



# Correlation of retinal nerve fiber layer thickness with optic disc parameters and disc damage likelihood scale in primary open-angle glaucoma: a cross-sectional study

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## ABSTRACT

**Objective:** To evaluate the relationship between retinal nerve fiber layer (RNFL) thickness and various optic disc parameters and Disc Damage Likelihood Scale (DDLS) in patients with primary open-angle glaucoma (POAG).

**Methods:** This cross-sectional study, conducted at Lahore General Hospital, included 295 eyes of 148 diagnosed/suspected POAG patients, aging > 18 years. Patients with significant refractive errors, media opacities, history of trauma, and poor OCT signal strength were excluded. Comprehensive ocular examination was performed and optic disc measurements were recorded. RNFL thickness was assessed using optical coherence tomography (OCT). Disease severity was staged DDLS. Statistical analysis involved descriptive statistics, Kolmogorov-Smirnov test for normality, and Spearman correlation coefficients.

**Results:** Of the 148 patients (90 males, 58 females; mean age  $52.41 \pm 15$  years), mean RNFL thickness was  $82.21 \pm 14.75 \mu\text{m}$ . Mean RNFL thickness was  $82.3 \pm 14.8 \mu\text{m}$ . The mean average CDR was  $0.67 \pm 0.12$  and mean vertical CDR was  $0.64 \pm 0.12$ . The mean rim-to-disc ratio was  $0.17 \pm 0.13$ . The median DDLS stage was 4 (IQR 3–5). Correlation analysis revealed a moderate negative correlation between RNFL thickness and vertical cup-to-disc (CD) ratio ( $r = -0.45$ ), a strong positive correlation between RNFL thickness and rim-to-disc ratio ( $r = 0.70$ ), and a strong negative correlation with DDLS ( $r = -0.65$ ). DDLS showed a moderate positive correlation with vertical CD ratio ( $r = 0.55$ ) and a very strong negative correlation with rim-to-disc ratio ( $r = -0.80$ ).

**Conclusions:** DDLS and rim to disc ratio are more reliable methods for assessing glaucomatous damage than the vertical or average CD ratios. Therefore, DDLS and rim-to-disc ratios should be integral parts of glaucoma assessment.

**Keywords:** Retina (MeSH); Optic Disk (MeSH); Disc Damage Likelihood Scale (Non-MeSH); Retinal nerve fiber layer thickness (Non-MeSH); Glaucoma (MeSH); Glaucoma, Open-Angle (MeSH); Tomography, Optical Coherence (MeSH); Intraocular Pressure (MeSH); Diagnostic Techniques, Ophthalmological (MeSH); Retinal Ganglion Cells (MeSH); Optic Nerve (MeSH).

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and refractive statuses. A small CD ratio may be associated with significant glaucomatous damage, whereas a large CD ratio may be physiological in eyes with large discs. Furthermore, in cases of focal neuroretinal rim loss (disc notching), the CD ratio may be misleading if the overall ratio remains within the statistically normal range despite localized damage.<sup>3</sup>

These limitations led to increased emphasis on rim-based assessment. The rim-to-disc ratio was proposed as a more anatomically relevant indicator of glaucomatous damage and based on the extent of rim loss adjusted for disc size, the Disc Damage Likelihood Scale (DDLS) was developed.<sup>4</sup>

Recent advances in glaucoma diagnostics have further strengthened structural assessment, particularly through measurement of retinal nerve fiber layer (RNFL) thickness and visual field analysis. Optical coherence tomography (OCT) enables objective quantification of RNFL loss and has reinforced the structure–function paradigm in glaucoma management. However, in resource-constrained settings such as many peripheral regions of Pakistan, access to OCT and automated perimetry remains limited. In such environments, careful clinical evaluation of the ONH using ophthalmoscopy often remains the principal method for assessing glaucomatous damage.

Despite the conceptual advantages of DDLS, direct evaluation of its correlation with RNFL thickness has not

## INTRODUCTION

**G**laucoma is one of the leading causes of irreversible blindness worldwide.<sup>1</sup> Its diagnosis remains challenging because structural and functional changes may not always correlate, particularly in the early stages of the disease. Clinically, assessment of the optic nerve head (ONH) remains fundamental, most commonly quantified, using Armary's cup-to-disc

ratio (CD ratio).<sup>2</sup>

Although several structural and functional parameters are available to diagnose and monitor disease progression, the CD ratio remains widely used due to its simplicity and ease of clinical assessment. However, reliance on CD ratio has important limitations. There is considerable inter-individual variability in optic disc size across different populations, ethnicities,

been extensively studied in our regional context. Whether DDLS and rim-to-disc ratio demonstrate a stronger structural association with RNFL thickness than the traditional CD ratio remains insufficiently established.

Therefore, this study was designed to compare the correlation of RNFL thickness with DDLS, rim-to-disc ratio, and conventional CD ratio. Specifically, it aimed to determine whether rim-based assessment using DDLS provides a closer association with RNFL thickness than the traditional CD ratio. Clarifying this relationship is clinically important, as it may support more reliable glaucoma assessment and management in settings where advanced imaging modalities are unavailable.

## METHODS

This cross-sectional study was conducted at Lahore General Hospital from March 2023 to March 2024. Adult patients ( $\geq 18$  years) who were either diagnosed with or suspected of having primary open-angle glaucoma (POAG) and attended the ophthalmology outpatient department during the study period were screened for eligibility.

A total of 295 eyes from 148 patients met the inclusion criteria and were enrolled in the study. Exclusion criteria included spherical refractive error greater than  $\pm 5.0$  diopters or astigmatism greater than  $\pm 3.0$  diopters, significant media opacities, prior ocular trauma, neurological or systemic disorders affecting the optic nerve head, pigment dispersion syndrome, pseudoexfoliation syndrome, ocular inflammation, and OCT scans with poor signal strength.

Ethical approval was obtained from the Institutional Review Board of Lahore General Hospital (Reference #: 296/24 dated: July 09, 2024). Written informed consent was obtained from all participants prior to enrollment.

After obtaining a comprehensive history, a detailed ocular examination was conducted, including best-corrected visual acuity (BCVA), intraocular pressure (IOP) measurement, slit-lamp biomicroscopy, and fundoscopic evaluation using a 78D

lens. The measured optic disc size was multiplied by a correction factor of 1.1 to compensate for magnification error associated with the 78D lens. The average and vertical CD ratio, as well as the rim-to-disc ratio, were recorded. Retinal nerve fiber layer (RNFL) thickness was assessed using OCT.

DDLS was applied to stage the disease based on optic disc size and the width of the neuroretinal rim. The DDLS grading was determined using the thinnest neuroretinal rim width. In cases where the rim was absent, the circumferential extent of rim loss was documented in degrees. All measurements were performed by a single observer, a glaucoma specialist and subspecialty supervisor, to ensure consistency.

Descriptive statistics included mean and standard deviation. Normality of data was calculated using Kolmogorov-Smirnov test. Spearman correlation coefficients were calculated between RNFL thickness and CD ratio, rim to disc ratio and DDLS. Correlations were also calculated among different variables. Strength of correlation was compared according to the following standard academic scale:

*Very weak correlation:* Correlation coefficient of 0 to 0.19

*Weak correlation:* 0.3 to 0.39

*Moderate correlation:* 0.40 to 0.59

*Strong correlation:* 0.60 to 0.79

*Very strong:* 0.80 to 1.0

## RESULTS

A total of 295 eyes of 148 patients with glaucoma or suspected glaucoma were included. There were 90 males and 58 females. Mean age was  $52.41 \pm 15$  years. Mean RNFL thickness was

$82.21 \pm 14.75 \mu$ . The descriptive statistics are presented in Table I.

The details of correlation are shown in Table II. The table shows significant relationship between various ophthalmic parameters, especially highlighting how different measures of optic disc morphology correlate with each other and with disease severity.

There is a moderate negative correlation between RNFL thickness and vertical CD ratio, and a strong positive correlation between RNFL thickness and rim to disc ratio and a strong negative correlation of RNFL with DDLS. The stage of disease (DDLS) has a moderate positive correlation with vertical CD ratio and a very strong negative correlation with rim to disc ratio.

## DISCUSSION

This study demonstrates a stronger correlation between RNFL thickness and both the rim-to-disc ratio and the DDLS than with the CD ratio, emphasizing the importance of these parameters in glaucoma management. These low-cost methods can be readily employed in settings where OCT and visual fields are unavailable, as well as in advanced cases of glaucoma where OCT RNFL and visual field measurements become less reliable. The results align with a previous study that highlighted the superiority of DDLS over the CD ratio in describing glaucomatous optic nerve damage.<sup>5</sup> Our study takes a step further by incorporating RNFL in the correlation analysis.

DDLS utilizes narrowest rim-to-disc ratio and grades the damage on a scale of 1 to 10. It also considers optic disc size, categorizing diameters into three

**Table I: Descriptive statistics of the studied population**

Variables	Mean $\pm$ SD	Median (IQR)	Minimum-Maximum
Average RNFL Thickness ( $\mu$ m)	82.21 $\pm$ 14.76	84 (72-92)	50-130
Average Cup-Disc Ratio	0.67 $\pm$ 0.12	0.68 (0.60-0.76)	0.21-0.95
Vertical Cup-Disc Ratio	0.64 $\pm$ 0.12	0.65 (0.58-0.73)	0.14-0.94
Rim-to-Disc Ratio	0.17 $\pm$ 0.13	0.20 (0.10-0.30)	0.00-0.60
DDLS Stage	4.63 $\pm$ 1.87	4 (3-5)	0.3-8

CD=Cup to Disc ratio, DDLS= Disc Diameter Likelihood Scale, RNFL=Retinal nerve fiber layer

**Table II: Correlation of different optic nerve head parameters with RNFL thickness and among themselves**

Correlations of different variables		Spearman's correlation coefficient	p-value
Correlations of different variables with RNFL thickness	Average CD ratio	-0.536	< 0.001
	Vertical CD	-0.516	< 0.001
	Rim to Disc ratio	0.709	< 0.001
	Stage of DDLS	-0.706	< 0.001
Correlations of different variables with vertical CD ratio	RNFL thickness	-0.516	< 0.001
	Average CD ratio	0.922	< 0.001
	Rim to Disc ratio	-0.550	< 0.001
	DDLS stage	0.564	< 0.001
Correlations of different variables with DDLS	Average RNFL thickness	-0.706	< 0.001
	Average CD ratio	0.619	< 0.001
	Vertical CD ratio	0.564	< 0.001
	Rim to Disc ratio	-0.995	< 0.001
Correlations of different variables with Rim to Disc ratio	Average RNFL thickness	.709**	< 0.001
	Average CD ratio	-.607**	< 0.001
	Vertical CD ratio	-.550	< 0.001
	DDLS	-.995	< 0.001

\*\* Correlation is significant at the 0.01 level (2-tailed); CD=Cup to Disc ratio; DDLS= Disc Diameter Likelihood Scale; RNFL=Retinal nerve fiber layer

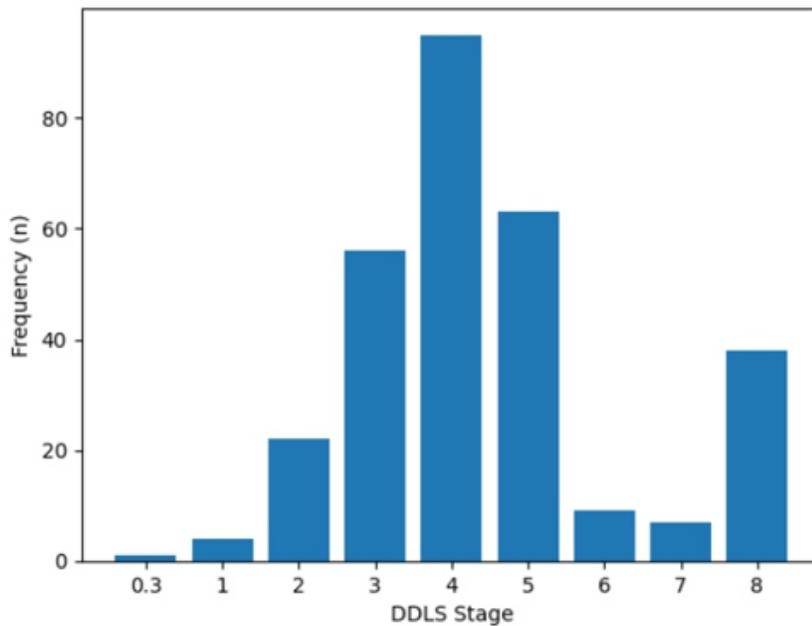


Figure 1: Distribution of Disc Damage Likelihood Scale (DDLS) stages among study eyes (n=295)

groups: less than 1.5 mm, 1.5 to 2 mm, and greater than 2 mm. Several studies have demonstrated that DDLS is more reproducible than the CD ratio.<sup>6</sup>

In our study, all measurements were conducted by a qualified ophthalmologist, and it was found that DDLS has a strong correlation with RNFL thickness. In contrast, another study, where parameters were evaluated by community optometrists, showed a weaker correlation, possibly due to errors in grading (Spearman's  $\rho$  of 0.378 for average RNFL thickness compared to 0.706 in our study).<sup>7</sup> Other studies, however, have shown results more consistent with ours. For instance, Kara-Jose AC, et al., reported a correlation coefficient of 0.64 in their study.<sup>8</sup> In their study, a glaucoma specialist assessed the DDLS, likely resulting in more accurate DDLS gradings and a stronger correlation.

Singh K, et al., found a positive correlation between DDLS and the vertical CD ratio, with a correlation coefficient ( $r$ ) of 0.562 ( $p < 0.001$ ).<sup>9</sup> In our study, the correlation coefficient was 0.564. These findings suggest that DDLS is a better method for assessing glaucomatous damage than the vertical or average CD ratios. Therefore, DDLS and rim-to-disc ratios should be integral parts of glaucoma assessment.

In a recent study, Philippin H, et al., compared DDLS and the CD ratio, indicating a moderate advantage of DDLS over the CD ratio.<sup>6</sup> Kitaoka Y, et al., evaluated DDLS using a stereo fundus camera and found that DDLS was strongly correlated with both the vertical and horizontal CD ratios.<sup>10</sup> However, they observed that the mean DDLS stage was higher in patients with myopic glaucomatous damage than in those with other refractive errors. Our study did not include patients with high myopia.

Glaucoma is a multifactorial disease, and since structural changes appear earlier than functional loss, DDLS can be a valuable parameter for monitoring disease progression. Literature shows that large disc and cup area at baseline and large CD ratio are correlated with early glaucoma progression.<sup>11</sup> This underscores the importance of

incorporating DDLS into routine glaucoma assessments to better track and manage the disease.

When assessing neural losses in glaucoma, Tatham AJ, et al., found that the CD ratio is not a reliable method for evaluating progressive neural losses. They noted that even small changes in CD ratio are associated with significant ganglion cell loss, highlighting the need for alternative parameters to accurately assess real damage.<sup>12</sup>

Some researchers compared DDLS with standard automated perimetry (SAP) and RNFL thickness.<sup>8</sup> They found better results of DDLS in early glaucoma. In contrast, our study did not include visual field (VF) measurements and encompassed all stages of open-angle glaucoma.

Chandra A, et al., demonstrated a stronger correlation between DDLS and mean deviation in VF ( $r = -0.7958$ ). However, the correlations of DDLS with pattern standard deviation and vertical CD ratio were weaker.<sup>13</sup> Similarly, the correlation between DDLS and RNFL thickness was greater than the value found in our study ( $r = -0.8472$  versus  $r = -0.706$ ). Our study did not include correlations with VF. DDLS grading also performs well compared to the CD ratio and Heidelberg Retina Tomograph-II (HRT-II) evaluation.<sup>14</sup>

Another study described that a change in the CD ratio from 0.7 to 0.9 resulted in an approximate loss of 350,000 retinal ganglion cells, highlighting the importance of more reliable methods for assessing glaucoma progression.<sup>15</sup> One recently introduced parameter is the minimum rim width (MRW), which can potentially predict changes in RNFL in glaucoma.<sup>16</sup> However, detecting changes in MRW also requires OCT.<sup>16</sup>

Literature shows that there are transient changes in the ONH due to IOP fluctuations, which further underscores the importance of assessing the remaining rim rather than focusing solely on the cup to evaluate damage.<sup>17</sup> Once understood, DDLS proves to be a more reliable method for detecting both early and late changes in glaucoma. However, it requires proper training to address variations caused by examiner error.

Like any method, DDLS has its limitations. Because it focuses on specific areas of the neuro-retinal rim, it may not detect new areas of notching if they appear. Patients with abnormal discs, who were excluded from our study, may not fit well into the DDLS criteria for assessing glaucoma progression. DDLS also requires expertise, as highlighted by the optometrist study that showed a low correlation with glaucoma damage. When OCT is available, DDLS and OCT can complement each other in glaucoma management. OCT provides detailed structural information about the retina and ONH, while DDLS offers a broader assessment of optic disc changes. Together, they can provide a more comprehensive understanding of glaucoma progression and aid in treatment decisions.<sup>18</sup>

The study has several limitations. It includes individuals from a single center, which limits its generalizability to broader populations. Being cross-sectional study, it does not provide longitudinal analysis, which is crucial for understanding disease progression over time.

Therefore, other modalities may be needed to comprehensively assess damage progression in glaucoma. Furthermore, compared to CD ratio, DDLS may have a longer learning curve, requiring more training and expertise to be used effectively. These factors underscore the importance of considering these limitations when interpreting and applying the study findings.

## CONCLUSION

DDLS and the rim-to-disc ratio demonstrated stronger correlations with RNFL thickness compared with vertical and average cup-disc ratios, suggesting that rim-based parameters may provide a more reliable assessment of glaucomatous structural damage. Therefore, incorporating DDLS and rim-to-disc ratio into routine glaucoma evaluation may enhance diagnostic accuracy and disease staging.

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### AUTHORS' CONTRIBUTION

The following authors have made substantial contributions to the manuscript as under:

**HK, TGM & FK:** Conception and study design, acquisition, analysis and interpretation of data, drafting the manuscript, approval of the final version to be published

**RA, MM & IA:** Acquisition, analysis and interpretation of data, drafting the manuscript, approval of the final version to be published

*Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.*

### CONFLICT OF INTEREST

Authors declared no conflict of interest, whether financial or otherwise, that could influence the integrity, objectivity, or validity of their research work.

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### DATA SHARING STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.



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