

## Applying Grading on Degree of Disc Damage Scaling Method to Assess Risk Stages of Glaucomatous Eye at Optic Cup and Disc Segmentation

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### Abstract:

In general, the visual information will be extracted and transferred by Optic Nerve Head from normal eye to brain. The process is very common in healthy eyes. The gradual damages and age related degeneration causes to the development of Primary Open Angle Glaucoma (POAG) at Optic Nerve Head(OH). The formation of optic cup segmentation with in the optic disc and also the structure of the neuroretinal rim will cause to glaucomatous eye. The huge collection of optic fiber nerves act as a network system which is called Optic Nerve Head. The neuroretinal rim along with optic cupping with in the disc will be created automatically where ever weak optic nerves are becoming inactive. It is clear that the thick rim is common in any healthy eye, but the gradual change in to thin structure causes to glaucomatous eye. The degree of the risk factor and the percentage of damage level will be observed with gradual changes in the healthy eye to transform in to Glaucomatous eye. In this paper, we measure various disk damage risk factors by considering the current structure of narrowest rim width and how it is located and placed in between disc and cup. The measurement on Grading of Degree on Disc Damage(GD3) method is to assess primary open angle glaucoma.

**Keywords:** Vision defect, Optic cup, Optic Disc, Neuroretinal rim, Optic Nerve Head, Glaucomatous Eye, Disk Damage, Grading Scale.

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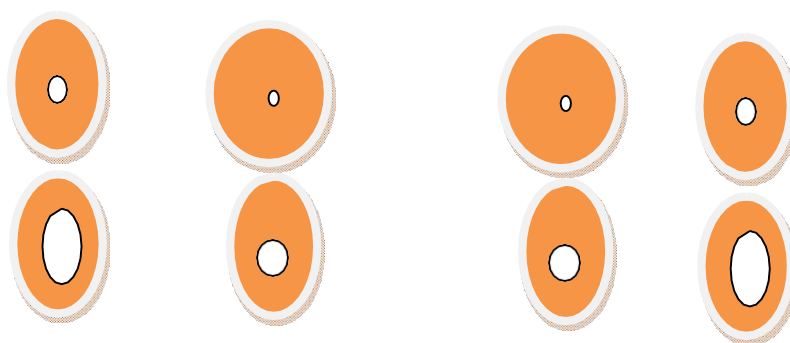
## Introduction

Glaucoma is one of the chronic eye disease with vision loss and eye Sight impairment are the common signs as in all other eye diseases. These fundamental problems causes to transform an healthy to glaucomatous eye. In the first phase the vision loss problem can be identified as eye sight impairment or any eye disease. In the later stages with the support of clinical examination, it can be concluded as Primary Open Angle Glaucoma, During the second phase the measurement of cup and disc ratio can be derived as CDR and also the placement and location of narrowest rim width is required. In all clinical laboratories disc and cup segmentation is common to identify glaucomatous eyes. The activities performed by clinical experts while examination are Intraocular Pressure(IOP) nerves of the eye, blockage of outflow of liquid in and out of the drainage canal system to assess the possibility POAG at retinal nerve fiber layers(RNFL)[2-4] retinal ganglion cell axons. From the eye retina to human brain the transmission of information will be performed by the dense set of optic nerves. Set of all millions of thousands of optic nerves can create optic nerve head (ONH). This

glue network area of the optic nerve head is located inside the bright orange colored oval shaped optic disc. Among these optic nerves few of them are very inactive and weak and will die inside the optic nerve head and creates an optic cup. A negligible formation of optic cup is common in every healthy eye also. It is too small and appears at the center part of the disc as a dot. [3,15]. This forms as a clear thick rim in the normal eye of the optic disk[1].

The thick rim gradually will become thin if the healthy eye is damaged and transforming as glaucomatous eye. Sometimes the rim may disappear at the most risk level. It is noticed that the cup size and rim width are inversely proportional & can predict the severity stage.[1-3].

Figure 1: Glaucomatous eye progression states.



In a normal eye, the size of the optic cup is proportional to the size of the optic disc. However, in defected eyes, this proportionality may be disrupted. Eyes with larger optic discs may exhibit irregular cup enlargement, leading to cup overlapping on the disc. This condition can cause displacement of the cup in the disc, leading to a potential glaucomatous eye. The overlapping of the cup on the disc may clog the outflow, resulting in a lack of fluid flow and a higher chance of absence of the rim.

The width of the narrowest rim is crucial in predicting the current status of glaucoma accurately, and it can be used as an indicator to identify the initial risk stage. Early identification of the risk stage is crucial in preventing the progression of glaucoma to more advanced levels, and it requires prompt and appropriate care and treatment.

Machine learning algorithms have been extensively researched for disease diagnosis, including glaucoma. These algorithms can analyze large datasets and identify patterns and risk factors that may not be apparent through traditional methods. Applying machine learning to glaucoma diagnosis may offer valuable insights and help improve the accuracy and efficiency of identifying and managing the condition. However, it's essential to validate and refine these algorithms continually to ensure their effectiveness and reliability in clinical settings.

In this current study, the researchers focus on medium and advanced stages of glaucoma, specifically the "damage" and "disability" stages. They aim to measure the degree of disk damage from the optic disc to the optic cup, especially when the cup is located within the disc. The changes in the rim width, from thick to thin structure, are also investigated in relation to the optic cup.

To achieve their goals, the researchers consider various parameters, including disc size, disc and cup diameter, the location of the disc, optic cup placement, cup location with an angle, circumference of the optic disc, focal rim width, ratio of rim and disc, and narrowest rim width. These measurements are used to determine the different grades and stages of glaucoma.

## Methodology

The methodology involves identifying the major developments that occur with increased path and reduced capacity of fluid outflow, abnormal intraocular pressure (IOP), and changes in the cup-to-disc ratio (CDR). These factors contribute to vision impairment due to the disturbance in the normal functionalities of the eye's internal part while transferring information to the brain, resulting from damage to the nerve system. As a consequence, a narrow and thin rim may form or, in severe cases, the entire rim may gradually disappear between the optic disc and the optic cup.

In their approach, known as GD3, the researchers first identify the pinkish optic cup within the area of the bright optic cup. They observe that during the initial stages of healthy eyes, there is no formation of a thin rim due to the absence of clogging of fluid outflow. In such cases, the rim value is negligible and can be considered as zero.

It's evident that this study attempts to provide a comprehensive understanding of the optic cup's role in glaucoma progression and how it relates to changes in the rim width. The measurement of various parameters and grading scales may aid in accurately diagnosing and monitoring the disease's advancement. However, it's essential to conduct further research and validation to ensure the reliability and applicability of their GD3 approach in clinical settings.

**Table 1:** Observations at Narrowest rim width to estimate possible risk factor stages.

(Source: European Glaucoma Society)

Disc Size/Stages	Small < 1.4 mm	Average 1.4mm-1.9mm	Large >1.9mm	Risk Stages
1	$\geq 0.5$	$\geq 0.4$	$\geq 0.3$	Initial Risk
2	0.4 -0.49	0.3- 0.39	0.2-0.29	Initial Risk
3	0.3-0.39	0.2-0.29	0.1-0.9	Advanced Risk
4	0.2-0.29	0.1-0.19	<0.19	Advanced Risk
5	0.1-0.9	<0.1	0 or <45 <sup>0</sup>	Damage
6	<0.1	0 or <45 <sup>0</sup>	0 or 46 <sup>0</sup> -90 <sup>0</sup>	Damage
7	0 or <45 <sup>0</sup>	0 or 46 <sup>0</sup> -90 <sup>0</sup>	0 or 91 <sup>0</sup> -180 <sup>0</sup>	Advanced Damage
8	0 or 46 <sup>0</sup> -90 <sup>0</sup>	0 or 91 <sup>0</sup> -180 <sup>0</sup>	0 or 180 <sup>0</sup> -270 <sup>0</sup>	Advanced Damage
9	0 or 91 <sup>0</sup> -180 <sup>0</sup>	0 or 180 <sup>0</sup> -270 <sup>0</sup>	0 or 270 <sup>0</sup>	Disability
10	10	0 or 180 <sup>0</sup> -270 <sup>0</sup>	0 or 270 <sup>0</sup>	Disability

The probable six stages of healthy Glaucoma is given below.

Illustration of the complete procedure in the flow diagram for deriving grading scale is given by the following flowchart.

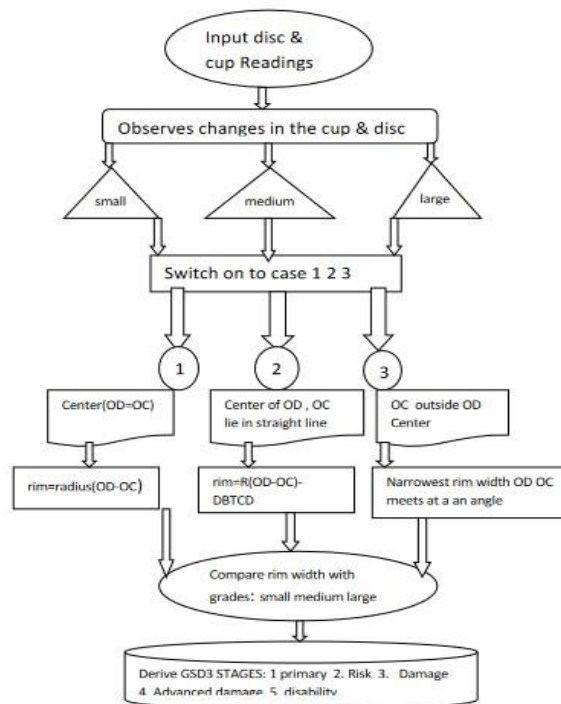


Figure 2: Complete Process Flow Diagram

DBTCP: Obtaining the distance between centers of OD and OC : Disk damage likely hood grade scale: GD3

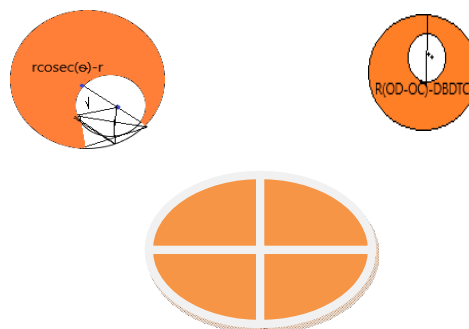


Figure 3: Probable cases of Cup lies in a Disc

**Components to find the rim width:**

Usage of different variable to find rim width: RW1,RW2,RW3,RW4,RW5,RW6,RW7,RW8 & 8 locations from 8 angles 45°, 90°, 135°, 180°, 225°,270°, 315°,360° one by one respectively.

Algorithm:

**Step 1:** Take Input Readings OD & OC { As mentioned in the given components divide disc area into 8 different PARTS }

**Step 2:Case 1:** OC & OD center points are same.

{Possible normal rim: Currently cup is placed at center of the disc then enlargement is possible for cup in later stages}

**Step 3:** Initialize the variable FP. { A Fixed Pointer on the circumference of the Optic Disc}.

**Step 4:** Retrieve locations from the fixed points

{ FP to RW1 :  $45^0$ , FP to RW2 :  $90^0$ , FP to RW3 :  $135^0$ , FP to RW4 :  $180^0$  , FP to RW5:  $225^0$  , FP to RW6:  $270^0$ , FP to RW7:  $315^0$  , FP to RW8:  $360^0$ }

**Step5:** Array Initialization:  $O[] = \{0,1,2,3,4,5,6,7\}$ , indexed by {Var p=0, Init q=0}.

**Step 6:** Initialize  $RW[] = \{0,1,2,3,4,5,6,7\}$

**Step 7:** \*Loop:

Find radius of OD & OC from the point  $RW[q]$ .

$O[p] = \text{radius of (OD - OC) : \{rim width\}}$

Increment q by 1:

repeat step 5 until  $q > 7$ .

**Step 8:** {Sort the Array  $O[]$ }

$O[0] = \text{first} : p = 0 :$

loop;

if  $\text{first} > O[p]$  then store  $\text{first} = O[p]$ ;

$p = p + 1 :$

repeat loop until  $p > 7$

**Step 9:** Print rim width(RW){ var : retrieves narrowest rim width with disc damage stages }

**step 10:** { Deriving GD3 stages with grading scale }

**Case 1** { measurement will be disk damage grades are given referred from Table 1 }

**Case 2 :** OC & OD are in same Center point and narrowest rim which lies in a straightline .

{ Find narrowest rim width based on gradual displacement of the optic cup }

**Step 11:** Take input values of centers & radius OC and OD.

**Step12:** Measure DBTCP.{thee distance between two centerpoints }

**Step 13:**  $\text{Narrowest\_Rim.Width} = (\text{Radius (OD-OC)} - \text{DBTCP})$ .

{ With reference from table 1 stages are derived }

**Case 3:** At angle OC located in OD .

{ Process of the development of the rim with in the Optic Disc }

**Step 14:** Calculate  $\text{narrowest\_Rim.Width} = (r \csc \Theta - r)$  .{as in Figure 3} { r: narrowest rim width } {derived possibilities and states}.

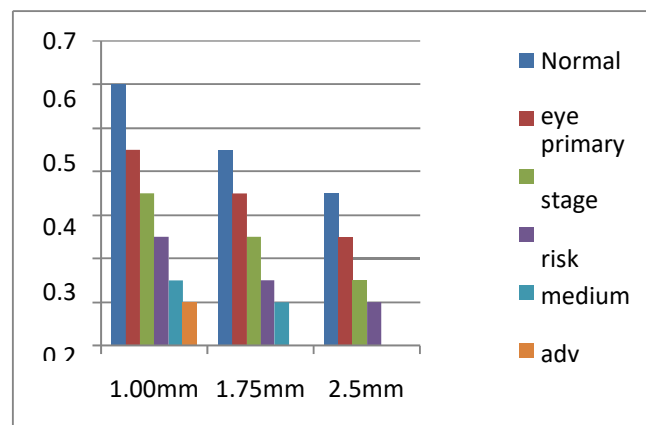
**Results**

With reference from Table 1, the measurement scale values of the narrowest rim width will always rely on the size of the disc. Clearly an optic disc is abbreviated with 3 different sizes 1.00mm, 1.75mm, 2.5 mm as given in the order. These will produce variations according to reference from Table-2. rim width will be gradually decreased to narrow points and risk in the stage will increase. Optic cup size and rim width both are inversely proportional. Cup size increases rim width decreases.

**Table 2:** Readings of all stages: width of the rim Vs small, medium and large size discs

Disk Size/Rim width	Healthy Eye	Primary Risk	Risk Advanced	Damage	Adv Damage	Disability
1.00mm	0.6	0.45	0.35	0.25	0.15	0.1
1.75mm	0.45	0.35	0.25	0.15	0.1	0.0
2.5mm	0.35	0.25	0.15	0.1	0.0	0.0

The above assumptions are clearly observed between the ranges of the disc size. As shown in the Figure 4, the bar graph illustrates the transformation of a normal eye to glaucomatous eye and finally tends to disability. The key observation is noticed that the glaucoma at a primary stage identification is necessary to provide timely and proper treatment from medical experts. Our study focuses on the primary stages of glaucoma to produce better results.



**Figure 4:** Illustration of Table 2 measurement levels of all stages : Scales of (X axis: disc size , Y axis: rim width).

In the Figure 6. In the Case 3 of GSD3 algorithm analyzes on the final states according to cup and width of the rim. It yields to complete vision impairment and confirmed that “disability” or “damage” stage as shown in figure 7. It is an impossible state to get recovery and unable to respond for any treatment. The timely decision must be taken either in Case 1 or Case 2.

**Table 3:** (CDR→rim\_width)

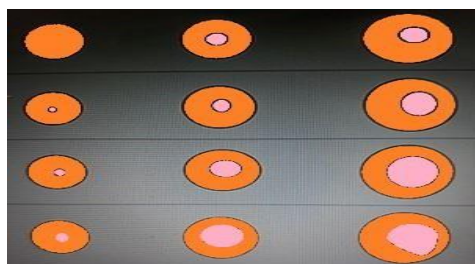
Size of Optic Disc	Size of Optic Cup	Possible width of the rim
L	S	Th
M	L	Tn
M	M	N
M	S	Tk
S	L	Tn
S	M	Tn
S	S	N

\*Large = L : \*Small = S : Medium = M \*Thick = Th : \*Thin = Th\* : Normal= N

**Discussion**

It is to denote that the better neuroretinal rim is always broader than Nasal rim. More about Nasal rim is thicker than the temporal rim. The comparison with relation operator as Temporal < Nasal < Superior < Inferior . From the Table 1 the readings have been taken for disc size. It is considered as a key role in the assessment of POAG and performed by Optical Coherence Tomography in the clinics by experts. These readings may vary by the techniques they implemented. As in Table 3, many changes in the structure and size of disc are possible. These assumptions are assuring about the stage of disc damage or damage to effect on eye with Glaucoma . The final observations from Table 3 are proving that, if the structure of the rim is normal and thick then it is a safe state. The damage state starts with cup with medium or large size with thin rim.

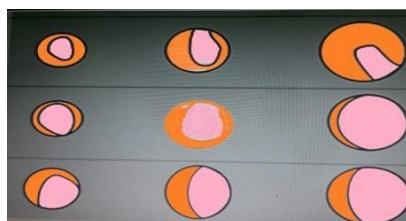
GSD3- Grading Scale algorithm which is rely on 3 possible cases. Case 1 propagates on possibility of narrowest rim when cup formed at the center location of the disc. Figure 5 shows about two measurements in all sizes. Al most 90% of the readings shows that, it produce either “primary risk” or ” advanced “. The remaining 10% is “damage” stage. The evaluation of Case 3 barely shields primary stages, because of the cup migration is almost “damage” or “advanced”.



**Figure 5 :** Case 1 : Demonstration of Glaucoma primary and advanced risk stages. Primary and advanced risks during OD & OC meets at one center point.



**Figure 6 :** Case 2: Demonstration of glaucoma damaged stage during Center(OD & OC) lies in a single line.



**Figure 7:** Case 3: Demonstration of Glaucoma Advanced damage and disability : During the advanced stage of OC detected in OD at different angles.

## Conclusion:

In the current study we observed that the vision loss is gradually developed to high level degree along with the changes occurred in the neuroretinal rim placed between cup and disc. This study includes three possible cases about the displacement of Optic cup in the disc. We concluded that by the measurement of the narrowest rim width by using the GSD3 method of disk damage scaling approach can produce accurate outputs to determine different levels of disk damage stages. This idea can be applied in the further work to design a modeling tool which will determine the CDR to forecast glaucoma at an early stage.

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