

DETAILING THE NEURORETINAL RIM TISSUE FOR GLAUCOMA

by

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Has been approved

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## ABSTRACT

**Purpose.** Twenty percent of all law suits filed against Eye Care Practitioners (ECP) are related to the misdiagnosis of glaucoma, which is currently the highest amongst all other ocular anomalies. Diagnosis of glaucoma is based upon a multitude of techniques including information provided by a dilated non-contact fundus examination, Heidelberg Retinal Tomographer (HRT), Glaucoma Diagnosis (GDx), Optical Coherence Tomography (OCT) and scanning laser ophthalmoscope (SLO). All methods mentioned provide objective quantitative information of the optic nerve head; however, many ECP do not have access to this equipment. For the average ECP, diagnosis of glaucoma is primarily based upon a subjective dilated non-contact fundus examination with a cup-to-disc ratio (C/D) as the only quantitative information available. Assessing the C/D ratio has inherent flaws including overlooking the placement of the cup, judgment based upon color and concentration of the cup as opposed to the neuroretinal rim tissue which is where loss occurs during the process of glaucoma. The need for a standardized objective method to evaluate the neuroretinal rim tissue is required for the proper diagnosis of a suspicious or glaucomatous optic nerve during a dilated non-contact fundus examination. **Methods.** Fundus photography has been obtained from subjects in order to describe proper evaluation of the rim tissue based upon a grid format. A literature review was conducted to support our findings. **Results.** A measurement system is explained within the article taking into account optic nerve head size and appropriate conversion factors. **Conclusions.** A grid format for measurement of the optic nerve head rim tissue will assist in the standardization of evaluation glaucomatous changes.

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Finally, I would also like to thank my family, closest friends, and Michigan College of Optometry colleagues for providing much support and encouragement throughout this experience.



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Finally, I would like to extend my sincerest gratitude toward my family, friends, colleagues, and the faculty at the Michigan College of Optometry for their encouragement, guidance and assurance throughout my experience.

# Detailing the Neuroretinal Rim Tissue for Glaucoma

*Joanna M. Deluco, Kimberly M. Dillivan, BS, Phillip Walling, OD, FAAO*

**Purpose.** Twenty percent of all law suits filed against Eye Care Practitioners (ECP) are related to the misdiagnosis of glaucoma, which is currently the highest amongst all other ocular anomalies. Diagnosis of glaucoma is based upon a multitude of techniques including information provided by a dilated non-contact fundus examination, Heidelberg Retinal Tomographer (HRT), Glaucoma Diagnosis (GDx), Optical Coherence Tomography (OCT) and scanning laser ophthalmoscope (SLO). All methods mentioned provide objective quantitative information of the optic nerve head; however, many ECP do not have access to this equipment. For the average ECP, diagnosis of glaucoma is primarily based upon a subjective dilated non-contact fundus examination with a cup-to-disc ratio (C/D) as the only quantitative information available. Assessing the C/D ratio has inherent flaws including overlooking the placement of the cup, judgment based upon color and concentration of the cup as opposed to the neuroretinal rim tissue which is where loss occurs during the process of glaucoma. The need for a standardized objective method to evaluate the neuroretinal rim tissue is required for the proper diagnosis of a suspicious or glaucomatous optic nerve during a dilated non-contact fundus examination. **Methods.** Fundus photography has been obtained from subjects in order to describe proper evaluation of the rim tissue based upon a grid format. A literature review was conducted to support our findings. **Results.** A measurement system is explained within the article taking into account optic nerve head size and appropriate conversion factors. **Conclusions.** A grid format for measurement of the optic nerve head rim tissue will assist in the standardization of evaluation glaucomatous changes.

Twenty percent of all law suits filed against Eye Care Practitioners (ECP) are related to the misdiagnosis of glaucoma, which is currently the highest amongst all other ocular anomalies.<sup>1</sup> Diagnosis of glaucoma is based upon a multitude of techniques including information provided by a dilated non-contact fundus examination, Heidelberg Retinal Tomographer (HRT), Glaucoma Diagnosis (GDx), Optical Coherence Tomography (OCT) and scanning laser ophthalmoscope (SLO). All methods mentioned provide objective quantitative information of the optic nerve head; however, many ECP do not have access to this equipment. For the average ECP, diagnosis of glaucoma is primarily based upon a subjective dilated non-contact fundus

examination with a cup-to-disc ratio (C/D) as the only quantitative information available. Assessing the C/D ratio has inherent flaws including overlooking the placement of the cup, judgment based upon color and concentration of the cup as opposed to the neuroretinal rim tissue which is where loss occurs during the process of glaucoma. The need for a standardized objective method to evaluate the neuroretinal rim tissue is required for the proper diagnosis of a suspicious or glaucomatous optic nerve during a dilated non-contact fundus examination.

Estimation of the cup-to-disc (C/D) ratio is the primary method in which an ECP documents the state of the optic nerve head. Accurate recording of the optic disc requires

the ECP to subjectively and accurately measure the distinction of the contour between the cup and the neuroretinal rim tissue as opposed to accessing variation of color.<sup>2</sup> Obviously, this technique can be easily flawed by natural human error due to its subjective nature. In addition, a patient may be evaluated by multiple ECP throughout his/her life and the C/D ratio may be determined by using different examination techniques such as direct ophthalmoscopy or biomicroscopy using a 66D, 78D, or 90D lens, either a Volk, Nikon or another type of fundus lens. The variables to accessing the C/D ratio could be endless; therefore it is crucial that the C/D ratio estimate is consistent among each ECP.<sup>3</sup>

Studies have shown that inter-observer agreement of the C/D ratio is lower than intra-observer agreement. Much research has been put forth in order to reduce inter-observer disagreement. One example includes the development of a graticule in direct ophthalmoscopes, such as the Keeler Practitioner and Professional models. Another attempt to create consistency is the classic C/D ratio chart often provided to an ECP who is first learning C/D ratios (See Figure 1). Again this model has inherent flaws and does not describe the neuroretinal rim tissue thickness, the placement of the cup or any characteristics such as sloping, notching or depth. The C/D Chart in the Optometric Grading Scales, calculated by Jonas et al. using the Burek algorithm, was designed to be more accurate than the classic concentric circles. This was done by incorporating the change in shape of the cup with higher C/D ratios. When the cup-to-disc ratio ranges from 0.1-0.5, the disc has the shape of an oblate ellipse and the cup has the shape of a prolate ellipse. At higher ratios, the cup begins to take a more oblate shape (See Figure 2).<sup>2</sup>

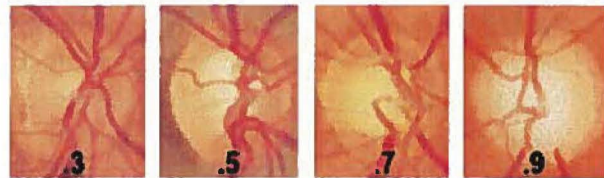


Figure 1. Classic C/D ratio provided to a beginning ECP. These types of diagrams are designed to be basic to introduce the concept of a C/D to an ECP. As such, these diagrams has inherent flaws and do not describe the placement of the cup or any characteristics of the optic nerve.

0.1	0.2	0.3	0.4	0.5
				95% confidence limit of normally Vert disc diam (mm)    Vert C/D ratio 1.2                      0.5 1.5                      0.6 1.8                      0.7 2.2                      0.8 (Garway-Heath et al 1998)

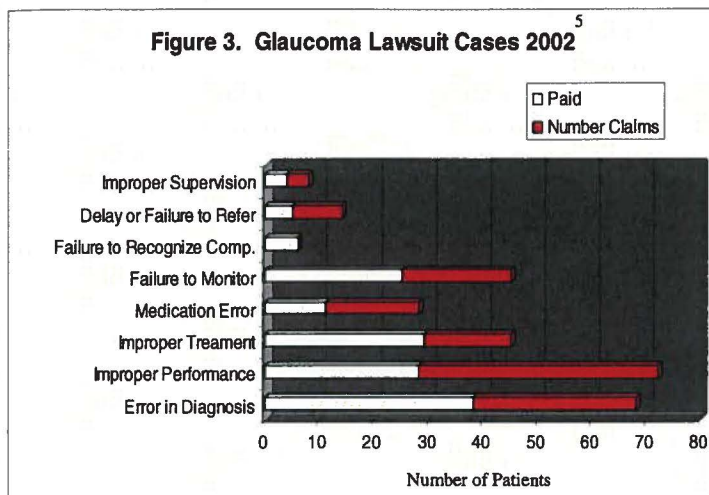
Figure 2. C/D Chart in the Optometric Grading Scale. Calibrated to be more accurate than the classic concentric circles to describe a C/D ratio. Based upon the cup assuming a more oblate shaped beyond a C/D ratio of 0.5.

### Litigation among Eye Care Practitioners

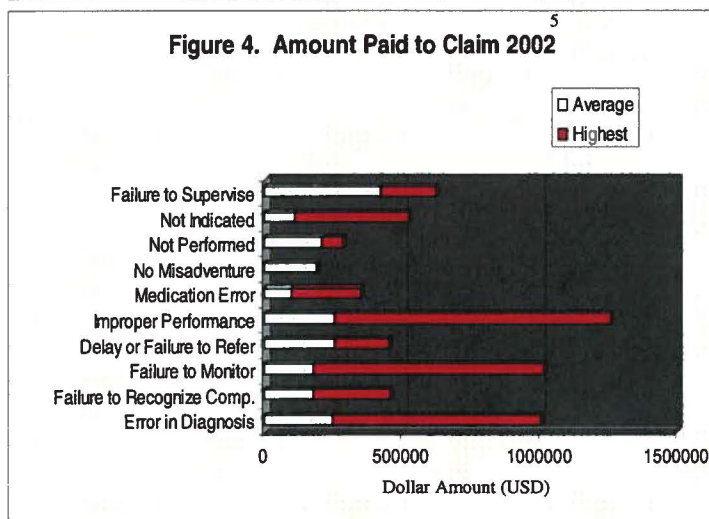
Documenting the nerve head properly not only provides quality patient care, it may also protect the ECP from legal issues. Recent statistical data shows that the most commonly paid lawsuit claim against an ECP is due to failure to diagnose glaucoma (See Figure 3). A decade ago, the paid claim never approached one million dollars; however, today, a million-dollar payout is not unheard of (See Figure 4). Documenting the C/D ratio properly the first time and consistently throughout the lifetime of patient's ocular health could deter failure to diagnose and other common causes of

claims such as improper supervision, delay or failure to refer, failure to recognize complications, failure to monitor, medication errors, and improper treatment.<sup>5</sup>

**Figure 3. Glaucoma Lawsuit Cases 2002**<sup>5</sup>



**Figure 4. Amount Paid to Claim 2002**<sup>5</sup>



These figures can be unnerving, but fortunately optometry ranks as the lowest malpractice pay-out specialty in medicine, this excludes ophthalmology. From the dates of September 1, 1990 to March 17, 2008, only 580 lawsuits against optometrists were settled with payment. This is drastically reduced compared to medical physicians, in which 232,727 paid lawsuits were granted over the same time frame. Even though statistics show there is a minimal chance to be sued as an optometrist, an ECP would not want to be among those

580 lawsuits. According to Jerome Sherman, OD, who has testified as an expert witness in numerous malpractice cases, the best way an ECP can protect him/herself from litigation is by proper documentation. Dr. Sherman states, the more you record, the better off you are and if it is not written on the patient exam form then the judge and jury will assume it was never done.<sup>5</sup>

### Determining the Cup-to-Disc Ratio: Intra-observer and Inter-observer Variability

The next facet of correctly and consistently documenting the optic nerve head and changes over time is the degree of variability between ECP's. One study took C/D ratio estimates from nine 3<sup>rd</sup> year optometry students, nine 4<sup>th</sup> year optometry students, and nine optometrists and statistically analyzed the intra-observer and inter-observer agreement after viewing an optic nerve head monoscopically and stereoscopically. It was found that inter-observer agreement was higher among optometrists than 4<sup>th</sup> year students and inter-observer agreement among 4<sup>th</sup> year students was higher than that of 3<sup>rd</sup> year optometry students. In addition, inter-observer agreement was higher when accessing the vertical component of the C/D ratio as opposed to the horizontal component. Intra-observer agreement did not have a high degree of variability since it predominantly depended upon experience. This study shows that inter-observer agreement of the C/D ratio increases with experience; however, intra-observer agreement does not.<sup>3</sup>

Another study investigated the inter-observer agreement between optometrists and ophthalmologists. Six optometrists and six ophthalmologists viewed 48 disc photographs stereoscopically. The results indicated that intra-observer agreement is

substantially greater than inter-observer agreement and is comparable for both optometrists and ophthalmologists. The study noted that there is close agreement between optometrists and ophthalmologists; however, the agreement between optometrists is significantly worse than the agreement between ophthalmologists when accessing the vertical component of the optic nerve head. The last finding of this study, which correlates with the previous study, was that there is a consistent under estimation of the C/D ratio from less experienced optometrists.<sup>6</sup>

### Calculating the Optic Disc Size

When evaluating the optic nerve head, generally an ECP has a specific lens that he/she has grown accustomed to. Whether this lens is a Volk or a Nikon lens or a 78D or a 90D lens, each lens possesses its own qualities and thus its own magnification and conversion factors. Depending on what type of non-contact fundus lens an ECP chooses can affect the apparent size of the optic nerve head. It has been shown that patients with a larger optic nerve head are diagnosed as glaucomatous whereas small discs are often deemed as normal. With this information, the optic nerve head size must be a consideration when diagnosing a patient with glaucoma. A precise measurement of the disc is not necessary; however an ECP must be able to determine the disc to be small, average or large since small neuroretinal rim changes to a small optic nerve could mean drastic progression of glaucoma.<sup>7</sup>

Each ECP must be aware that each non-contact fundus lens used has its own conversion factor and should be used when accessing the size of the disc. A quick way to determine the size of the optic nerve head is by creating a vertical optical beam and

adjusting the beam to the vertical size of the disc and viewing the measurement obtained on the slit lamp in millimeters. Once the measurement is acquired, a conversion factor must be used to adjust for the appropriate size depending on the type of non-contact fundus lens being used by the ECP (See Figure 5,6). The vertical dimension of the disc is most important since it is the area first affected by glaucomatous damage by loss of nerve fiber tissue.<sup>7</sup>

Figure 5<sup>7</sup>

Vertical Disc Diameters (mm) in Normal Eyes					
	-2 S.D.	-1 S.D.	Mean	+1 S.D.	+2 S.D.
Whites	1.52	1.67	1.82	1.97	2.12
Blacks	1.64	1.80	1.96	2.12	2.28

Figure 6<sup>7,8</sup>

### Magnification Correction Factors

Type of Lens	Lim CS	Jonas	Spencer	Vendor Data
Volk				
60D	0.88	-----	-----	0.92
78D	1.11			1.15
90D	1.33			1.39
Nikon				
60D	1.03	-----	-----	1.02
90D	1.63			1.54
Contact Goldmann	-----	1.27	-----	1.14
Zeiss 4-mirror	-----	-----	$\frac{X}{0.985}$	-----

## Grid Formulation for Measurement of the Optic Nerve

Once the size of the optic disc has been determined, one may ask what the most efficient way to document the C/D ratio is to circumvent such issues as using an oversimplified concentric circle system, inter-observer disagreement, and poor documentation concerning the placement of the cup, poor patient care, and litigation. The answer may be found in detailing the neuroretinal rim tissue as opposed to the cup by taking the fractional decimal value obtained by dividing the rim thickness by the diameter of the disc. This idea is not novel many ECP's incorporate the rim-to-disc (R/D) ratio on every patient seen; however, mainstream eye care focuses predominately on the C/D ratio. The system is simple and outlined diagrammatically through stereoscopically viewing fundus photographs.

The R/D ratio is one of the most efficient ways to describe the thickness of the neuroretinal tissue and ultimately the placement of the cup whether displaced inferiorly, superiorly, nasally or temporally. By documenting the disc more thoroughly, an ECP is more likely to elude litigation and provide better patient care by consistently documenting the disc throughout the patient's lifetime. Other benefits of the R/D ratio may include better inter-observer agreement; however, this would have to be studied more in depth. In addition, if an ECP is paying closer attention to neuroretinal rim tissue to describe the R/D ratio as opposed to concentrating on the cup to describe the C/D ratio, then an ECP could potentially notice other slight anomalies to the neuroretinal rim tissue such as notching, Drance hemorrhages, optic nerve head pits and drusen.

Below is a diagram describing how to accurately measure the R/D ratio. By

mentally dividing the optic nerve head into ten horizontal slivers the ECP can obtain the vertical neuroretinal rim tissue (Figure 7). As in the example below, the superior and inferior vertical component are 0.2 each. With this notation, the vertical component of the cup is assumed to be 0.6 by subtracting the superior and inferior vertical component from 1.0 ( $1.0 - 0.2 - 0.2 = 0.6$ ). Documentation on a patient exam form should be written as superior decimal/inferior decimal and would be written as 0.2/0.2.

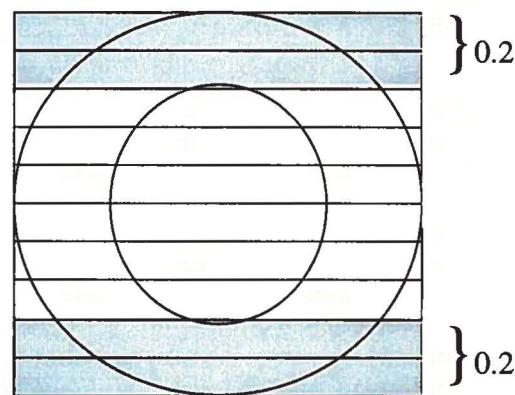


Figure 7. R/D ratio divides the disc into ten slices. Superior vertical component is 0.2. Inferior vertical component is 0.2. Written as 0.2/0.2. Cup is assumed to be 0.6.

The horizontal neuroretinal rim tissue is calculated in the same manner (Figure 8). The temporal neuroretinal rim tissue in the diagram below is 0.1 and the nasal component is 0.2. With this notation, the cup is assumed to be 0.7 ( $1.0 - 0.2 - 0.1 = 0.7$ ). Documentation on a patient exam form should be written as temporal decimal/nasal decimal and would be written as 0.1/0.2.

This method of performing the R/D ratio has one particular benefit in addition to the previous mentioned. This benefit is monitoring the vertical neuroretinal rim tissue and any changes over time. Multiple studies have proven that glaucomatous damage, thus visual field loss, primarily

occurs in the vertical meridian of the disc.<sup>2</sup> By cautiously monitoring any vertical rim tissue loss will allow the ECP to properly manage their glaucoma patients and glaucoma suspects.

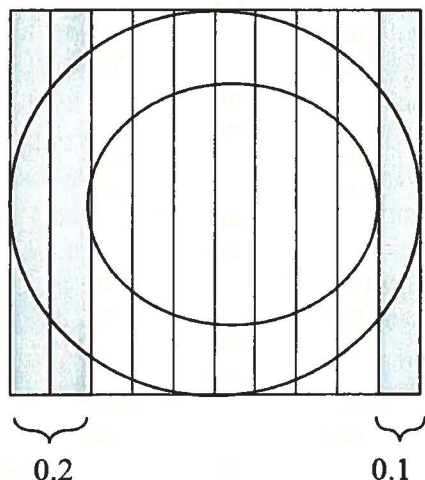


Figure 8. Horizontal R/D ratio dividing the disc into ten slices. Temporal rim is 0.1 and nasal R/D ratio is 0.2. Written as 0.1/0.2. The cup is assumed to be 0.7.

Another advantage is that the R/D ratio is independent of magnification used, thus independent of what type of non-contact fundus lens used. Magnification of the lens should not impact an ECP's judgment to divide the disc into ten slivers.

There are multiple benefits to perform the R/D ratio as opposed to performing a C/D ratio and each require the same amount of time for an ECP to evaluate.

### Properly Documenting the Neuroretinal Rim Tissue

Prior to describing each optic nerve head via a grid, a separate page is designated to the reader to complete a self-assessment quiz, this quiz can be found in the last section of this article. Ten optic nerve heads, Figures 9-18, have been provided with varying C/D and R/D ratios. After the reader has completed his/her estimation of

the C/D or R/D ratio, the next page provided in this article describes each optic nerve head with a grid and answers of the correct R/D ratio and assumed C/D ratio.

### Discussions

After accessing Figures 9-18, the authors would like address specific observations noted during the study. To begin with, Figure 9 was deceiving at first glance based upon color and shallow appearance. We first assumed the C/D ratio to be estimated at 0.1/0.1; however, after applying the grid format based upon the contour of the vessels, the assumed C/D ratio was .15/.325. This is an excellent example of Jonas' theory that C/D ratios under 0.5 appear more oblate and could be incorrectly measured by a C/D ratio alone.

The second example we would like to discuss is Figure 18. Obviously, this disc is glaucomatous; however, it is important to grade this cup correctly due to the fact of severe thinning inferiorly which can lead to substantial visual field defects. By calculating the R/D ratio as opposed to the C/D ratio it is evident that the cup is displaced inferiorly. Once the displacement of the cup is apparent to the EPC, attention must be paid to where the thinning is actually occurring (in this example at seven o'clock.)

Lastly, Figures 12-14 must be discussed based upon similar calculated R/D ratios, but dissimilar appearances. These figures are great examples of detailing where the cup actually begins compared to interpreting the C/D ratio on color alone. Again, by detailing the R/D ratio by the deviation of vessels, a more accurate measurement can be inferred. After our self-assessment of the ten optic nerve heads, we discovered that when a C/D ratio was under 0.5 we had a tendency to

underestimate the value and overestimated the value when the C/D ratio was over 0.5.

Other considerations when accessing the rim tissue is to be conscientious of the ISNT rule. This rule states that the thinnest quadrant should be the inferior, then followed by the superior, nasal, and then thickest quadrant should be the temporal aspect of the rim tissue.<sup>2,9</sup> In addition, it is important to remember that Afro-Caribbean patients have higher C/D ratios and a greater prevalence of 0.5 C/D ratios than Caucasians.<sup>2</sup> This means that in Afro-Caribbean patients, the R/D ratio will be smaller than those compared with Caucasians. By accessing the neuroretinal rim tissue in every patient, an ECP can pay close attention to the ISNT rule and race tendencies.

## Conclusion

This study was originally based upon an idea to create a small laminated card that ECP could carry with them to precisely grade the decimal size fraction of the rim tissue. The design was to position a vertical slit lamp beam to the superior rim tissue and adjust the size to match the size of the patient's rim tissue. By calculating the optics of the type of non-contact fundus lens, the optics of the slit lamp and devising specific distances to be measured to create consistency, the length of the measured slit beam could be placed upon premeasured readings on the small card and the ECP could directly read off the measurement. After the superior rim tissue reading was obtained, the ECP would measure the inferior, temporal, and nasal rim tissue. Unfortunately, it was found throughout the study that the slit lamp beam could not be adjusted any smaller than a 0.3 to 0.2 with consistency. Although this specific idea did not work in its entirety, the concept of

measuring the neuroretinal rim tissue in all four quadrants is still of great value.

By using the grid format as described within this article, the ECP can avoid overlooking the placement of the cup, any neuroretinal rim tissues and avoid measurement based solely on color of the cup. By following this proposed standardization of measurement, the ECP can provide better patient care and follow up, circumvent litigation and improve inter-observation with consulting colleagues. In addition, this proposed method eliminates all variable that can interfere with assessment of the optic nerve head. These variables can include the various techniques ECP use to measure the disc, magnification of the lens, type of lens used and size of disc.

There needs to be further testing on this concept, although fundamentally the concept of the R/D ratio is sound. Other studies on this subject could include intra-observer and inter-observer agreement of the R/D ratio or a study conducted to see if ECP's actually notice more rim anomalies when paying closer attention to the neuroretinal rim tissue by grading the R/D ratio as opposed to grading the C/D ratio.

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## Stereoscopic C/D Ratio Assessment: Self Examination

Figure 9



C/D Ratio Estimation \_\_\_\_\_

Figure 10



C/D Ratio Estimation \_\_\_\_\_

Figure 11



C/D Ratio Estimation \_\_\_\_\_

Figure 12



C/D Ratio Estimation \_\_\_\_\_

Figure 13



C/D Ratio Estimation \_\_\_\_\_

Figure 14



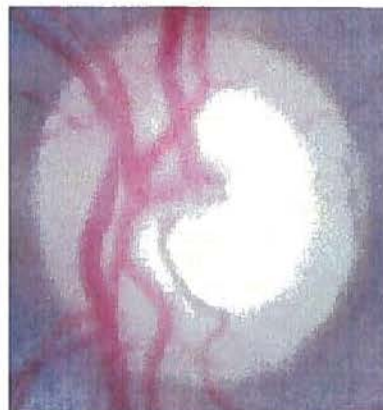
C/D Ratio Estimation \_\_\_\_\_

Figure 15



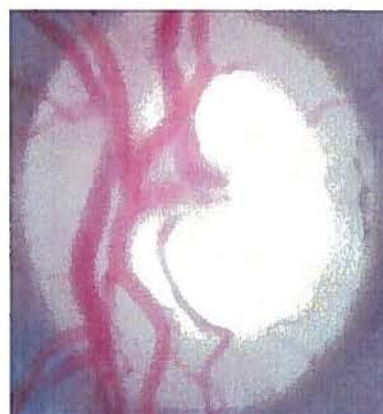
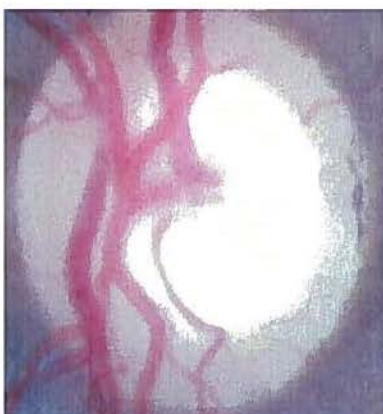
C/D Ratio Estimation \_\_\_\_\_

Figure 16



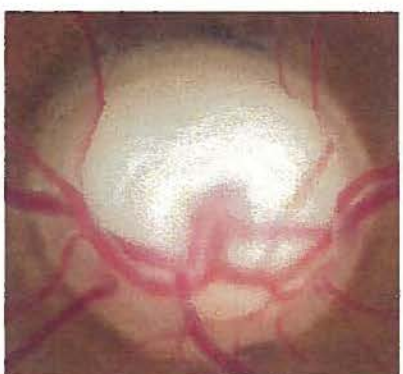
C/D Ratio Estimation \_\_\_\_\_

Figure 17



C/D Ratio Estimation \_\_\_\_\_

Figure 18



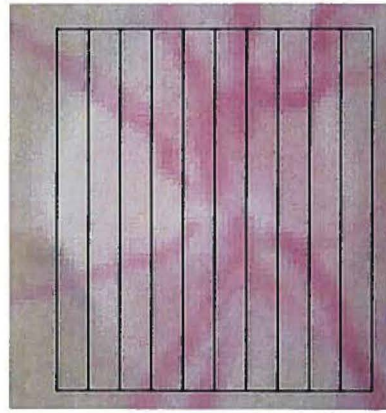
C/D Ratio Estimation

\_\_\_\_\_

Figure 9

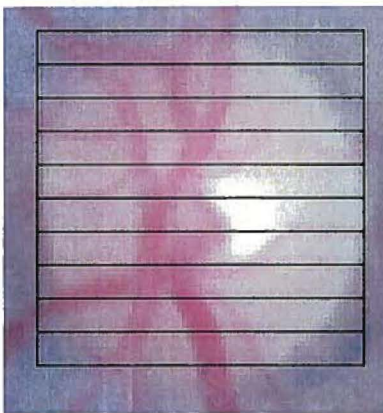


Vertical R/D: 0.45/0.40; assumed cup size of 0.15

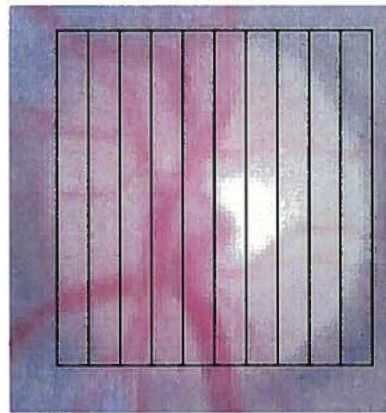


Horizontal R/D: 0.375/0.30; assumed cup size of 0.325

Figure 10

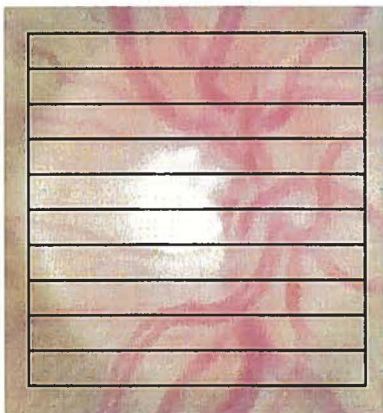


Vertical R/D: 0.375/0.30; assumed Cup size of 0.325

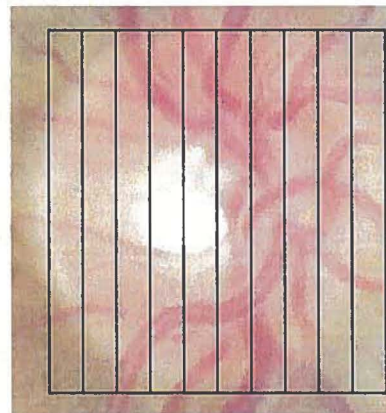


Horizontal R/D: 0.25/0.30; assumed cup size of 0.45

Figure 11

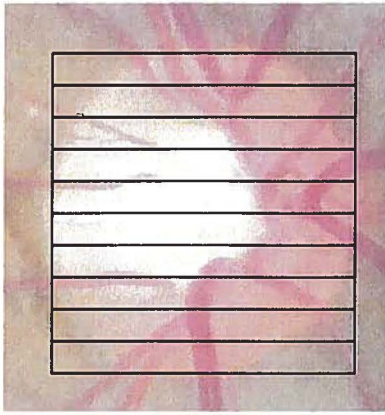


Vertical R/D: 0.25/0.375; assumed cup size of 0.375

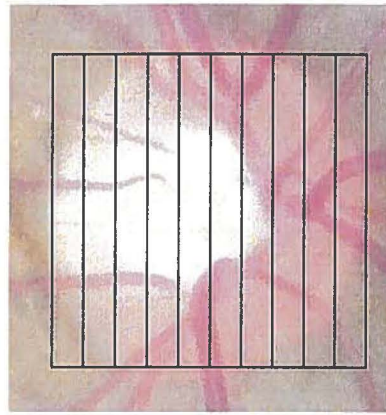


Horizontal R/D: 0.275/0.275; assumed cup size of 0.45

Figure 12

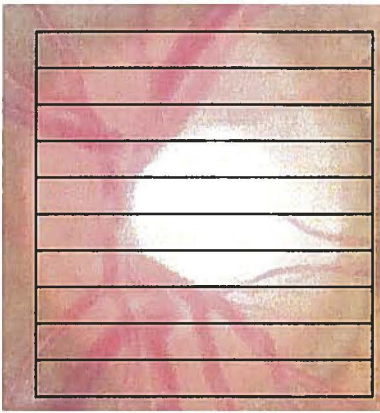


Vertical R/D: 0.20/0.25; assumed cup size of 0.55

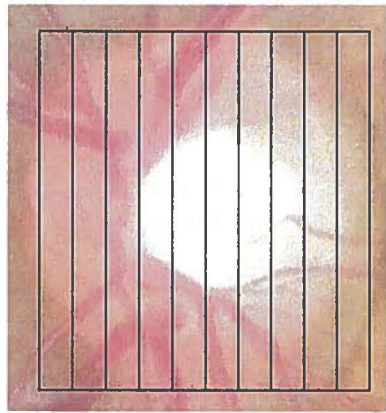


Horizontal R/D: 0.225/0.25; assumed cup size of 0.525; temporal sloping

Figure 13

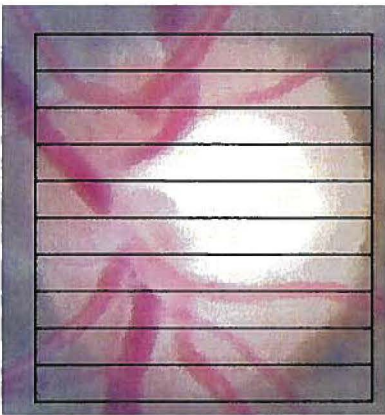


Vertical R/D: 0.225/0.275; assumed cup size of 0.50

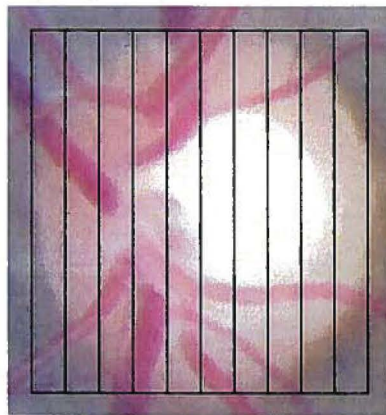


Horizontal R/D: 0.25/0.25; assumed cup size of 0.50

Figure 14



Vertical R/D: 0.20/0.275; assumed cup size of 0.525

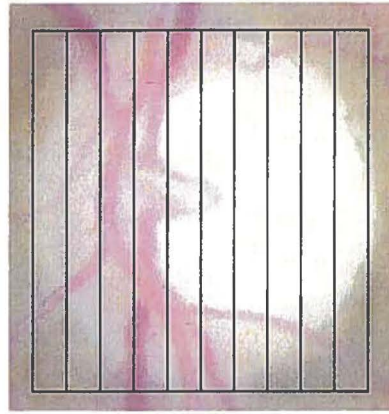


Horizontal R/D: 0.15/0.25; assumed cup size of 0.60

Figure 15

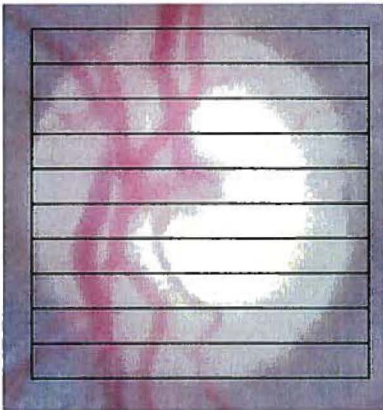


Vertical R/D: 0.15/0.20; assumed cup size of 0.65

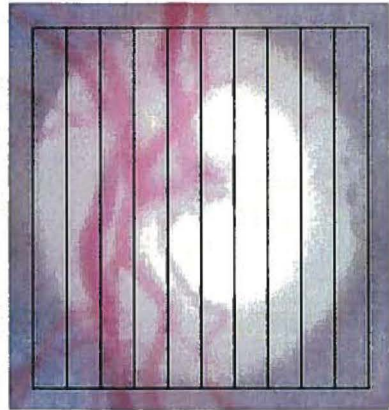


Horizontal R/D: 0.1/0.25; assumed cup size of 0.65

Figure 16

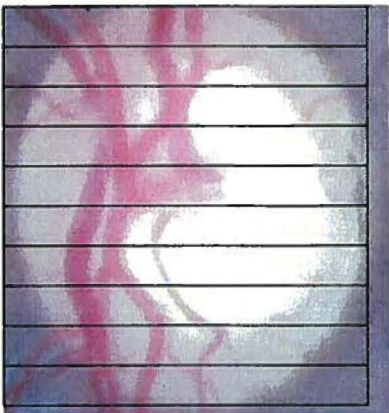


Vertical R/D: 0.15/0.20; assumed cup size of 0.65

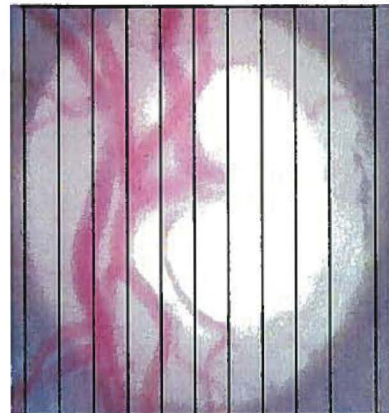


Horizontal R/D: 0.15/0.25; assumed cup size of 0.60

Figure 17

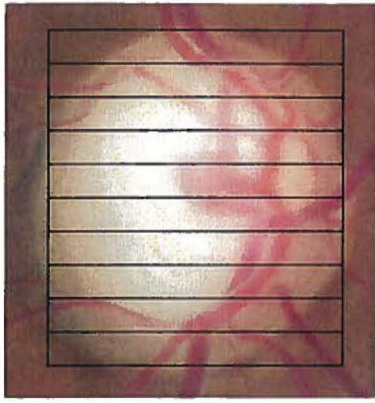


Vertical R/D: 0.125/0.20; assumed cup size of 0.675

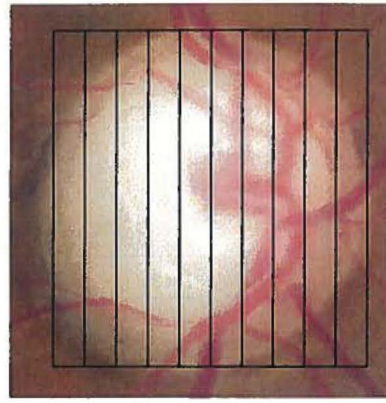


Horizontal R/D: 0.1/0.275; assumed cup size of 0.625

Figure 18



Vertical R/D: 0.1/0.125; assumed cup size of 0.775



Horizontal R/D: 0.05/0.1; assumed cup size of 0.85



APPENDIX A

HRSC Application Approval

Connie Meinholdt, Ph.D.  
Psychology Program  
820 Campus Drive  
Ferris State University  
Big Rapids, MI 49307  
(231) 591-2759

To: Dr. Phillip Walling, Ms Kimberly Dillivan & Ms Joanna Deluco  
From: C. Meinholdt, HSRC Chair  
Re: HSRC Applications #090111 (Title: Detailing the Neuroretinal Rim Tissue for  
Glaucoma)  
Date: February 9<sup>th</sup>, 2009

The Ferris State University Human Subjects Research Committee (HSRC) has reviewed your application for using human subjects in the study, "Detailing the Neuroretinal Rim Tissue for Glaucoma" (#090111) and approved it under the category of expedited - 2D, 2F.

Your application has been assigned a project number (#090111) which you may wish to refer to in future applications involving the same research procedure. All project approvals receive an expiration date one year from the date of approval. As such, you may collect data according to procedures in your applications until February 10<sup>th</sup>, 2010; you must apply for a renewal if data collection continues beyond this date. Finally, it is your obligation to inform the HSRC committee of any changes in your research protocol that would substantially alter the methods and procedures reviewed and approved by the HSRC in this application.

Thank you for your compliances with these guidelines and best wishes for a successful research endeavor. Please let me know if the committee can be of future assistance.