CORRELATION OF DISC DAMAGE LIKELIHOOD SCALE WITH FIELD DEFECTS IN ESTABLISHED GLAUCOMAS- AN ANATOMICAL VERSUS FUNCTIONAL CORRELATION

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ABSTRACT

BACKGROUND
Glaucoma is a chronic progressive optic neuropathy characterised by optic nerve head changes and field defects due to apoptosis of ganglion cells, with raised intraocular pressure being the most important risk factor. Traditionally Armaly's cup/disc (C/D) ratio was considered as a standard method of evaluation of optic nerve head. The Disc Damage Likelihood Scale DDLS relies on the optic nerve as a direct indicator of disease. Because the scale divides glaucomatous progression into 10 stages, it can also aid to monitor the disease progression. DDLS helps in quantification of the amount of damage that the optic nerve has sustained. This study correlates the DDLS score with the visual field indices establishing a structural and functional correlation. We wanted to analyse Disc Damage Likelihood Ratio in patients with established open angle glaucoma and to correlate it with field defects and to thereby obtain an anatomical versus functional correlation. This study also evaluates the diagnostic ability of disc damage likelihood scale in glaucoma.

METHODS
50 cases of established open angle glaucoma were included in this study. For all cases visual fields were recorded by Octopus 301 using G1 program and TOP strategy. After field testing, DDLS scores were calculated after dilatation. The DDLS score and field parameters of the patients were analysed.

RESULTS
Of the 50 patients included in this study, 70% were on topical antiglaucoma medications and 30% had undergone trabeculectomy. DDLS score and average loss variance showed a strong positive correlation as the r value was 0.95.

CONCLUSIONS
Disc diameter evaluation is an important part of optic nerve head evaluation. In cases with asymmetry of the cup disc ratio between two eyes, asymmetry of the disc size should also be considered if the neuroretinal rim is healthy. Disc Damage Likelihood Scale (DDLS) is a better indicator of optic nerve head status and has strong positive correlation with visual field indices.

KEYWORDS
Disc Damage Likelihood Scale, Automated Perimetry, Field Defects in Glaucoma.

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BACKGROUND

Glaucoma is a chronic progressive optic neuropathy characterised by optic nerve head changes and fields defects due to apoptosis of ganglion cells, with raised intraocular pressure being the most important risk factor. Evaluation of the optic nerve head plays an important role in the diagnosis and management of glaucoma.

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Traditionally Armaly's cup/disc (C/D) ratio was considered as a standard method of evaluation of optic disc.[1]

Disc Damage Likelihood Scale

This system of quantification of disc changes was first devised by Spaeth et al.[2,3] Traditionally cup/disc (C/D) ratio was considered as a standard method of evaluation of optic disc. However, the C/D ratio does not take into consideration the diameter of the optic disc. The disc damage likelihood scale incorporates the evaluation of disc size and rim width in clinical grading of the disc.[4]

Step 1: Disc Classification

Disc diameter is calculated with a +60 D to +90 D lens with appropriate corrective factors. For Volk +90 D lens corrective factor of 1.33 is used. For +66 D, no correction factor is required and for +78 D a correction factor of 1.1 is multiplied.

Disc can be classified as follows-

- Small, with disc diameter less than 1.5 mm.
- Medium, with disc diameter between 1.5 - 2 mm.
- Large, with disc diameter more than 2 mm.

Step 2: NRR Assessment

The unit of measurement of DDLS scale 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 rim remaining, the rim/disc ratio is 0. The circumferential extent of rim absence is measured in degrees. Actual absence of rim should be differentiated from sloping rim. Sloping rim can occur temporally in myopes. Because rim width is a function of disc size, disc size must be evaluated prior to attributing a DDLS stage.

Stages of DDLS

The DDLS relies on the optic nerve as a direct indicator of disease. Because the scale divides glaucomatous progression into 10 stages, it can also aid to monitor the disease progression. The DDLS helps in quantification of the amount of damage that the optic nerve has sustained.

For small discs (disc diameter less than 1.5 mm), the DDLS scale is increased by one. For large discs (disc diameter more than 2 mm), the DDLS scale is decreased by one.

	DDLS Stage	Narrowest Rim Width (Rim Disc Ratio)
	1	0.4 or more
At risk	2	0.3-0.39
	3	0.2-0.29
	4	0.1-0.19
Glaucoma	5	Less than 0.1
Damage	6	0 (extension less than 45°)
	7	0 (extension: 46° to 90°)
Glaucoma	8	0 (extension: 91°-180°)
Disability	9	0 (extension: 181°-270°)
	10	0 (extension: more than 270°)

Armaly's Cup Disc Ratio vs. Disc Damage Likelihood Scale

Armaly's cup/disc (C/D) ratio describes the disc using cup diameter as a percentage of overall disc diameter.

Advantages

- Ease of use.
- Lack of magnification artefacts.

Limitations

- **Disc size not taken into consideration**
  The size of the nerve is widely variable among individuals,[5] while the neuroretinal rim area is similar.[6] If the rim area is roughly constant, the cup area is directly proportional to disc area. If cup/disc ratio alone is used as a criterion for damage then it is possible that large optic nerves will incorrectly be called glaucomatous, and small optic nerves incorrectly will be called normal.[7]
- **Focal narrowing of neuroretinal rim which is characteristic of glaucoma is missed.**

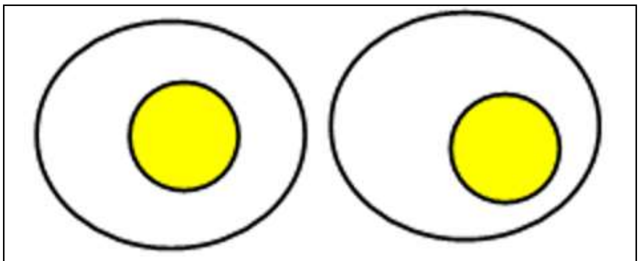

Figure 1 and 2

In both the figures, the vertical CD ratio is the same. But figure 2 has focal neuroretinal rim narrowing.

Disc Damage Likelihood Scale

Advantages: This scale classifies the disc based on its size.

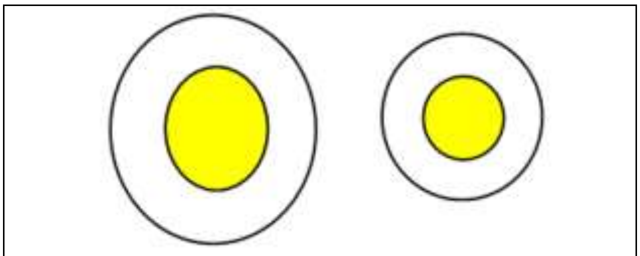

Figure 3 and 4

The asymmetry between figures 3 and 4 is due to asymmetry in disc size. I Studies by Henderer JD et al found Disc Damage likelihood scale to be superior to cup/disc ratio and the HRT-2 for distinguishing between normal and glaucoma or glaucoma suspects.[8] The main limitation of the DDLS by is the absence of a reliable quantitative method for estimating disc size .Studies by Kara Jose et al showed positive moderate correlation between DDLS and NFI obtained by GDx-VCC.[2]

METHODS

50 patients with open angle glaucoma attending glaucoma services of Regional Institute of Ophthalmology And Government Ophthalmic Hospital, Chennai between April 2016 and August 2016, who satisfied the following inclusion criteria were included in the study.

All patients underwent the following examinations

1. Best corrected visual acuity.
2. Detailed anterior segment examination by slit lamp biomicroscopy.
3. Intra ocular pressure by Goldmann applanation tonometry.
4. Gonioscopic examination of angle by Goldman single mirror gonioscopy.
5. Automated perimetry by octopus 301 using G1 program, TOP strategy.
6. Disc damage likelihood scale calculation.

Inclusion Criteria

- **Age:** Patients aged 45 yrs., or more were included.
- **Best Corrected Visual Acuity**: Patients with best corrected visual acuity of more than 6/24 were included. This is because the visual fields by automated perimetry are not very reliable in patients with low visual acuity. There is generalised decrease in retinal sensitivity in patients with low visual acuity.
- **Gonioscopy:** Patients with open angles by gonioscopy (Shaffer's grading more than or equal 3) were included
- **Fields:** patients with established field defects, at least 2 consecutive and reliable fields by Octopus 301 automated perimetry done over a period of 6 months showing glaucomatous fields, were included in this study.
- Post-operative patients (Post cataract, post trabeculectomy) of more than a year of surgery were included.

Exclusion Criteria

- Other causes of optic neuropathy like traumatic optic neuropathy were excluded.
- Gonioscopy: patients with narrow and occludable angles (Shaffer's grade less than 2) were excluded
- Best Corrected Visual Acuity: Patients with best corrected visual acuity of less than 6/24 were excluded.
- Patients with secondary glaucomas like lens induced glaucomas, traumatic angle recession glaucomas, post inflammatory glaucomas, neovascular glaucomas were excluded.
- Patients operated less than a year were excluded.

Disc Damage Likelihood Scale Calculation

- Disc damage likelihood scale was calculated after pupillary dilatation with 0.5% tropicamide.
- Using a volk 90 D lens and a slit lamp, the width of the disc and the rim width were calculated.
- A correction factor of 1.3 was used.
- The disc was classified as small, medium and large and the scale was calculated accordingly.

Clinical diagram was made for the discs. The recordings were done by a single ophthalmologist which was further verified by two other doctors.

Example:

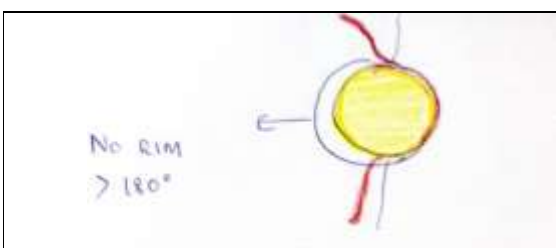

Figure 5. Right Eye Disc Diagram of a 50-Year-Old Male

Step 1:

- Measured disc diameter= 1.2
- Disc diameter= 1.2 x 1.33=1.66

Medium Disc.

Step 2:

- Rim width= 0 between 180°-270°

DDLS Stage 9.

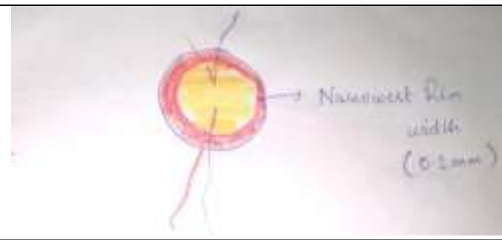

Figure 6. Left Eye of The Same Patient

Step 1:

- Measured disc diameter=1.2
- Disc diameter=1.2 x 1.33=1.66

Medium Disc

Step 2:

- Rim width=0.2 x 1.33=0.26
- Rim /Disc ratio=0.26/1.66=0.16

DDLS Stage 4.

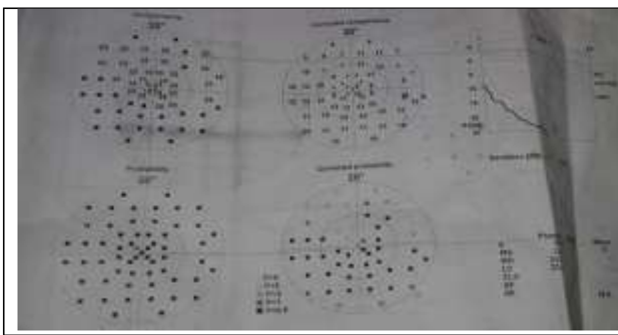

Figure 7. Field Defects- Right Eye

Impression: tubular fields

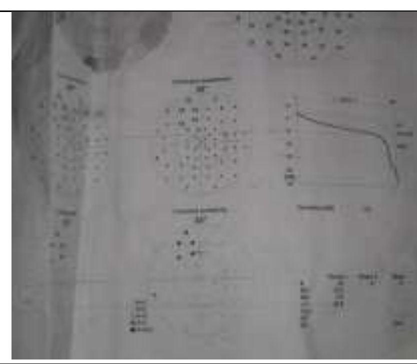

Figure 8. Field Defects- Left Eye

Impression: relative defects in superior arcuate region.

RESULTS

Demography

Age Group (in years)	No. of Patients
45-50	15
51-55	10
56-60	5
60-65	8
More than 66	12

Table 1. Age Distribution

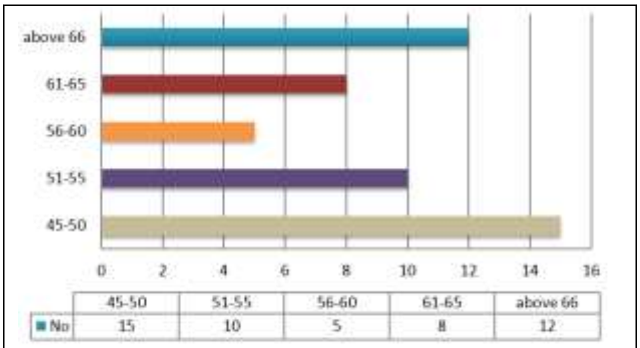

Chart 1. Showing Age Distribution

Sex Distribution

Of the 50 patients included in this study, 31 were males and 19 were females.

Sex Distribution	No. of Patients
Male	31 (62%)
Female	19 (38%)

Table 2. Sex Distribution

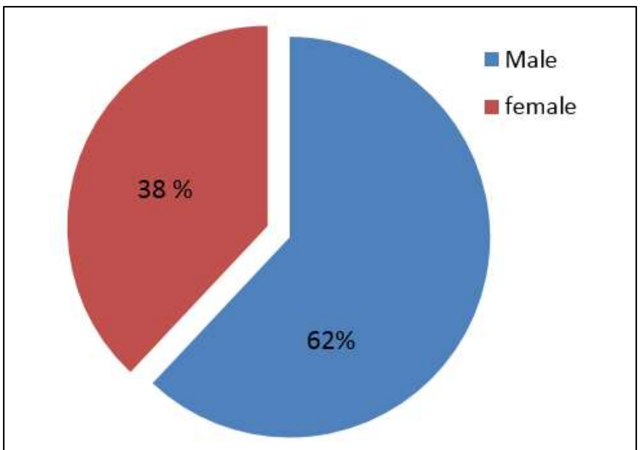

Chart 2. Sex Distribution

Modality of Treatment

Of the 50 patients included in this study,

- 35 patients were on medical management. They were on topical medications (which included topical beta blockers, prostaglandins, brimonidine or combination of drugs).
- 15 patients had antiglaucoma surgery done (trabeculectomy done).
- Of these 15 patients, 2 patients were on additional medical management Topical antiglaucoma medication for IOP control.

Treatment Modality	No. of Patients
Medical (topical antiglaucoma medication)	35(70%)
Surgical trabeculectomy	13(26%)
Both medical and surgical	2(4%)

Table 3. Showing Distribution According the Treatment Modality

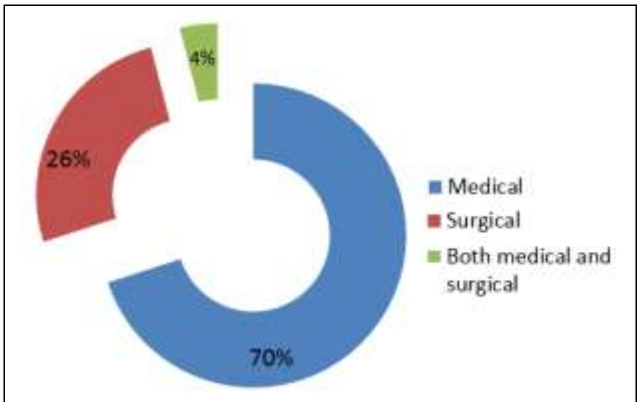

Chart 3. Distribution According the Treatment Modality

Disc Size

Of the 100 eyes of 50 patients examined,

- None of the patients had small discs (disc diameter of less than 1.5 mm).
- 86 eyes had medium size discs (diameter between 1.5-2 mm).
- 14 eyes had large discs (diameter more than 2 mm).

Disc Diameter	No. of Eyes
Small discs	0
Medium discs	86 (86%)
Large discs	14 (14%)

Table 4. Classification According to Disc Diameter

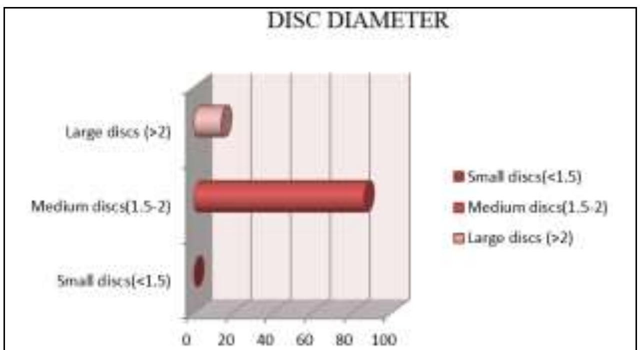

Chart 4. Classification According to Disc Diameter

Asymmetry of Disc Diameter

Of the 50 patients examined, 4 patients had asymmetry of disc diameter.

Disc Diameter of Two Eyes	No. of Patients
Symmetry of disc diameter	46
Asymmetry of disc diameter	4

Table 5. No. of Patients with Symmetrical and Asymmetrical Discs

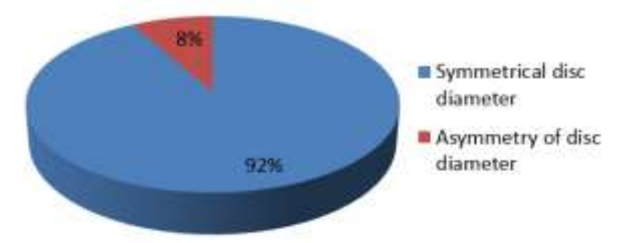

Chart 5. No. of Patients with Symmetrical and Asymmetrical Discs

DDLS Score

The following were the DDLS score of 100 eyes.

DDLS Score	No. of Eyes
1	0
2	4
3	11
4	19
5	18
6	15
7	9
8	11
9	13
10	0

Table 6. DDLS Score of 100 Eyes

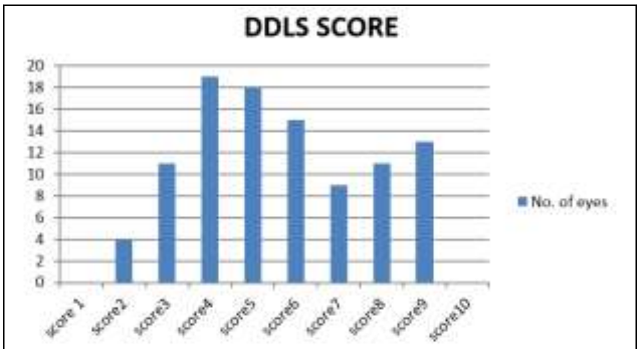

Chart 6. DDLS Score of 100 Eyes

Classification Based on DDLS Score

Of the 100 eyes included in the study

- 34 eyes came under classification of " At risk of glaucoma"
- 42 eyes came under classification of "Glaucoma damage"
- 24 eyes came under classification of " Glaucoma disability"

Classification	No. of Eyes
At risk	34 (34%)
Glaucoma damage	42 (42%)
Glaucoma disability	24 (24%)

Table 7. Classification According to DDLS Score

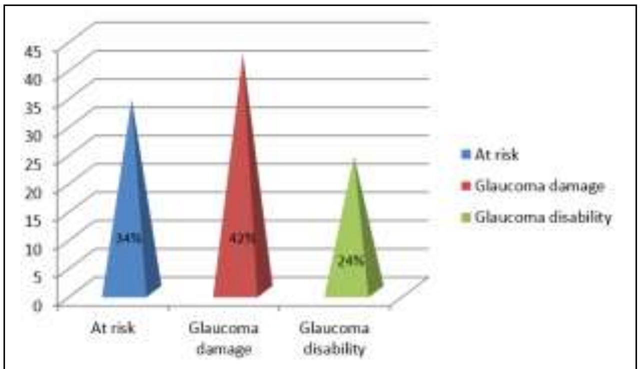

Chart 7. Classification According to DDLS Score Field Defects

Field Defects	No. of Eyes
Areas of depressed sensitivity in paracentral region	11
Paracentral scotoma	10
Relative defects in superior arcuate region	13
Relative defects in the inferior arcuate region	14
Superior arcuate scotoma	16
Inferior arcuate scotoma	8
Biarcuate scotoma with nasal step defects	13
Tubular fields	15

Table 8. The Field Defects in 100 Eyes

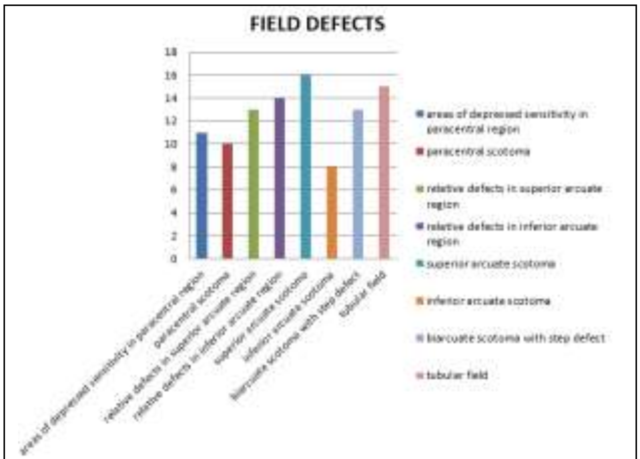

Chart 8. Field Defects in 100 Eyes

Classification of Field Defects:

Based on field defects, glaucoma can be classified as

- **Mild**

  Disc changes without field defects on white on white perimetry (defects may be present on swap blue on yellow perimetry. In this study, pre perimetric glaucoma patients were excluded.

- **Moderate**

  Disc changes with field defects, involving one hemifield and not involving the central 5° of fixation. In this study, the following field defects come under this classification.
  - Areas of depressed sensitivity in paracentral region
  - Paracentral scotoma
  - Relative defects in superior arcuate region
  - Relative defects in the inferior arcuate region
  - Superior arcuate scotoma
  - Inferior arcuate scotoma

- **Severe**
  Field defects in both hemifields and /or loss involving the central 5° of fixation. This includes biarcuate scotoma with step defects and tubular fields.

Grading According to Fields	No. of Eyes
Mild	0
Moderate	72
Severe	28

Table 9. Classification Based on Severity of Field Defects

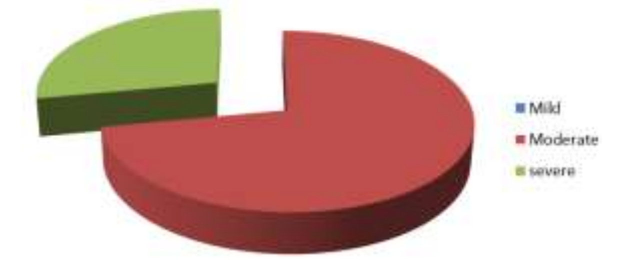

Chart 9. Pie Chart Showing Classification Based on Severity of Field Defects

Field Indices

Field Defects	Average Mean Sensitivity (db)
Defects in paracentral region and Paracentral scotoma	28.89
Relative defects in superior and inferior arcuate region	25.91
Arcuate scotoma(superior and inferior)	23.30
Biarcuate scotoma with step defects	18.95
Tubular fields	17.07

Table 10. Average Mean Sensitivity in Different Field Defects

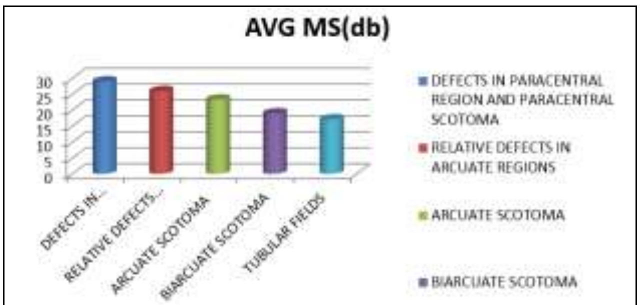

Chart 10. Bar Graph showing Average Mean Sensitivity in Different Field Defects

Field Defects	Average Mean Defect (db)
Defects in paracentral region and Paracentral scotoma	9.79
Relative defects in superior and inferior arcuate region	14.62
Arcuate scotoma(superior and inferior)	18.77
Biarcuate scotoma with step defects	26.83
Tubular fields	24.93

Table 11. Average Mean Sensitivity in Different Field Defects

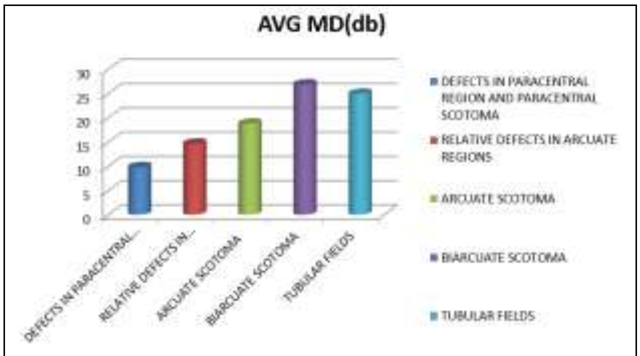

Chart 11. Bar Graph Showing Average Mean Defects in Different Field Defects

Field Defects	Average Loss Variance
Defects in paracentral region and Paracentral scotoma	8.66
Relative defects in superior and inferior arcuate region	14.62
Arcuate scotoma (superior and inferior)	39.30
Biarcuate scotoma with step defects	101.54
Tubular fields	106.94

Table 12. Showing Average Loss Variance in Different Field Defects

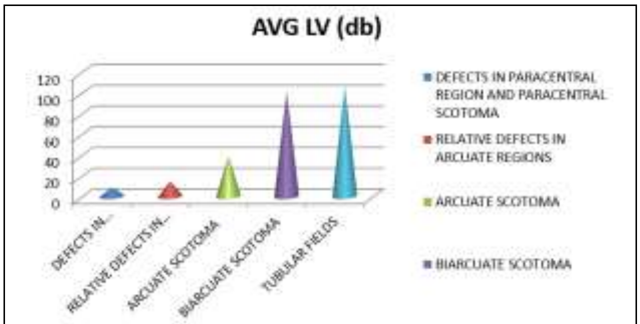

Chart 12. Graph Showing Average Mean Defects in Different Field Defects

DDLS Score	Average Mean Sensitivity (db)
2	30.15
3	28.58
4	27.35
5	26.42
6	23.26
7	20.28
8	18.56
9	16.88

Table 13. Average Mean Sensitivity in Various DDLS Scores

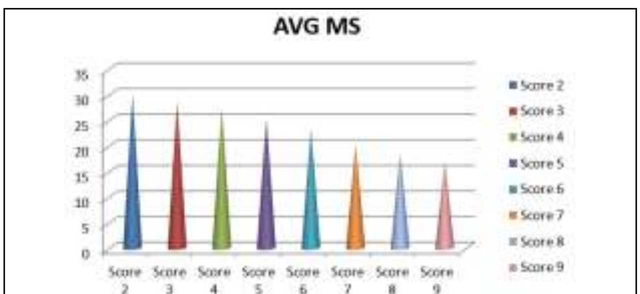

Chart 13. Average Mean Sensitivity in Various DDLS Scores

DDLS Score	Average Mean Defect (db)
2	7.45
3	11.11
4	13.49
5	16.04
6	20.75
7	24.38
8	24.90
9	24.82

Table 14. Average Mean Defect in Various DDLS Scores

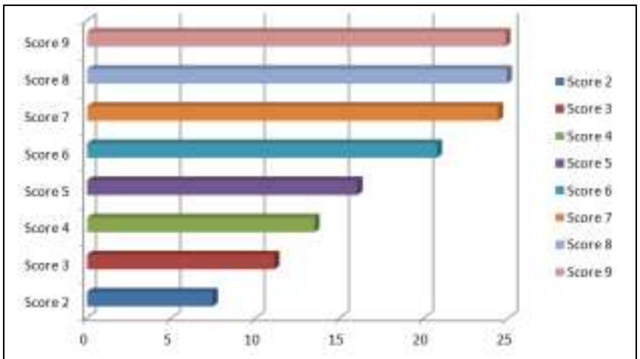

Chart 14. Average Mean Defect in Various DDLS Scores

DDLS Score	Average Loss Variance (db)
2	7.55
3	8.97
4	12.47
5	14.41
6	53.01
7	68.95
8	97.16
9	113.07

Table 15. Average Loss Variance in Various DDLS Scores

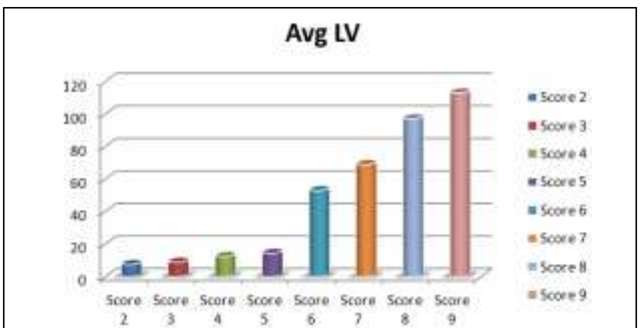

Chart 15. Average Loss Variance in Various DDLS Scores

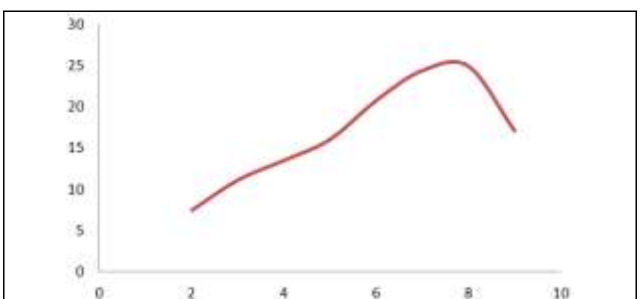

Chart 16. Linear Relationship Between DDLS Score and Mean Sensitivity

As the DDLS score increases, the mean sensitivity decreases.

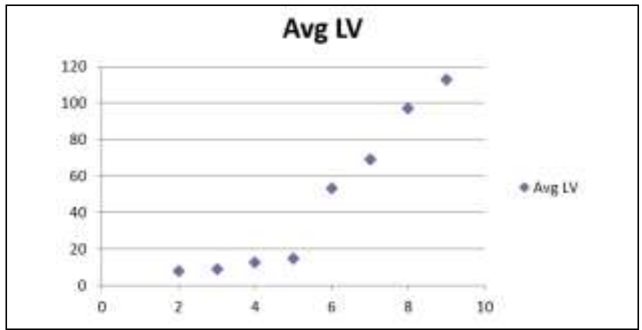

Chart 17. Scatter Plot Showing Correlation of DDLS Score with Loss Variance

The Pearson product-moment correlation coefficient r value is 0.95 (approximately equal to 1) showing strong positive correlation between the DDLS score and Field defect.

$$\boxed{r = 0.95}$$

DISCUSSION

50 cases of Primary open angle glaucoma with established field defects with visual acuity more than 6/24 were included in this study to analyse the Disc Damage Likelihood Scale and correlate with field defects.

Of the 50 patients included in this study, 30% were in the age group of 45-50 yrs. and 24% were aged more than 66 years. 62% were male patients and 38% were female patients.

Of the included established primary open angle glaucoma patients, 70% were on topical antiglaucoma medications and 30% had undergone trabeculectomy. Of the patients who had undergone trabeculectomy, 6% (2) of patients were on further antiglaucoma medications.

According to this study, the average vertical disc diameter was 1.86 mm. Studies by Quigley et al have also shown that the average vertical disc diameter to be 1.88 and horizontal disc diameter to be 1.77 mm.[9] Disc diameter in 50 patients ranged from 1.56 mm- 2.21 mm.

In this study, the discs were classified as small, medium and large discs based on the disc diameter. Of the 100 eyes examined, none of the patients had small discs (disc diameter of less than 1.5 mm), 86 eyes had medium size discs (diameter between 1.5 – 2 mm) and 14 eyes had large discs (diameter more than 2 mm)

Among the 50 patients, 4 patients had asymmetry of disc diameter between the right and left eye.

	DISC Diameter		CDR		DDLS	
Patient	**RE**	**LE**	**RE**	**LE**	**RE**	**LE**
Patient 1	2.08	1.69	0.7	0.4	2	2
Patient 2	1.95	2.08	0.4	0.7	4	4
Patient 3	1.56	1.82	0.4	0.6	2	2
Patient 4	1.82	1.56	0.7	0.5	4	4

This table shows that the asymmetry of the cupping is due to asymmetry of the disc diameter. The cup disc ratio in all four patients showed significant asymmetry, of more than 0.2. But the DDLS score in these patients of both the eyes in all four patients were the same. This highlights the importance of estimation of disc diameter in the evaluation of optic nerve head.[10]

DDLS score was calculated and of the 100 eyes included in the study. 34 eyes came under classification of "At risk of glaucoma" having a score of 1-4, 42 eyes came under classification of "Glaucoma damage" having a score of 5-7 and 24 eyes came under classification of "Glaucoma disability" having a score of 8-10.

The field defects which were seen in these patients include areas of depressed sensitivity in the paracentral region (11%), paracentral scotoma (10%), Relative scotomas in superior and inferior arcuate regions (27%), superior and inferior arcuate scotomas (24%), biarcuate scotoma with step defects (13%) and tubular fields (15%). Based on field defects, 72 eyes were classified to have moderate glaucoma and 28 eyes were classified to have severe glaucoma. Since this study did not include preperimetric glaucoma, none of the eyes could be classified to have mild glaucoma.

Field Indices

Mean sensitivity is the average of the threshold sensitivity values in a visual field test. Patients with defects in paracentral region and paracentral scotoma had a average mean sensitivity of 28.89 db. Patients with arcuate scotoma had a mean sensitivity of 23.30 db and patients with tubular fields had a mean sensitivity of 17.07 db. This shows that the average mean sensitivity decreases as the field defect progresses.

Mean defect is the weighted average of the total deviation values in a visual field test; the more important and less variable deviations near the centre of the field are weighted more than those at the edge. In this study, patients with defects in paracentral region and paracentral scotoma had a mean defect of 9.79 db. Patients with arcuate scotoma had a mean defect of 18.77 db and patients with tubular fields had a mean defect of 24.93 db. This study shows that the mean defect values are higher in patients with advanced field defects.

Loss variance is the local heterogeneity of a visual field defect. Loss variance is small in visual fields with generalized damage and loss variance increases with the number and depth of localized scotomas.[11] Patients with defects in paracentral region and paracentral scotoma had an average loss variance of 8.66 db. Patients with arcuate scotoma had a loss variance of 39.30 db and patients with tubular fields had a loss variance of 106.94 db. In this study, the loss variance values are higher in patients with advanced field defects.

Field Indices in Various DDLS Scores

The average mean sensitivity among the different DDLS score showed a linear relationship, that is, higher the DDLS score, lower is the sensitivity value.

Pearson product –moment correlation coefficient (r value) is a measure of linear dependence between two variables, giving a value between +1 and -1. +1 indicates total positive correlation, 0 indicates no correlation and -11 indicates total negative correlation. In this study, the variables compared were DDLS score and average loss variance. The variables showed a strong positive correlation as the r value was 0.95 (approximately equal to one). Studies by James C Borrow et al also showed a similar observation with a r value of 0.68 between the DDLS score and mean deviation (field testing done by Humphrey field analyser)[12]

Limitations of The Study

The disc diameter measurement and DDLS calculation by 90 D lens is a subjective measurement. Objective evidence for the same by imaging is needed to overcome inter observer variability.

CONCLUSIONS

Disc diameter evaluation is an important part of optic nerve head evaluation. In cases with asymmetry of the cup disc ratio between the two eyes, asymmetry of the disc size should also be considered if the neuroretinal rim is healthy.

Disc Damage Likelihood Scale (DDLS) is a better indicator of optic nerve head status and has strong positive correlation with visual field indices.

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