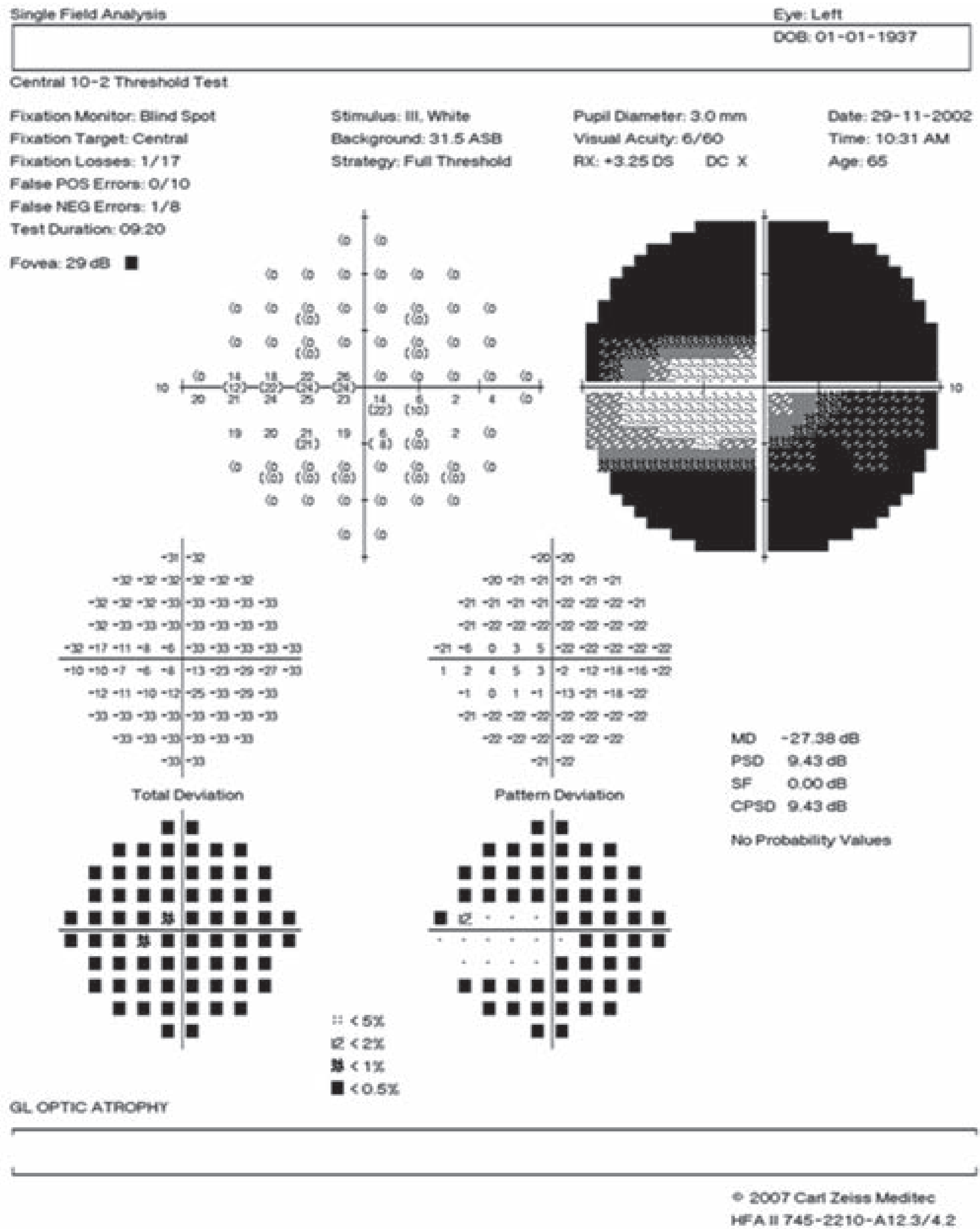
Severe glaucomatous field loss – as per the Hoddap-Parish-Anderson criteria. MD is > -12dB.

Case 20 (A)



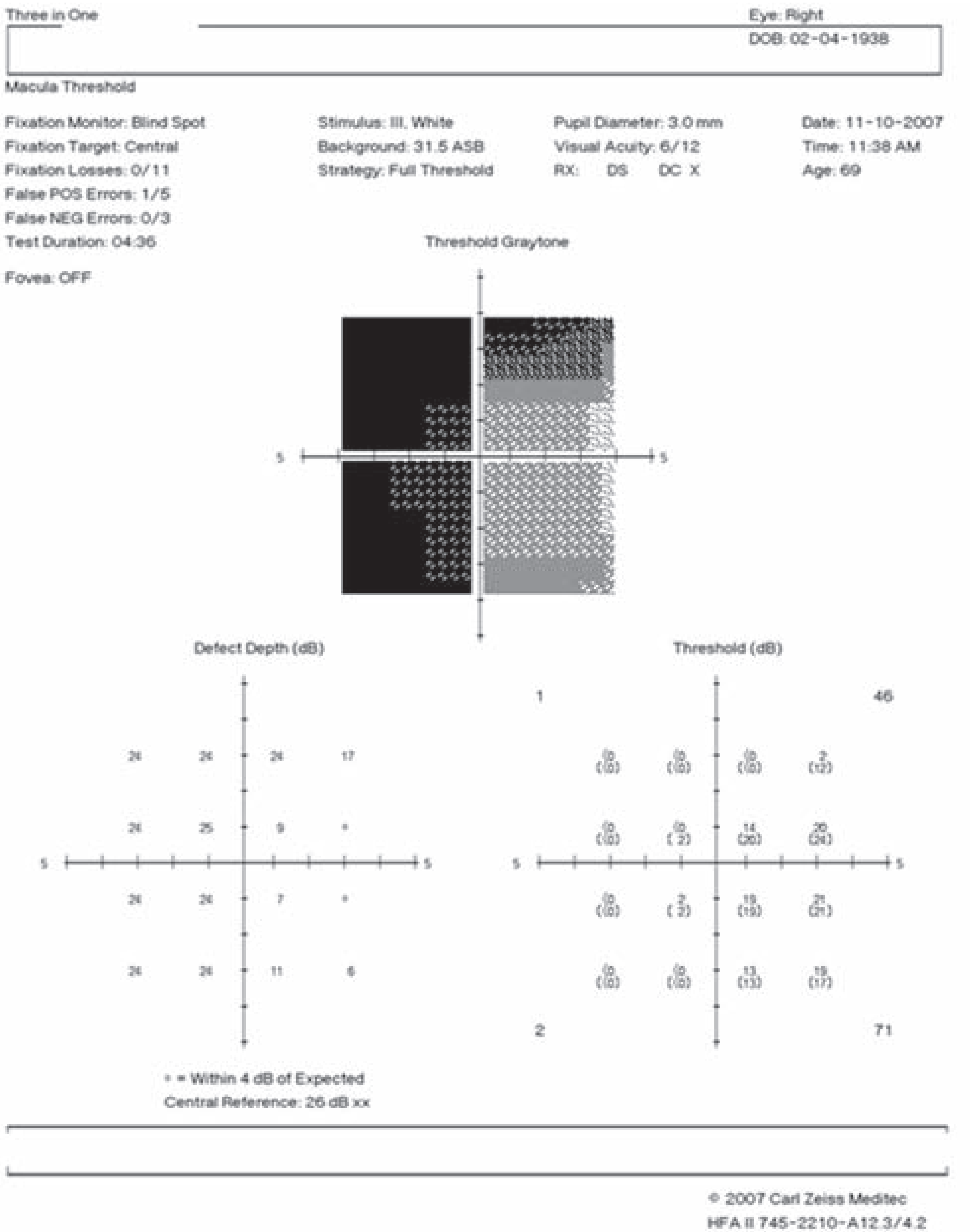
Advanced field defect – The total deviation plot shows generalised depression and the pattern deviation is not shown in view of severely depressed fields. In such cases 10-2 should be performed for determining the central field.

Case 20 (B)



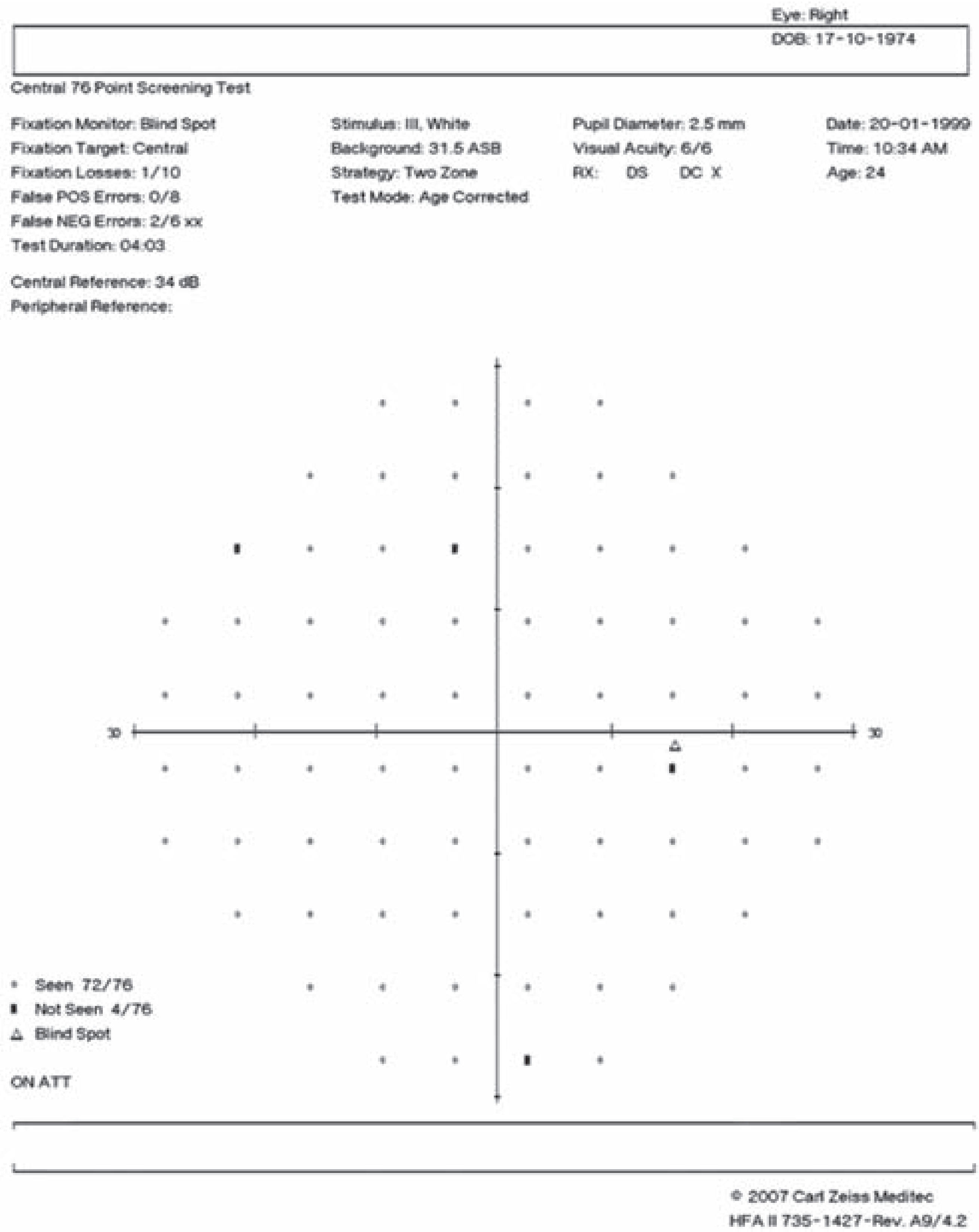
HVF 10-2 : of the same patient shows MD of -27.38dB with only central 5^{o} of remaining visual field.

Case 21



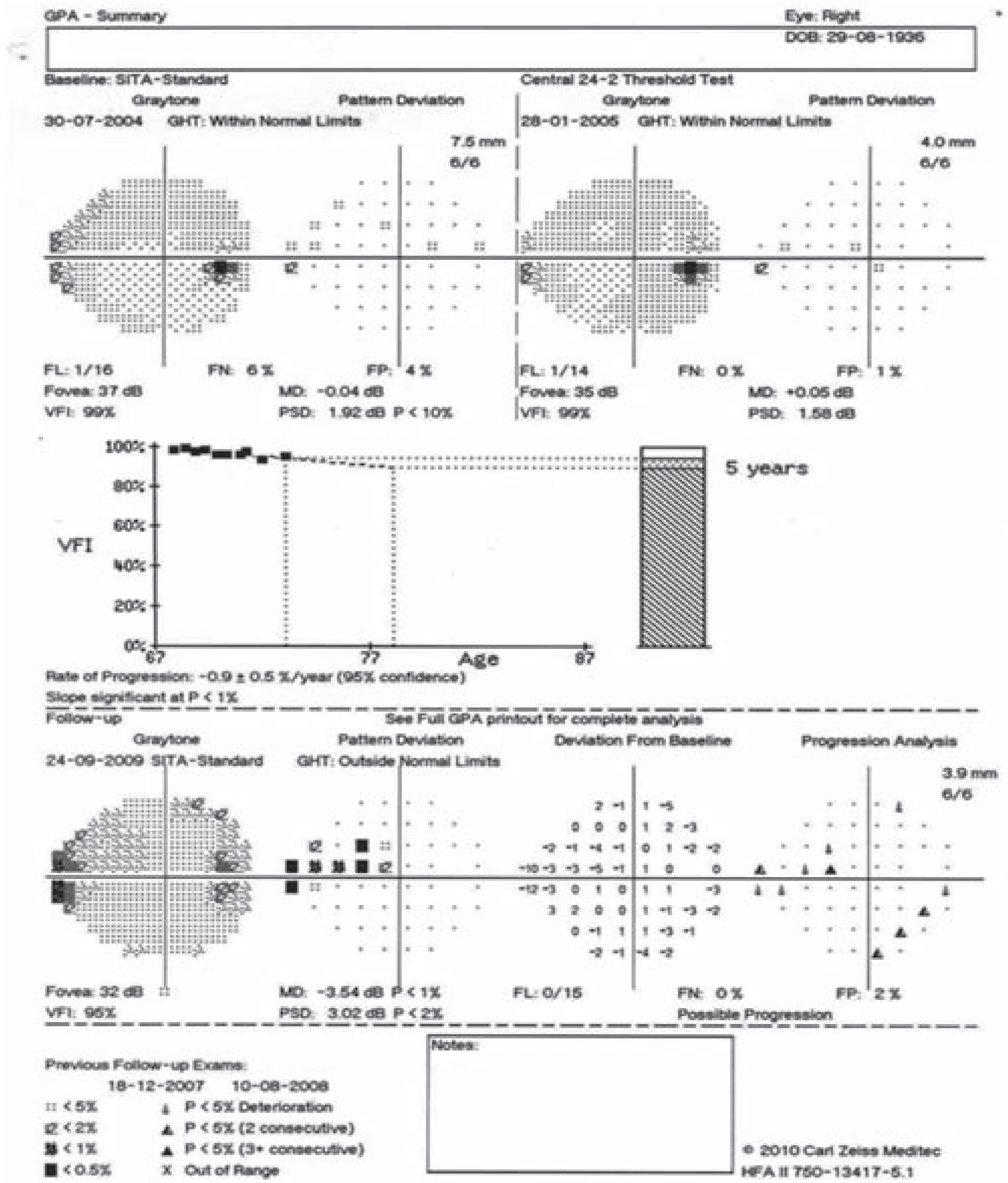
Macular Threshold Test.

Case 22



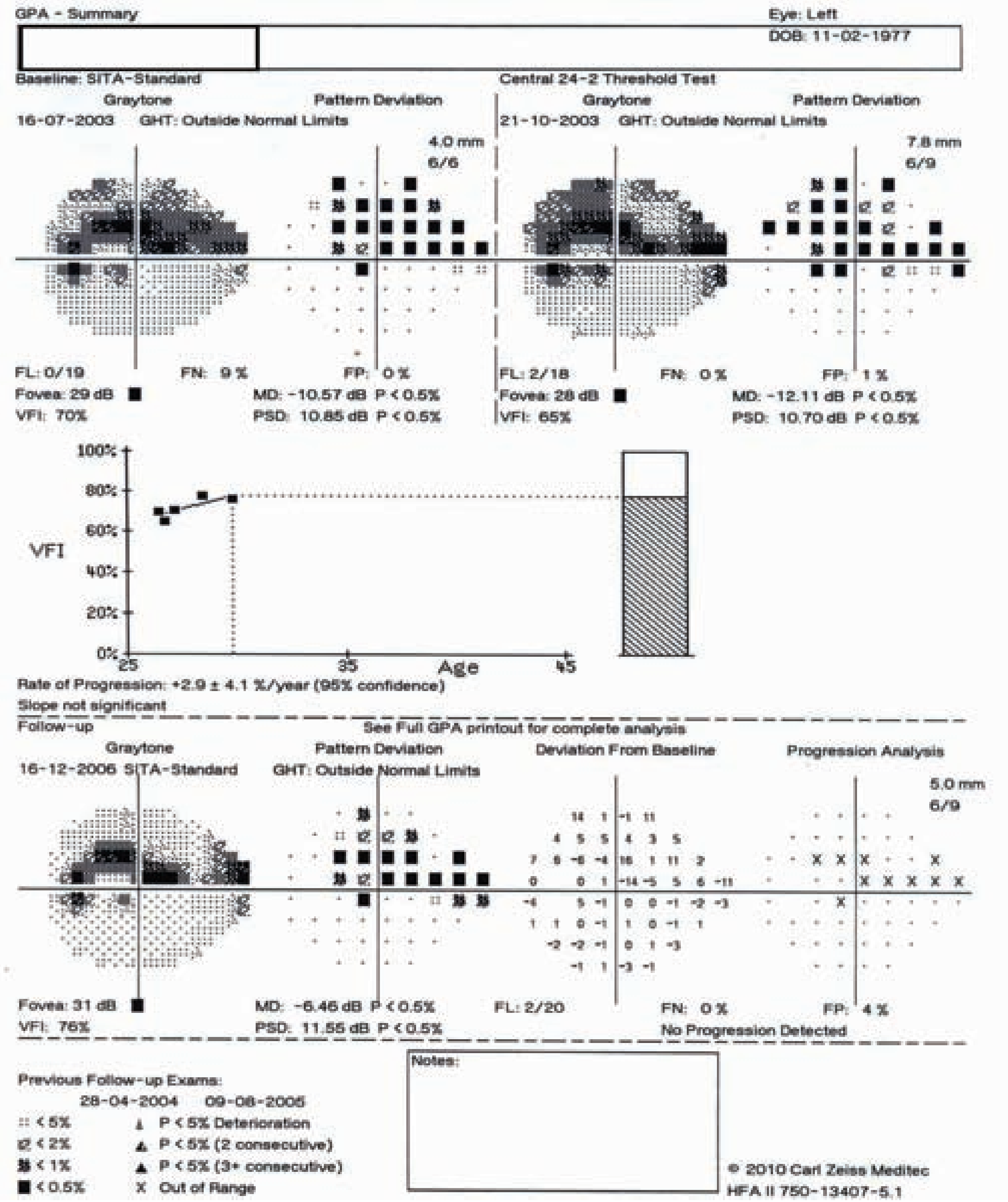
76 point screening test.

Case 23



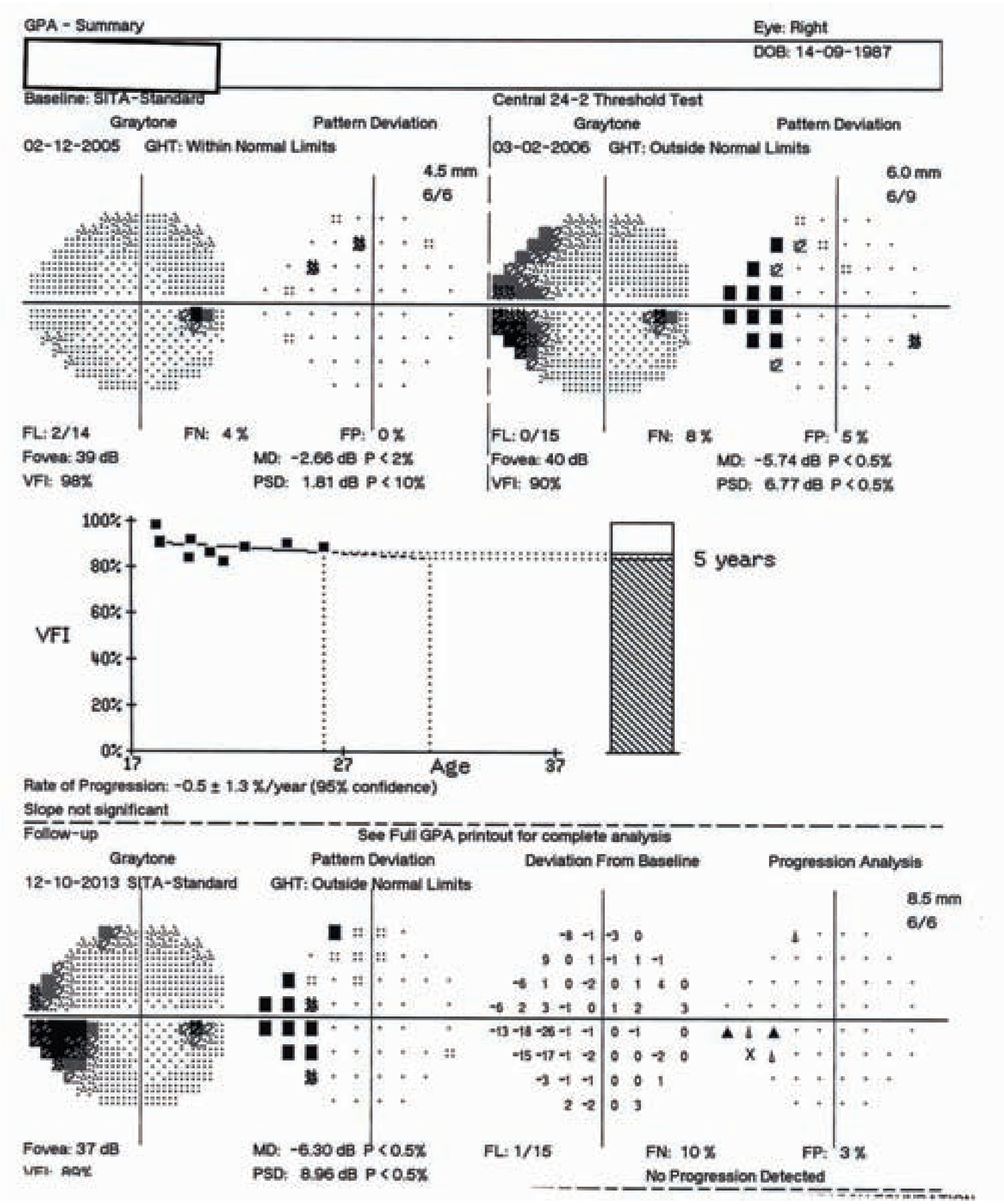
This GPA summary shows a number of visual fields (10) done over a 5 year period . They show a gradual deterioration of 0.9dB/year as well as progression on multiple points in the event analysis plot. This early progression can be detected because of the large number of visual fields available.

Case 24



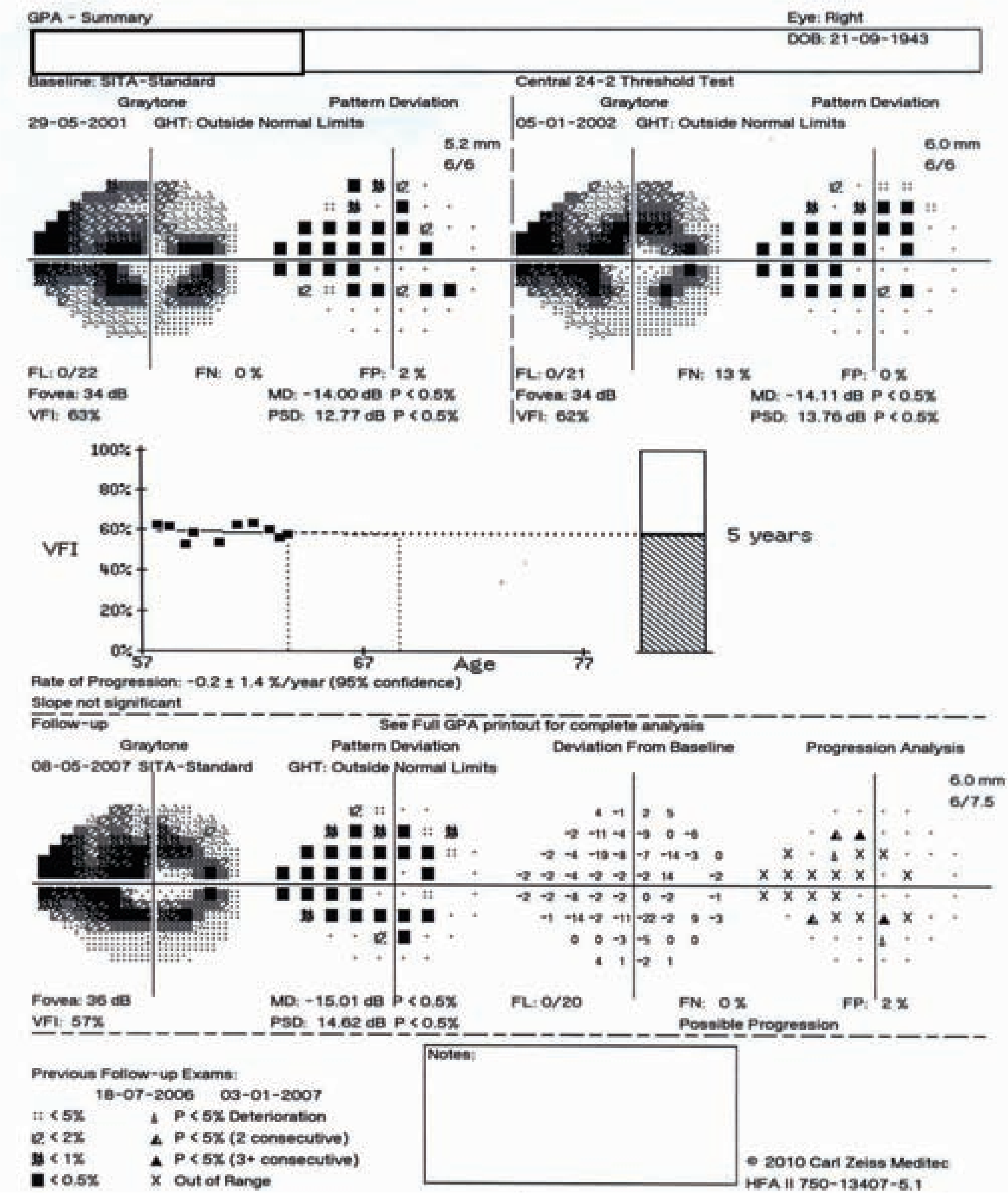
This GPA summary shows improving VFI values over time indicating that the learning curve is not over as yet. The event analysis plot shows a number of points marked 'x' indicating that those points have severe damage and progression cannot be assessed at those points.

Case 25



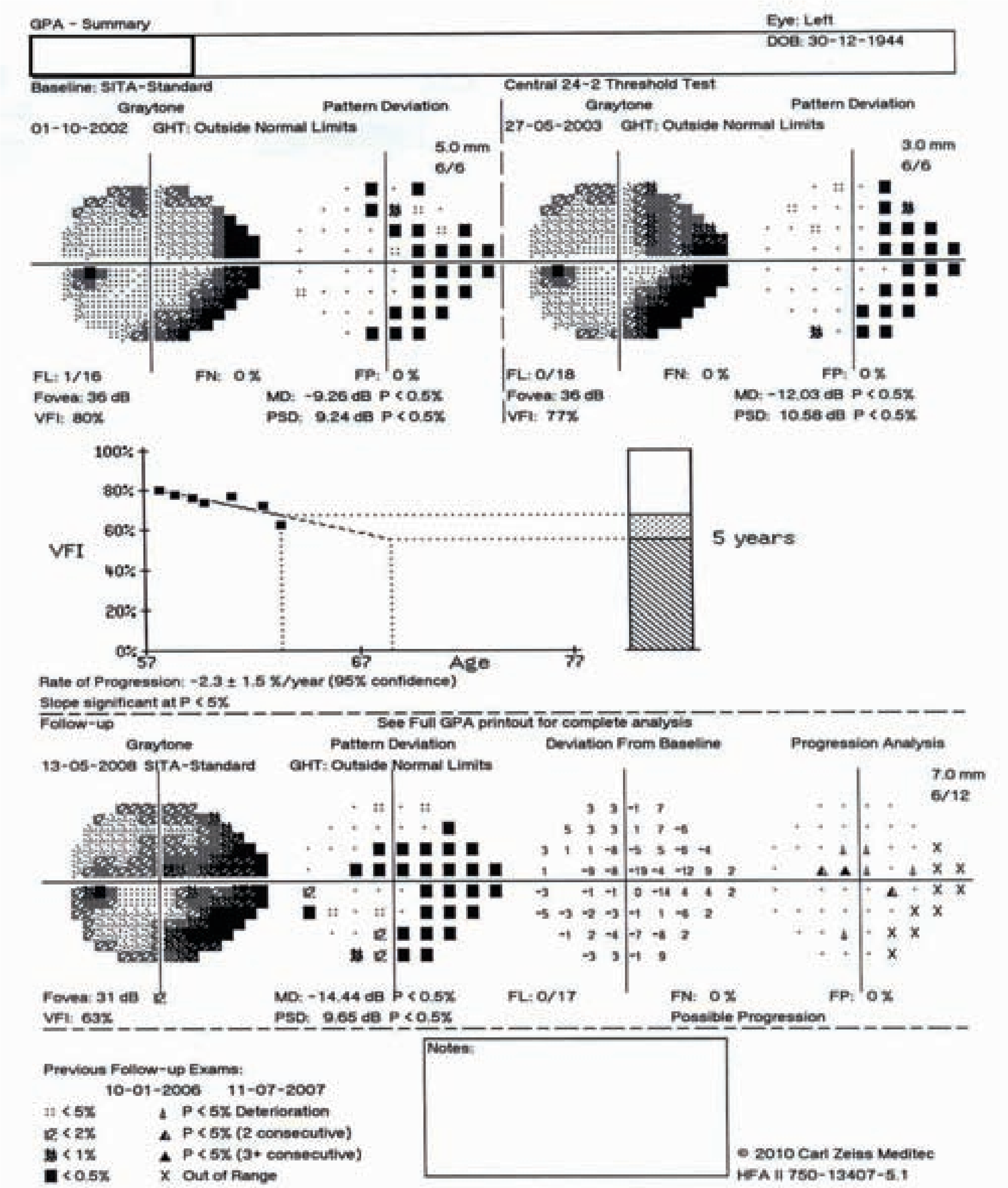
The baseline fields are significantly different , the VFI shows wide fluctuations and therefore even though a large number of tests are available (more than 10) it does not detect significant progression on the trend analysis but some points are worsening on the event analysis.

Case 26



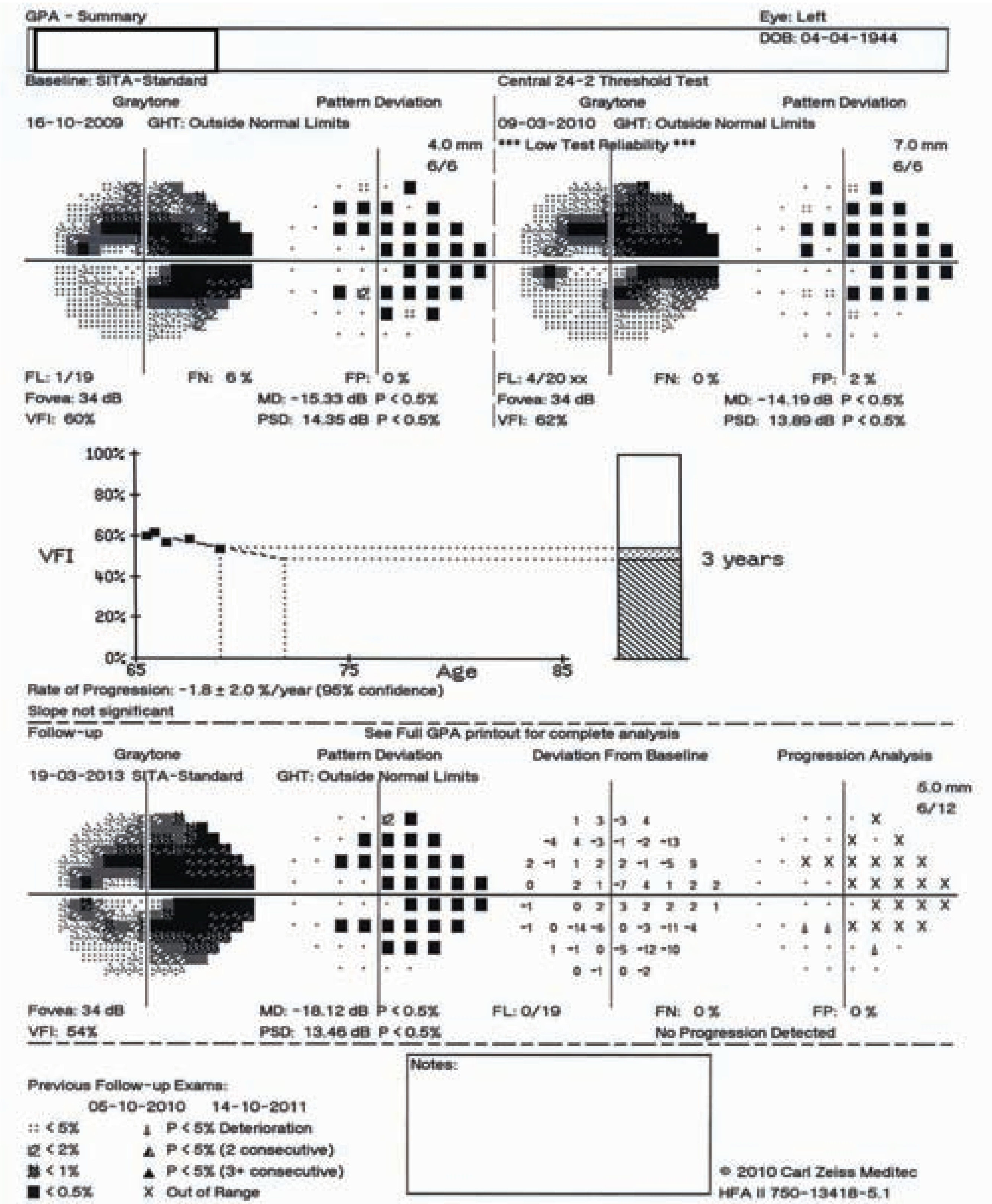
Progression on the trend analysis (enlargement of an existing scotoma). The trend analysis again shows wide fluctuations and therefore even though a large number of tests are available it does not detect significant progression.

Case 27



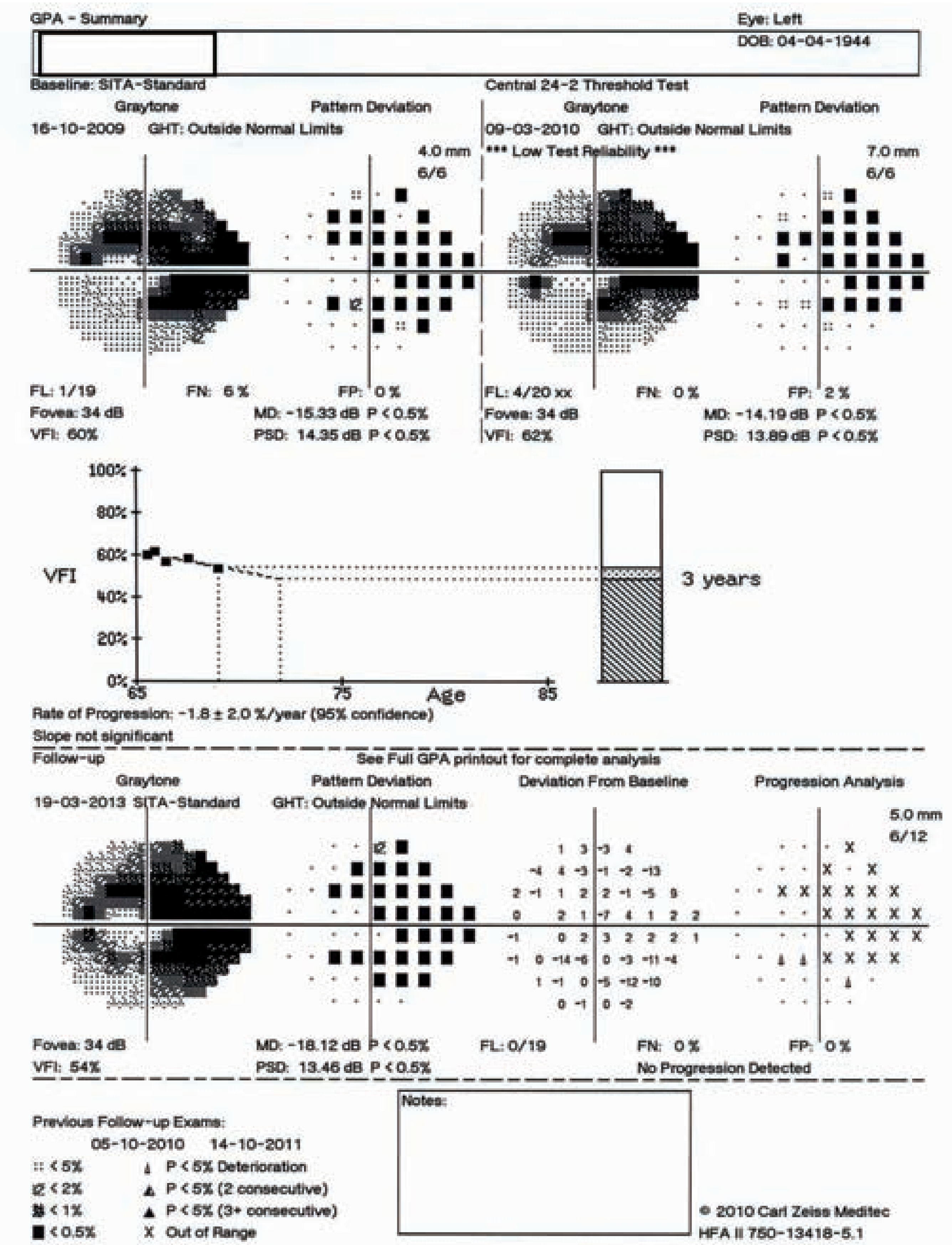
This GPA summary shows worsening trend and event analysis (new areas showing damage). While the VFI is worsening note that the last VFI is lower than the previous values . To confirm it would be advisable to repeat the test and see if the pattern is consistent.

Case 28 (A)



(a) and (b): In (a) trend towards progression is noted but this is not statistically significant on trend analysis. As the number of fields available increases this trend becomes significant.

Case 28 (B)


GPA - Summary
Eye: Left
DOB: 04-04-1944
Baseline: SITA-Standard
Central 24-2 Threshold Test
Graytone
Pattern Deviation
16-10-2009 GHT: Outside Normal Limits
4.0 mm
6/6
FL: 1/19
FN: 6 %
FP: 0 %
Fovea: 34 dB
MD: -15.33 dB P < 0.5%
VFI: 60%
PSD: 14.35 dB P < 0.5%
Graytone
Pattern Deviation
09-03-2010 GHT: Outside Normal Limits
*** Low Test Reliability ***
7.0 mm
6/6
FL: 4/20 xx
FN: 0 %
FP: 2 %
Fovea: 34 dB
MD: -14.19 dB P < 0.5%
VFI: 62%
PSD: 13.89 dB P < 0.5%
100%
80%
60%
VFI
40%
20%
0%
65
75
Age
85
3 years
Rate of Progression: -1.8 ± 2.0 %/year (95% confidence)
Slope not significant
Follow-up
See Full GPA printout for complete analysis
Graytone
Pattern Deviation
Deviation From Baseline
Progression Analysis
19-03-2013 SITA-Standard
GHT: Outside Normal Limits
5.0 mm
6/12
Fovea: 34 dB
MD: -18.12 dB P < 0.5%
FL: 0/19
FN: 0 %
FP: 0 %
VFI: 54%
PSD: 13.46 dB P < 0.5%
No Progression Detected
Notes:
Previous Follow-up Exams:
05-10-2010 14-10-2011
< 5%
< 2%
< 1%
< 0.5%
P < 5% Deterioration
P < 5% (2 consecutive)
P < 5% (3+ consecutive)
X Out of Range
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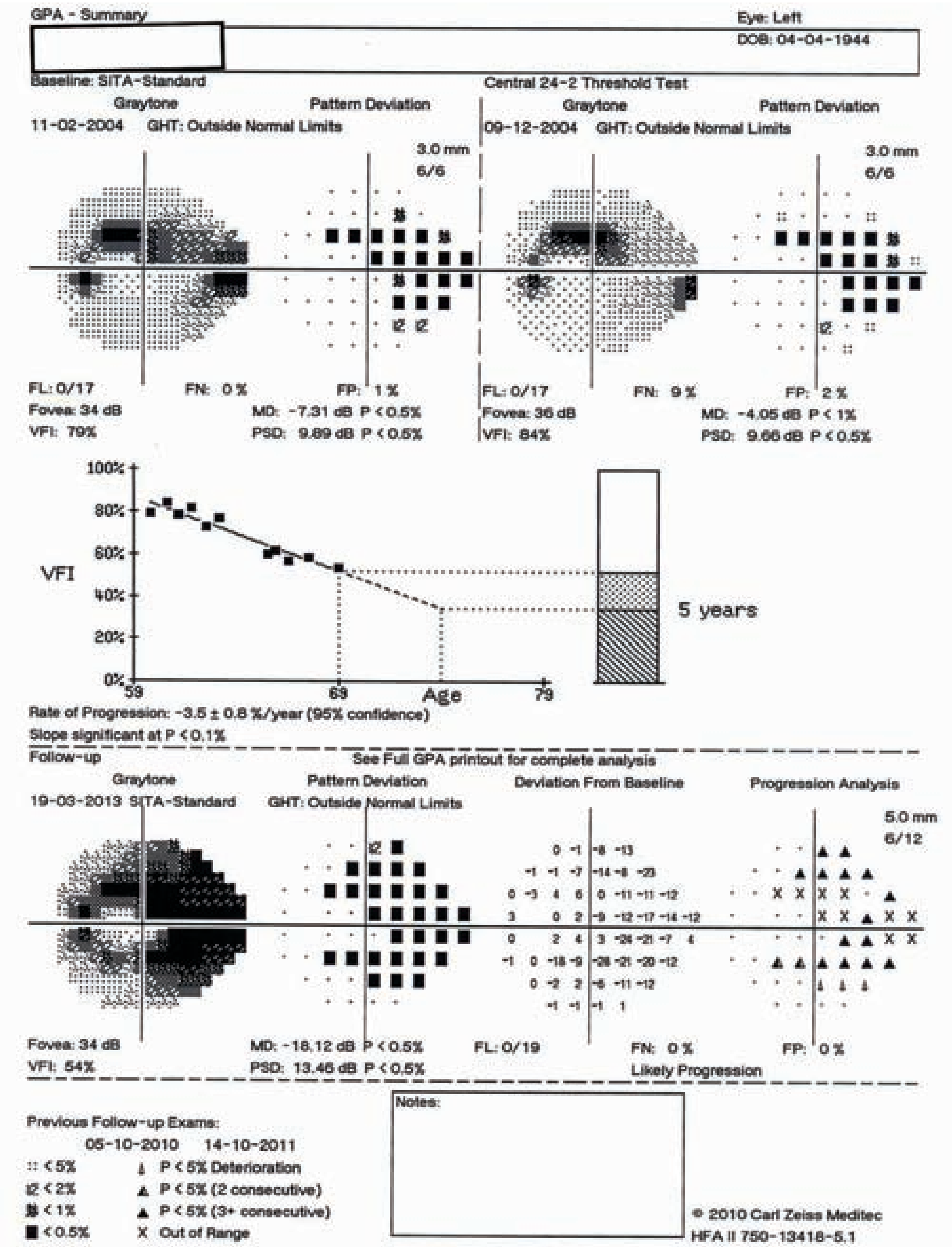
Case 28 (C)



GPA - Summary
Eye: Left
DOB: 04-04-1944
Baseline: SITA-Standard
Central 24-2 Threshold Test
Graytone
Pattern Deviation
11-02-2004 GHT: Outside Normal Limits
3.0 mm
6/6
FL: 0/17
FN: 0 %
FP: 1 %
Fovea: 34 dB
VFI: 79%
MD: -7.31 dB P < 0.5%
PSD: 9.89 dB P < 0.5%
09-12-2004 GHT: Outside Normal Limits
FL: 0/17
FN: 9 %
FP: 2 %
Fovea: 36 dB
VFI: 84%
MD: -4.05 dB P < 1%
PSD: 9.66 dB P < 0.5%
VFI
100%
80%
60%
40%
20%
0%
59
69
Age
79
5 years
Rate of Progression: -3.5 ± 0.8 %/year (95% confidence)
Slope significant at P < 0.1%
Follow-up
See Full GPA printout for complete analysis
Graytone
Pattern Deviation
Deviation From Baseline
Progression Analysis
19-03-2013 SITA-Standard
GHT: Outside Normal Limits
5.0 mm
6/12
Fovea: 34 dB
VFI: 54%
MD: -18.12 dB P < 0.5%
PSD: 13.46 dB P < 0.5%
FL: 0/19
FN: 0 %
FP: 0 %
Likely Progression
Notes:
Previous Follow-up Exams:
05-10-2010 14-10-2011
< 5%
< 2%
< 1%
< 0.5%
P < 5% Deterioration
P < 5% (2 consecutive)
P < 5% (3+ consecutive)
X Out of Range
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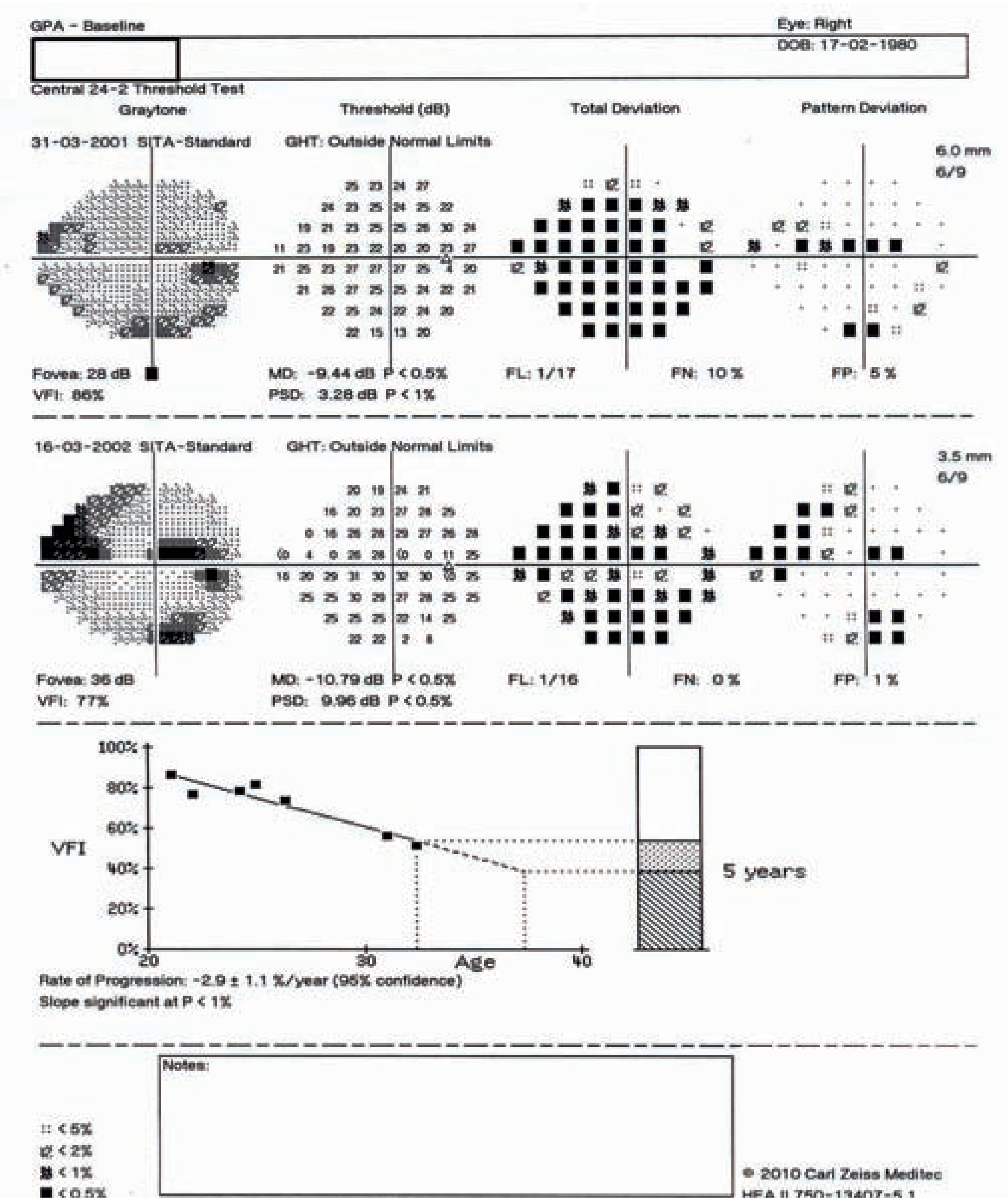
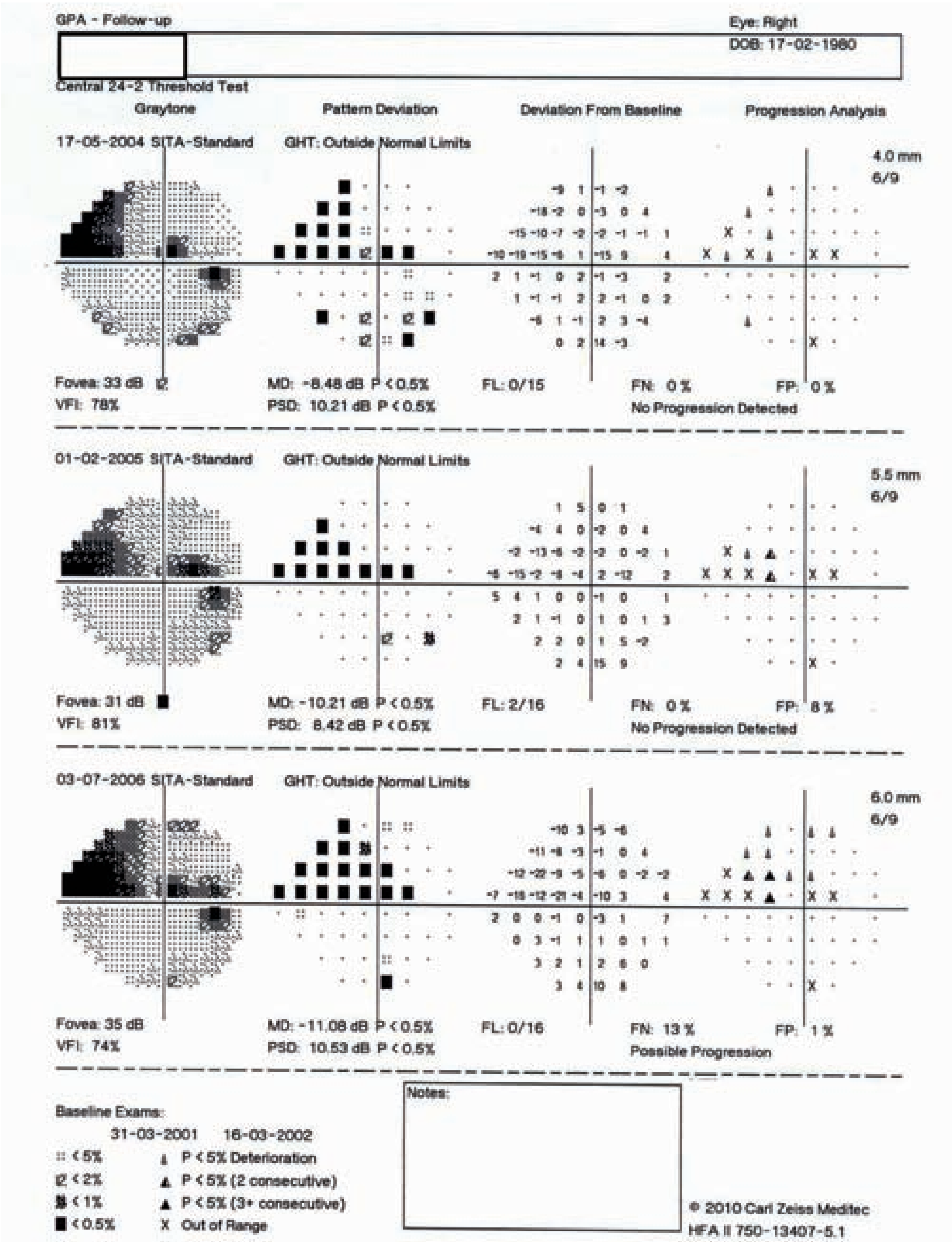
Case 29 (A)



(a), (b) and (c) : Show the entire GPA for a patient over a 10 year period. It shows both significant trend and event progression. Since the patient had a surgical intervention in 2005 a new baseline is taken (d). This too shows progression even with few fields because the rate of progression is large.

Case 29 (B)


GPA - Follow-up
Eye: Right
DOB: 17-02-1980
Central 24-2 Threshold Test
Graytone
Pattern Deviation
Deviation From Baseline
Progression Analysis
17-05-2004 SITA-Standard
GHT: Outside Normal Limits
4.0 mm
6/9
Fovea: 33 dB
VFI: 78%
MD: -8.48 dB P < 0.5%
PSD: 10.21 dB P < 0.5%
FL: 0/15
FN: 0 %
FP: 0 %
No Progression Detected
01-02-2005 SITA-Standard
GHT: Outside Normal Limits
5.5 mm
6/9
Fovea: 31 dB
VFI: 81%
MD: -10.21 dB P < 0.5%
PSD: 8.42 dB P < 0.5%
FL: 2/16
FN: 0 %
FP: 8 %
No Progression Detected
03-07-2006 SITA-Standard
GHT: Outside Normal Limits
6.0 mm
6/9
Fovea: 35 dB
VFI: 74%
MD: -11.08 dB P < 0.5%
PSD: 10.53 dB P < 0.5%
FL: 0/16
FN: 13 %
FP: 1 %
Possible Progression
Baseline Exams:
31-03-2001
16-03-2002
< 5%
< 2%
< 1%
< 0.5%
P < 5% Deterioration
P < 5% (2 consecutive)
P < 5% (3+ consecutive)
X Out of Range
Notes:
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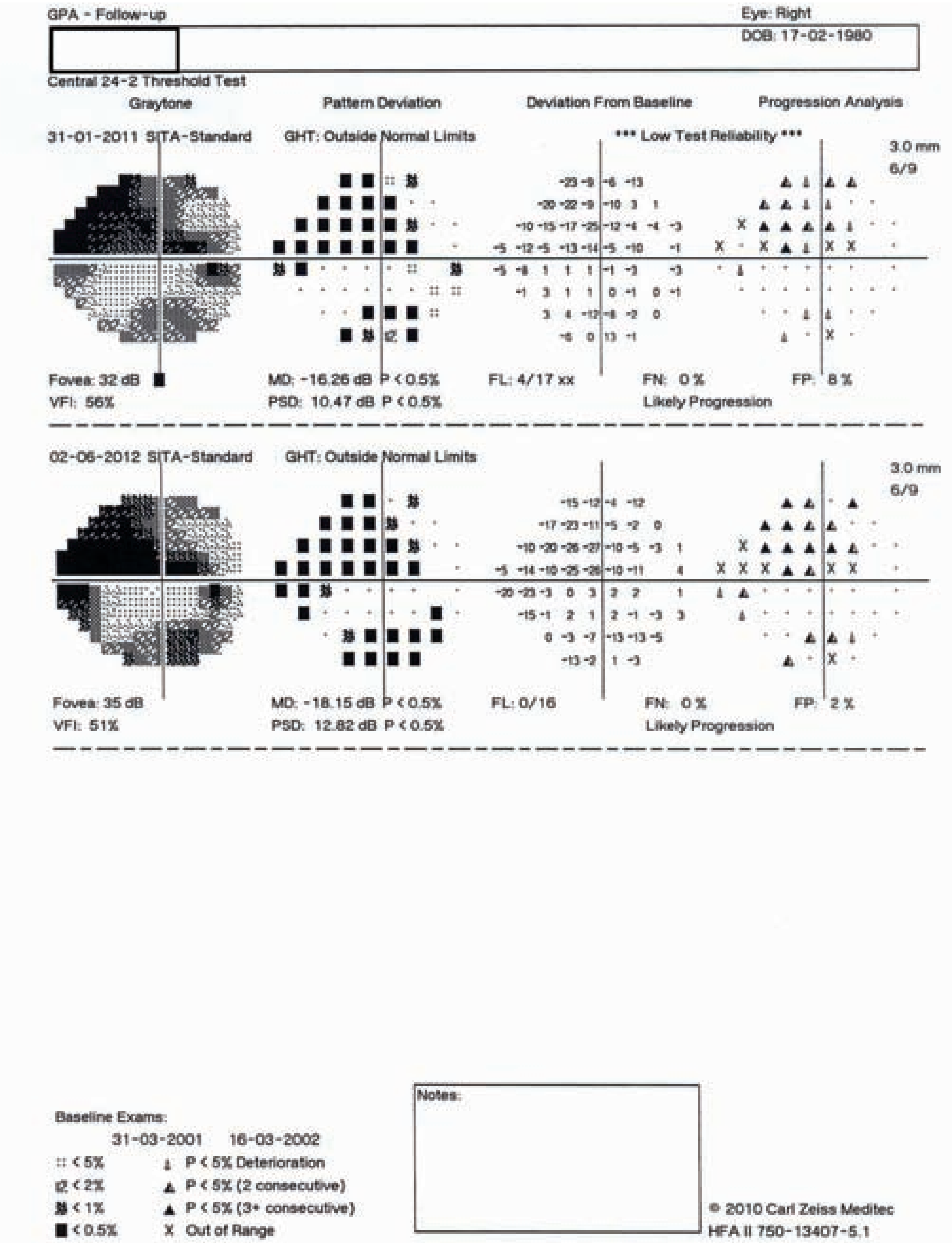
Case 29 (C)


GPA - Follow-up
Eye: Right
DOB: 17-02-1980
Central 24-2 Threshold Test
Graytone
Pattern Deviation
Deviation From Baseline
Progression Analysis
31-01-2011 SITA-Standard
GHT: Outside Normal Limits
*** Low Test Reliability ***
3.0 mm
6/9
Fovea: 32 dB
VFI: 56%
MD: -16.26 dB P < 0.5%
PSD: 10.47 dB P < 0.5%
FL: 4/17 xx
FN: 0 %
FP: 8 %
Likely Progression
02-06-2012 SITA-Standard
GHT: Outside Normal Limits
3.0 mm
6/9
Fovea: 35 dB
VFI: 51%
MD: -18.15 dB P < 0.5%
PSD: 12.82 dB P < 0.5%
FL: 0/16
FN: 0 %
FP: 2 %
Likely Progression
Baseline Exams:
31-03-2001 16-03-2002
< 5%
< 2%
< 1%
< 0.5%
P < 5% Deterioration
P < 5% (2 consecutive)
P < 5% (3+ consecutive)
X Out of Range
Notes:
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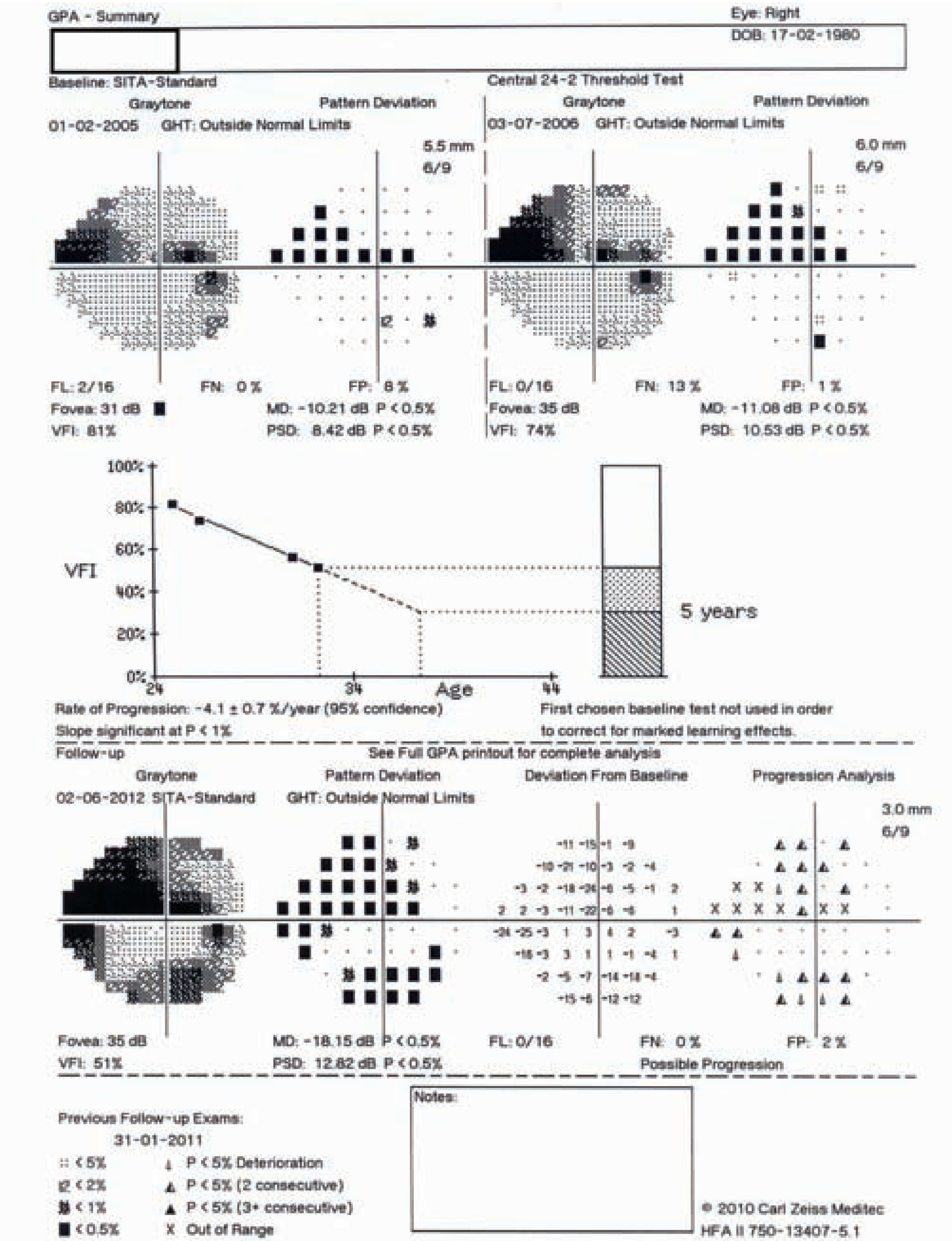
Case 29 (D)



GPA - Summary
Eye: Right
DOB: 17-02-1980
Baseline: SITA-Standard
Central 24-2 Threshold Test
Graytone
Pattern Deviation
01-02-2005 GHT: Outside Normal Limits
5.5 mm
6/9
FL: 2/16 FN: 0 % FP: 8 %
Fovea: 31 dB
MD: -10.21 dB P < 0.5%
VFI: 81%
PSD: 8.42 dB P < 0.5%
Graytone
Pattern Deviation
03-07-2006 GHT: Outside Normal Limits
6.0 mm
6/9
FL: 0/16 FN: 13 % FP: 1 %
Fovea: 35 dB
MD: -11.08 dB P < 0.5%
VFI: 74%
PSD: 10.53 dB P < 0.5%
100%
80%
60%
VFI
40%
20%
0%
24
34
Age
44
5 years
Rate of Progression: -4.1 ± 0.7 %/year (95% confidence)
Slope significant at P < 1%
First chosen baseline test not used in order
to correct for marked learning effects.
Follow-up
See Full GPA printout for complete analysis
Graytone
Pattern Deviation
Deviation From Baseline
Progression Analysis
02-06-2012 SITA-Standard
GHT: Outside Normal Limits
3.0 mm
6/9
Fovea: 35 dB
MD: -18.15 dB P < 0.5%
FL: 0/16 FN: 0 % FP: 2 %
VFI: 51%
PSD: 12.82 dB P < 0.5%
Possible Progression
Previous Follow-up Exams:
31-01-2011
< 5%
< 2%
< 1%
< 0.5%
P < 5% Deterioration
P < 5% (2 consecutive)
P < 5% (3+ consecutive)
X Out of Range
Notes:
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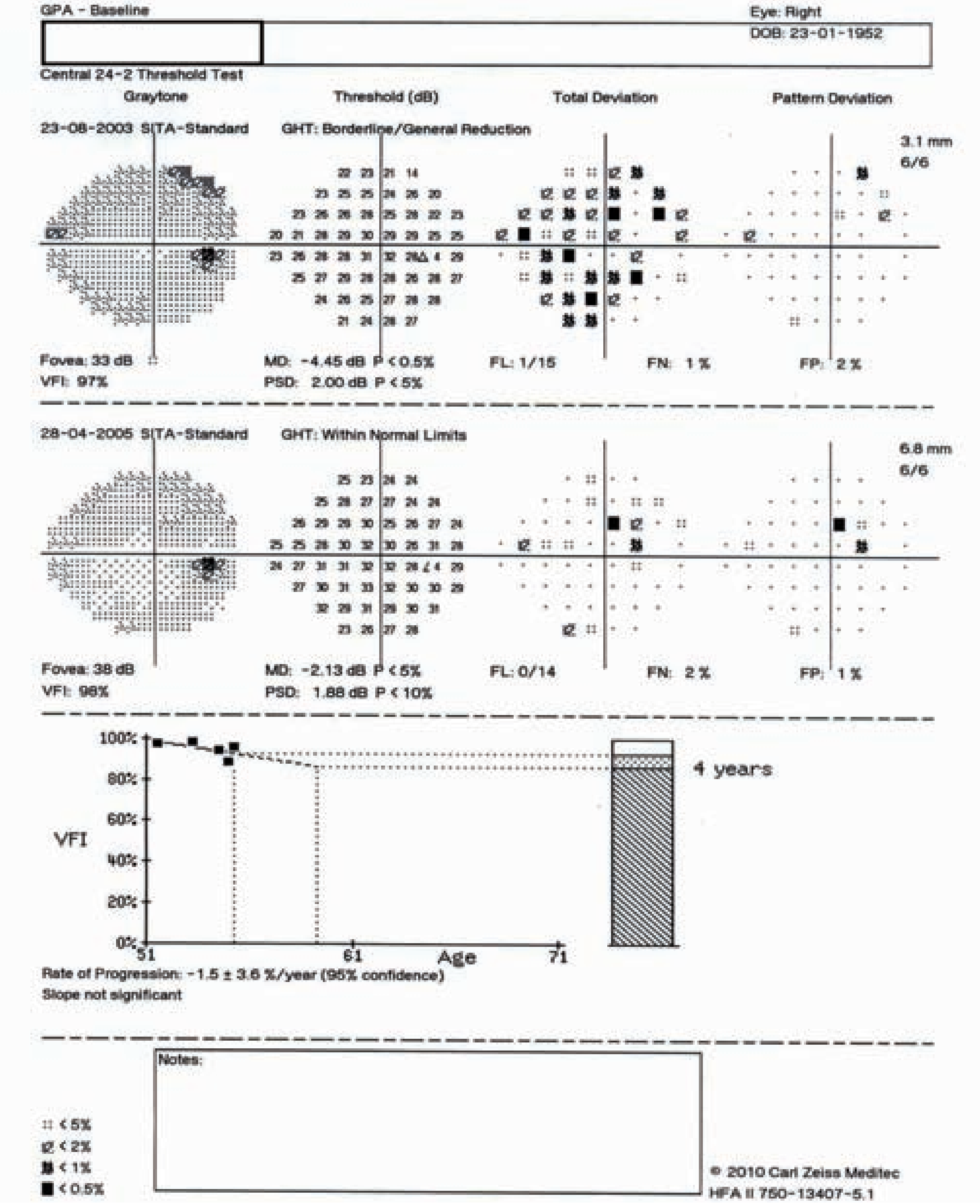
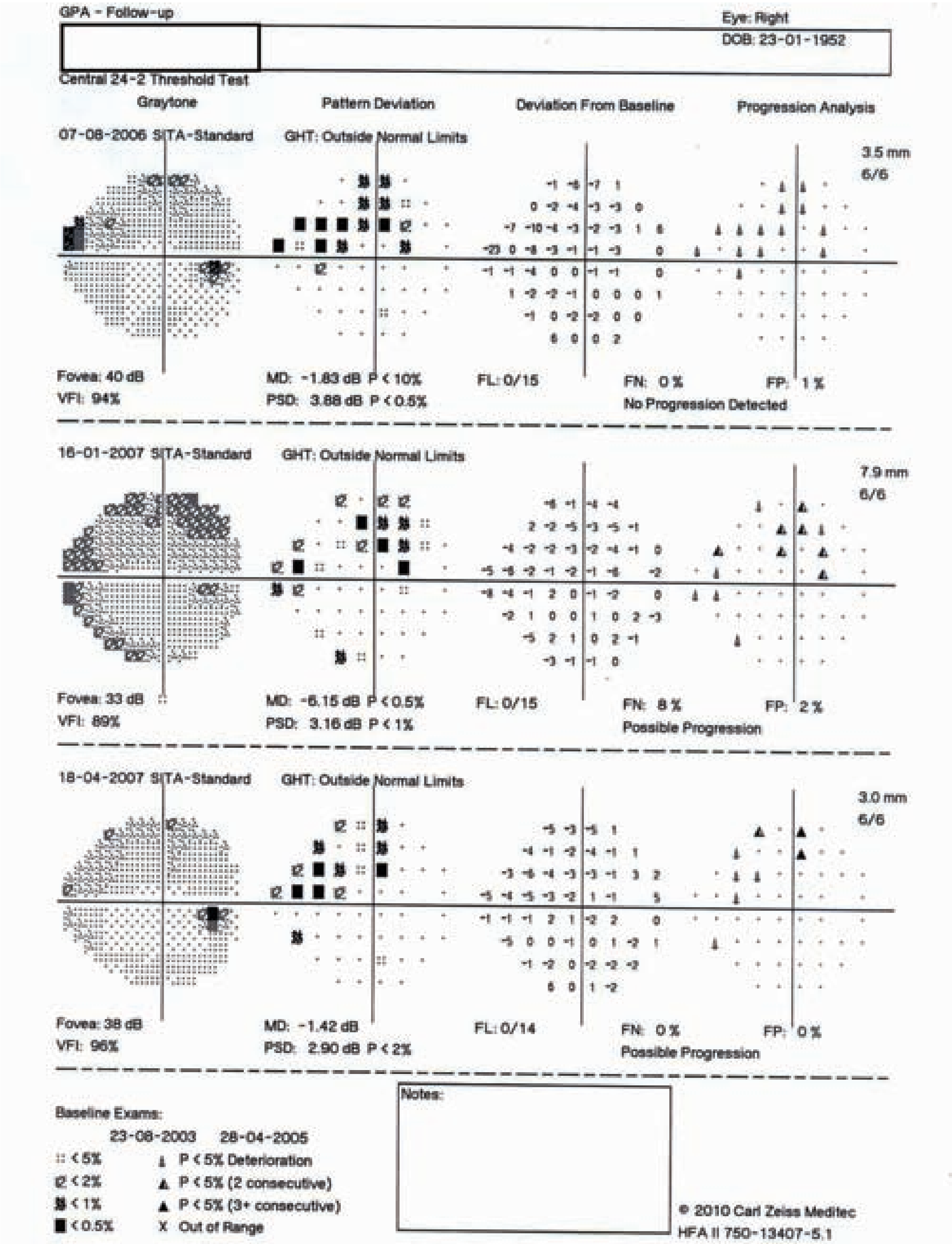
Case 30 (A)



(a) and (b) : The trend analysis here shows some fluctuations but no progression. On the event analysis however a few points in the superior hemi-field show worsening on three consecutive visits.

Case 30 (B)


GPA - Follow-up
Eye: Right
DOB: 23-01-1952
Central 24-2 Threshold Test
Graytone
Pattern Deviation
Deviation From Baseline
Progression Analysis
07-08-2006 SITA-Standard
GHT: Outside Normal Limits
3.5 mm
6/6
Fovea: 40 dB
VFI: 94%
MD: -1.83 dB P < 10%
PSD: 3.88 dB P < 0.5%
FL: 0/15
FN: 0 %
FP: 1 %
No Progression Detected
16-01-2007 SITA-Standard
GHT: Outside Normal Limits
7.9 mm
6/6
Fovea: 33 dB
VFI: 89%
MD: -6.15 dB P < 0.5%
PSD: 3.16 dB P < 1%
FL: 0/15
FN: 8 %
FP: 2 %
Possible Progression
18-04-2007 SITA-Standard
GHT: Outside Normal Limits
3.0 mm
6/6
Fovea: 38 dB
VFI: 96%
MD: -1.42 dB
PSD: 2.90 dB P < 2%
FL: 0/14
FN: 0 %
FP: 0 %
Possible Progression
Baseline Exams:
23-08-2003 28-04-2005
< 5%
< 2%
< 1%
< 0.5%
P < 5% Deterioration
P < 5% (2 consecutive)
P < 5% (3+ consecutive)
X Out of Range
Notes:
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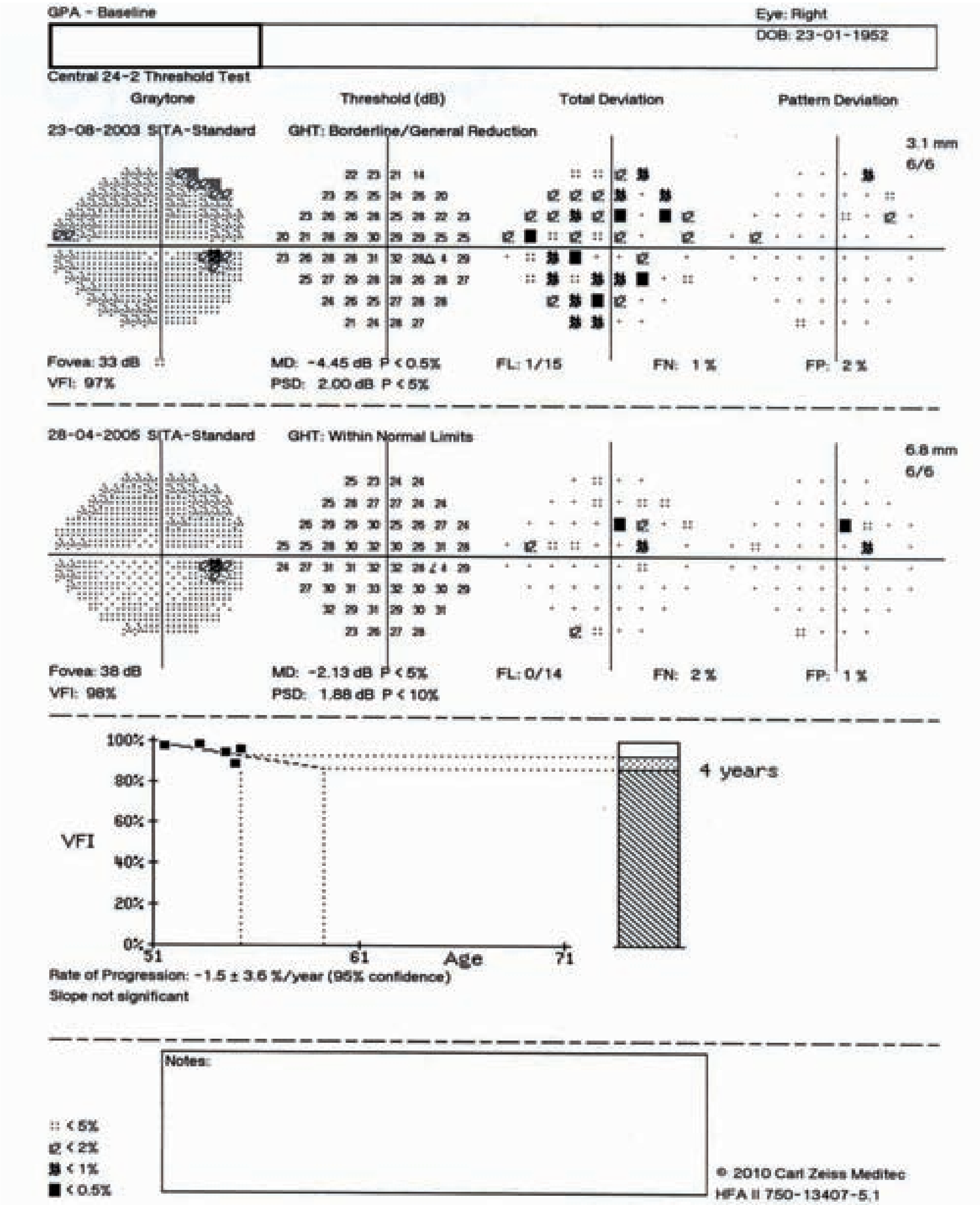
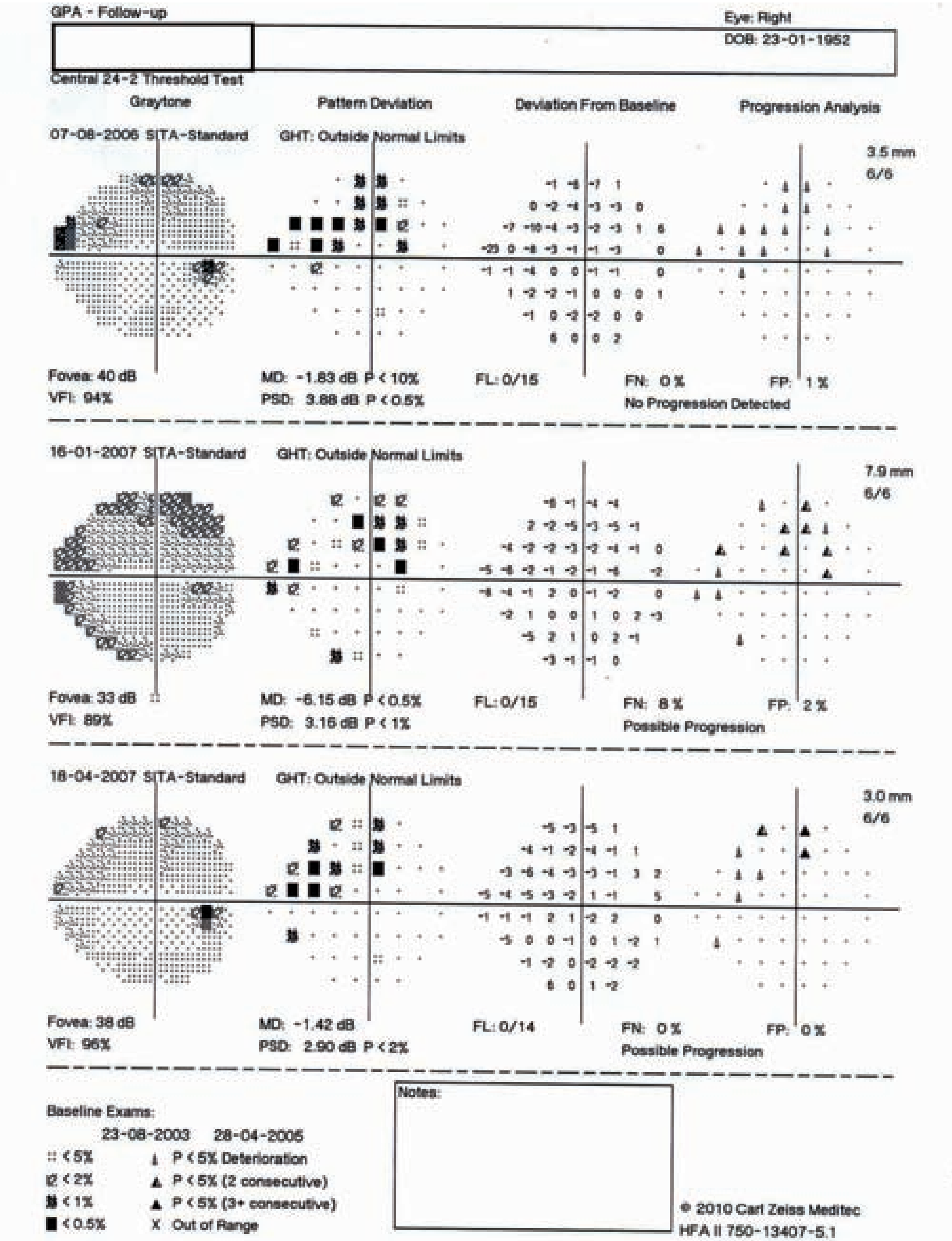
Case 31 (A)



(a) and (b) : In this series of visual fields the trend analysis does not show any changes but the event analysis shows progression at multiple points in the superior hemifield.

Case 31 (B)


GPA - Follow-up
Eye: Right
DOB: 23-01-1952
Central 24-2 Threshold Test
Graytone
Pattern Deviation
Deviation From Baseline
Progression Analysis
07-08-2006 SITA-Standard
GHT: Outside Normal Limits
3.5 mm
6/6
Fovea: 40 dB
VFI: 94%
MD: -1.83 dB P < 10%
PSD: 3.88 dB P < 0.5%
FL: 0/15
FN: 0 %
FP: 1 %
No Progression Detected
16-01-2007 SITA-Standard
GHT: Outside Normal Limits
7.9 mm
6/6
Fovea: 33 dB
VFI: 89%
MD: -6.15 dB P < 0.5%
PSD: 3.16 dB P < 1%
FL: 0/15
FN: 8 %
FP: 2 %
Possible Progression
18-04-2007 SITA-Standard
GHT: Outside Normal Limits
3.0 mm
6/6
Fovea: 38 dB
VFI: 96%
MD: -1.42 dB
PSD: 2.90 dB P < 2%
FL: 0/14
FN: 0 %
FP: 0 %
Possible Progression
Baseline Exams:
23-08-2003 28-04-2006
< 5%
< 2%
< 1%
< 0.5%
P < 5% Deterioration
P < 5% (2 consecutive)
P < 5% (3+ consecutive)
X Out of Range
Notes:
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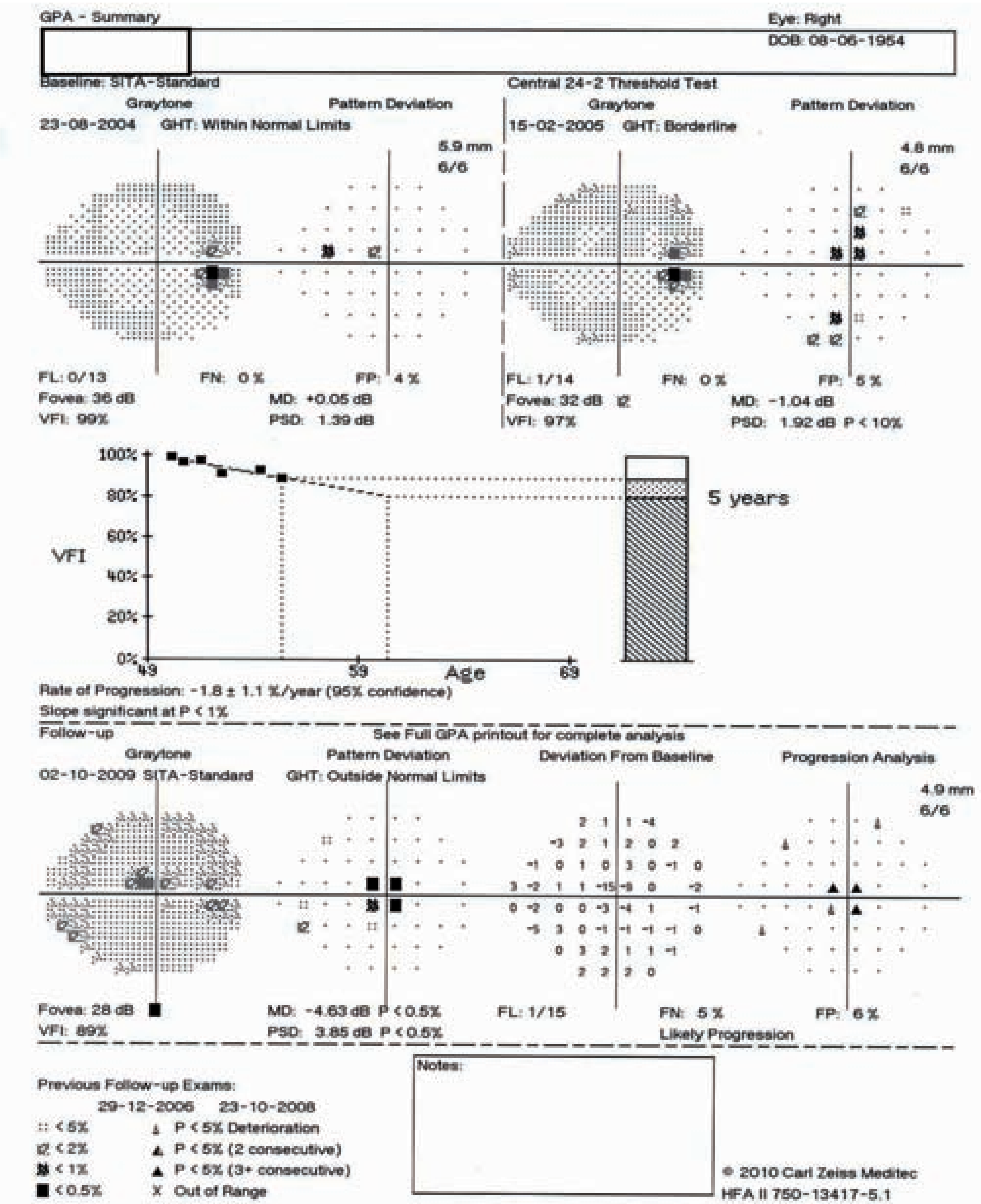
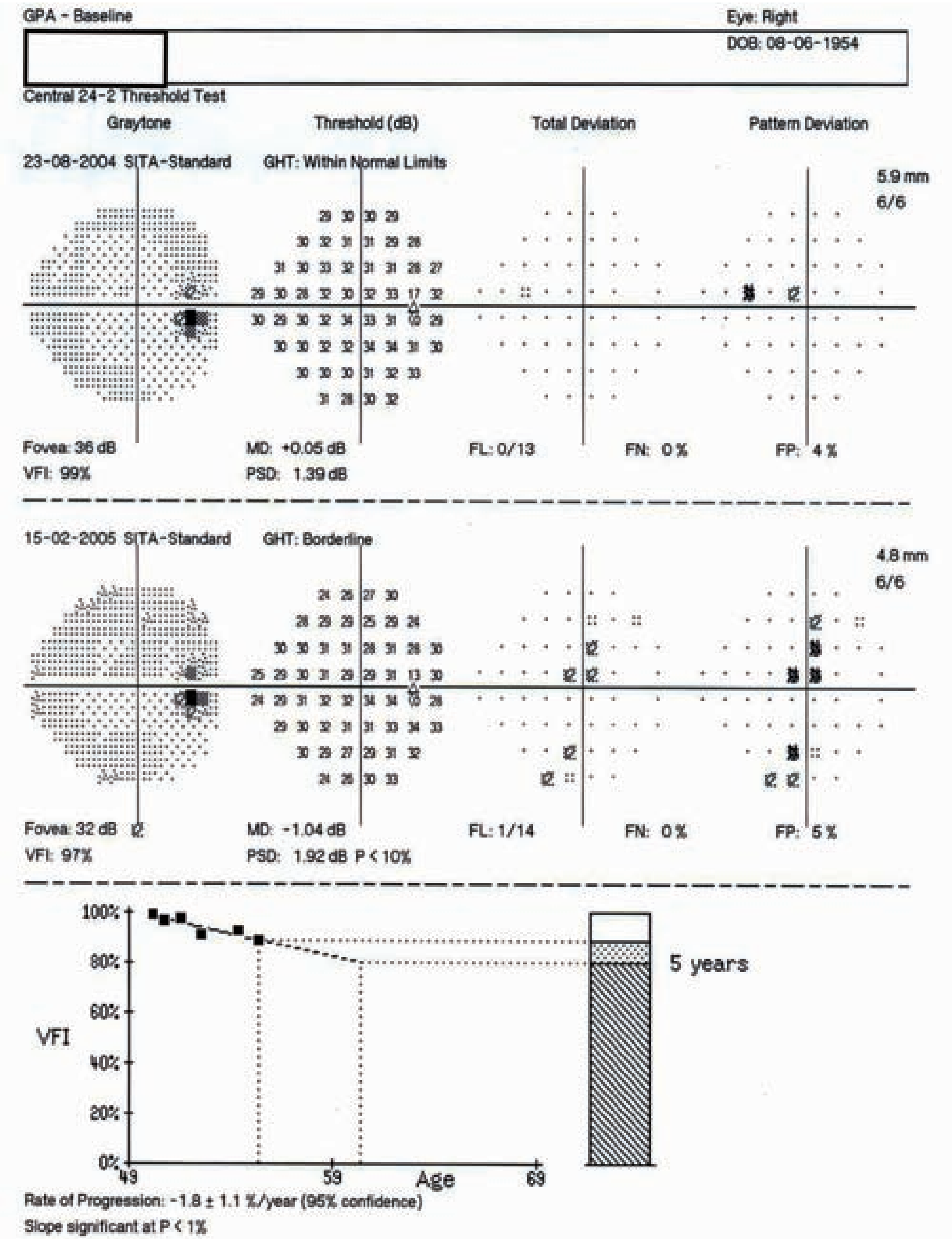
Case 32 (A)

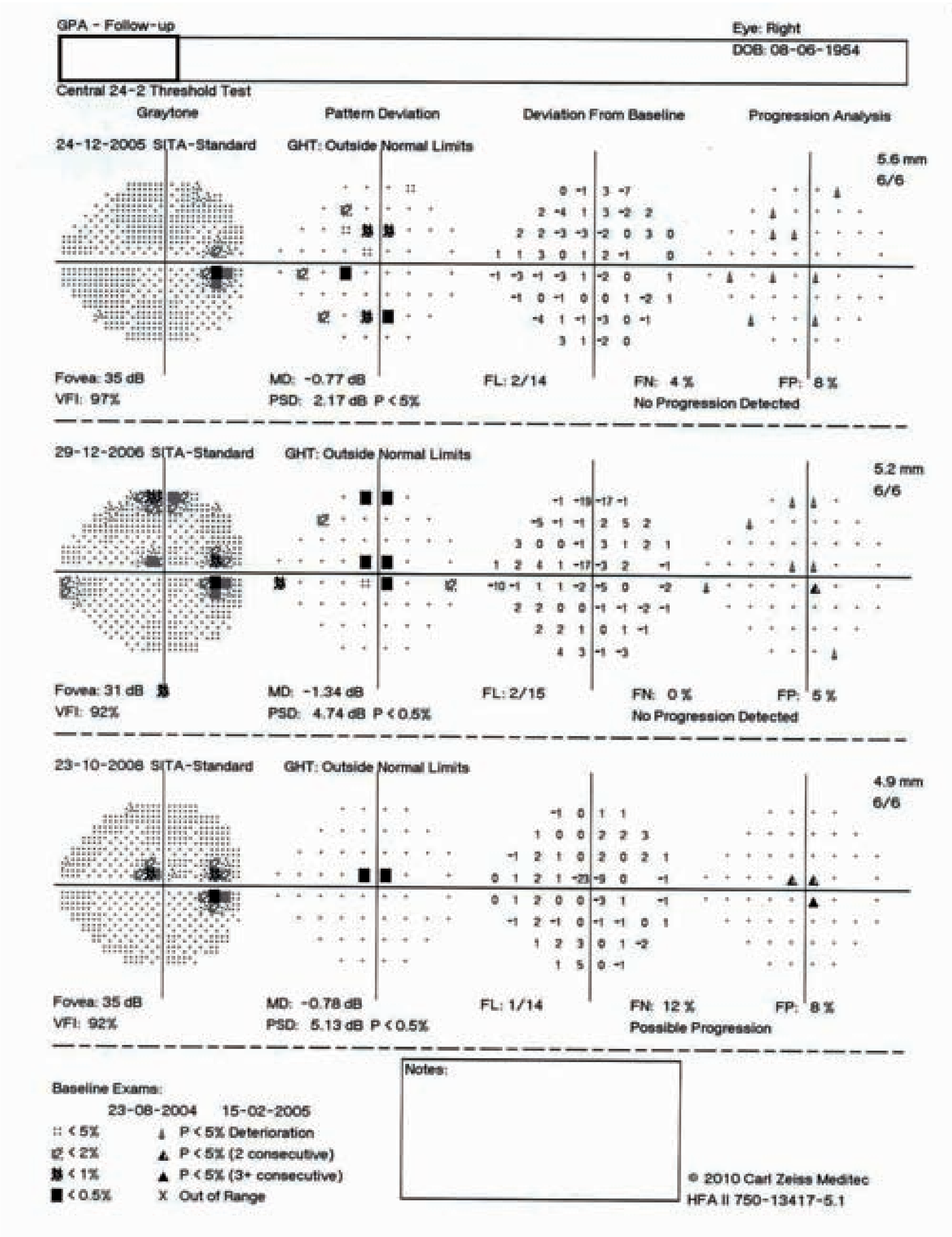


(a) to (d) : Both the event and trend analysis show significant changes. However, these changes are not in a location typical for glaucoma. This patient was a glaucoma suspect with worsening macular pathology.

Case 32 (B)


GPA - Baseline
Eye: Right
DOB: 08-06-1954
Central 24-2 Threshold Test
Graytone
Threshold (dB)
Total Deviation
Pattern Deviation
23-08-2004 SITA-Standard
GHT: Within Normal Limits
5.9 mm
6/6
Fovea: 36 dB
VFI: 99%
MD: +0.05 dB
PSD: 1.39 dB
FL: 0/13
FN: 0 %
FP: 4 %
15-02-2005 SITA-Standard
GHT: Borderline
4.8 mm
6/6
Fovea: 32 dB
VFI: 97%
MD: -1.04 dB
PSD: 1.92 dB P < 10%
FL: 1/14
FN: 0 %
FP: 5 %
100%
80%
60%
VFI
40%
20%
0%
49
59
Age
69
5 years
Rate of Progression: -1.8 ± 1.1 %/year (95% confidence)
Slope significant at P < 1%

Case 32 (C)


GPA - Follow-up
Eye: Right
DOB: 08-06-1954
Central 24-2 Threshold Test
Graytone
Pattern Deviation
Deviation From Baseline
Progression Analysis
24-12-2005 SITA-Standard
GHT: Outside Normal Limits
5.6 mm
6/6
Fovea: 35 dB
VFI: 97%
MD: -0.77 dB
PSD: 2.17 dB P < 5%
FL: 2/14
FN: 4 %
FP: 8 %
No Progression Detected
29-12-2006 SITA-Standard
GHT: Outside Normal Limits
5.2 mm
6/6
Fovea: 31 dB
VFI: 92%
MD: -1.34 dB
PSD: 4.74 dB P < 0.5%
FL: 2/15
FN: 0 %
FP: 5 %
No Progression Detected
23-10-2008 SITA-Standard
GHT: Outside Normal Limits
4.9 mm
6/6
Fovea: 35 dB
VFI: 92%
MD: -0.78 dB
PSD: 5.13 dB P < 0.5%
FL: 1/14
FN: 12 %
FP: 8 %
Possible Progression
Baseline Exams:
23-08-2004 15-02-2005
< 5%
< 2%
< 1%
< 0.5%
P < 5% Deterioration
P < 5% (2 consecutive)
P < 5% (3+ consecutive)
X Out of Range
Notes:
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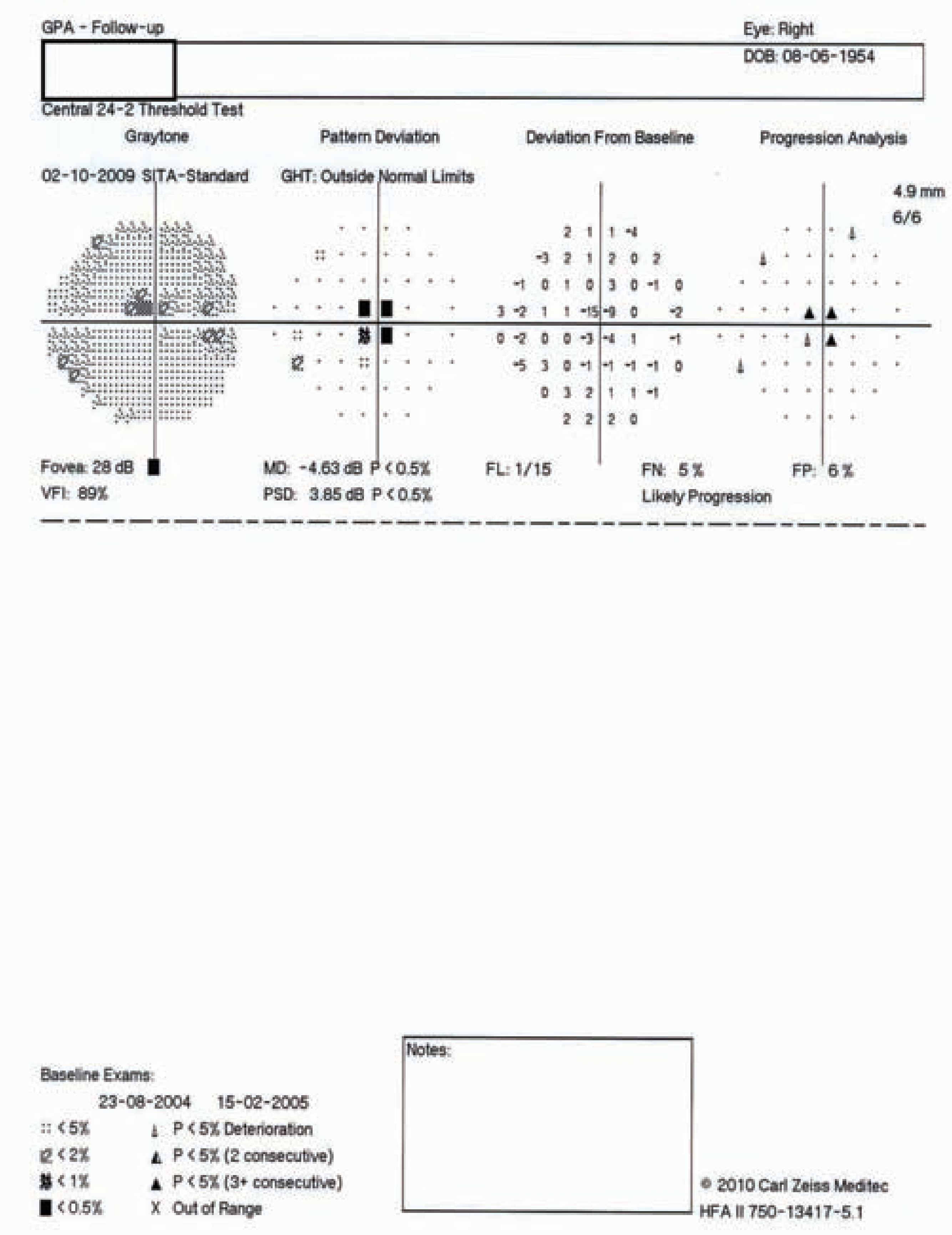
Case 32 (D)


GPA - Follow-up
Eye: Right
DOB: 08-06-1954
Central 24-2 Threshold Test
Graytone
Pattern Deviation
Deviation From Baseline
Progression Analysis
02-10-2009 SITA-Standard
GHT: Outside Normal Limits
4.9 mm
6/6
Fovea: 28 dB
VFI: 89%
MD: -4.63 dB P < 0.5%
PSD: 3.85 dB P < 0.5%
FL: 1/15
FN: 5 %
FP: 6 %
Likely Progression
Baseline Exams:
23-08-2004 15-02-2005
< 5%
< 2%
< 1%
< 0.5%
P < 5% Deterioration
P < 5% (2 consecutive)
P < 5% (3+ consecutive)
X Out of Range
Notes:
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