Color Consistency Analysis in Fundus Photography
19 June 2014
1:00 – 4:00 p.m.

The meeting was called to order at 1:45 p.m. (EDT) by Christye Sisson, chair, with the following attendees:

Christye Sisson, chair
Francisco Imai
John Sweeney
Debbie Orf
Rich Amador

Via webinar:
David Clunie
John Penczek
Susan Farnand
William Fischer
Yves vander Haeghen
Vitaly

Ms. Sisson presented an update on work to quantify the difference in color between different fundus cameras [see attached]. Results show that it is potentially possible to calibrate a fundus camera. Applying the calibration to RAW images in the system would be ideal. What we believe to be "correct" retinal color is not correct at all, and a standard approach to color calibration is needed.

Phase I of the project has been completed and Phase II will include determining a minimum color patch size, refining the testing materials, determining and refining the imaging protocol and then doing an analysis of the results of TIFF vs. RAW image.

There was discussion on changing the angle of the camera to achieve a higher magnification if the group agrees to use the "middle" angle of view protocol.

Findings:

- Illumination/ exposure ratio issue
- What impact does field of view have? Flat field?
- Colors of target?
- Color of the inside of model eye?
- RAW vs. exported TIFF?

- Implementation?

Illumination influences final flash exposure depending on brightness of illumination and flash setting. These variables cannot be standardized, so should illumination be included as it exists on average in patient photography or be eliminated as a variable for the purposes of testing.

We can eliminate the illumination if the goal is to have a user partner create the profile for the camera. This is reflected in commercial photography where the user customizes for their environment. The results demonstrate that we are viewing the images very warm.

There is a spectral mismatch between setup illumination and flash exposure. Ideally the illumination should have the same spectral power distribution as the flash, and one way to accomplish would be to use LED illumination. This is unlikely to be adopted because the cooler the light source the more difficult for the patient to tolerate. It was felt that solutions for this could be found (for example a mechanical shutter for the flash exposure).

The question was asked who performs the correction in a clinical trial and on the basis of what data.

The procedure for producing the targets is a 3-D printing approach, so a target could be made that is curved in the same shape as the eye. If built this way the base of the target becomes less expensive so that the targets could be left with people in the clinical trial so that when they leave they could photograph the target.

The sensors on fundus cameras vary in spectral sensitivity and resolution. Vendors do not allow users to have access to the RAW data. Using a camera that provides linear data would be easier to do corrections and rendering. The Gretag MacBeth color checker is widely used but may not optimally represent the colors of the retina, and it might be better to use a target that has a larger gamut for this application.

RAW processing may solve questions of changing camera parameters. Recalibration for every patient should not be necessary. It was suggested that an image setter be used. The issue of how small a target size is needed will determine what to use in finding representative colors that provide usable data. A shading correction is also needed due to the curvature of the eye.

Do we want to focus on the variation in hardware or test all viewing angles to see where the changes occur?

The three main angles are: narrow (20 °), middle (30°-45°), and wide (50°-60°). In clinical practice it is relatively rare to use a higher magnification. The most typical clinical practice is to photograph at either the middle or wide angle. Issue is related to how small a color checker target can be made. It was suggested for research purposes to use a color spectral source instead of a ColorChecker. This would have to occur at the manufacturer level where the source in the fundus camera be changed. Exposure, illumination and working distance to the patient are the parameters for working in clinical practice. There is no post-processing that takes place.

It was suggested that we use more than one color patch, moving away from the color checker and develop a customized target. From the calibration standpoint, the manufacture may build the camera into a locked setting where the calibration is fixed at a certain point. The working distance could be standardized, then swap out the color patches and calibrate against a wider spectrum of colors. In an effort to create

consistency a more detailed level of user specificity is needed. The number of colors must be determined as well as the level of complexity in adopting as a technique.

It was agreed that precision is more important than accuracy; meaning that if patches are well chosen it is possible to get very good reproducibility. After discussion it was agreed that 20 would be an optimum number of colors.

It was suggested that representative pathologies be included and refined as we move forward; also modification of the model eye to lower magnification lens.

It was suggested that matte black be kept for the inside of the model eye rather than trying to recreate a retinal background.
The next phase of work in this group includes modification of the color patches and model eye if needed, extension of camera testing at multiple sites, implementation of software strategies and to provide a final feasibility report.

The meeting closed at 15:00.

Next meeting: the regularly scheduled MIWG meeting August 21.

Action items:

MIWG-14-36: Sisson/Farnand to define colors that should be included in target (limit 20)

MIWG -14-37: Vander Haeghen to provide his dermatological color chart as an example

MIWG -14-38: Sisson to modify protocol to standardize field of view, illumination and modify model eye to a lower magnification

Color Eye Model Progress and Discussion

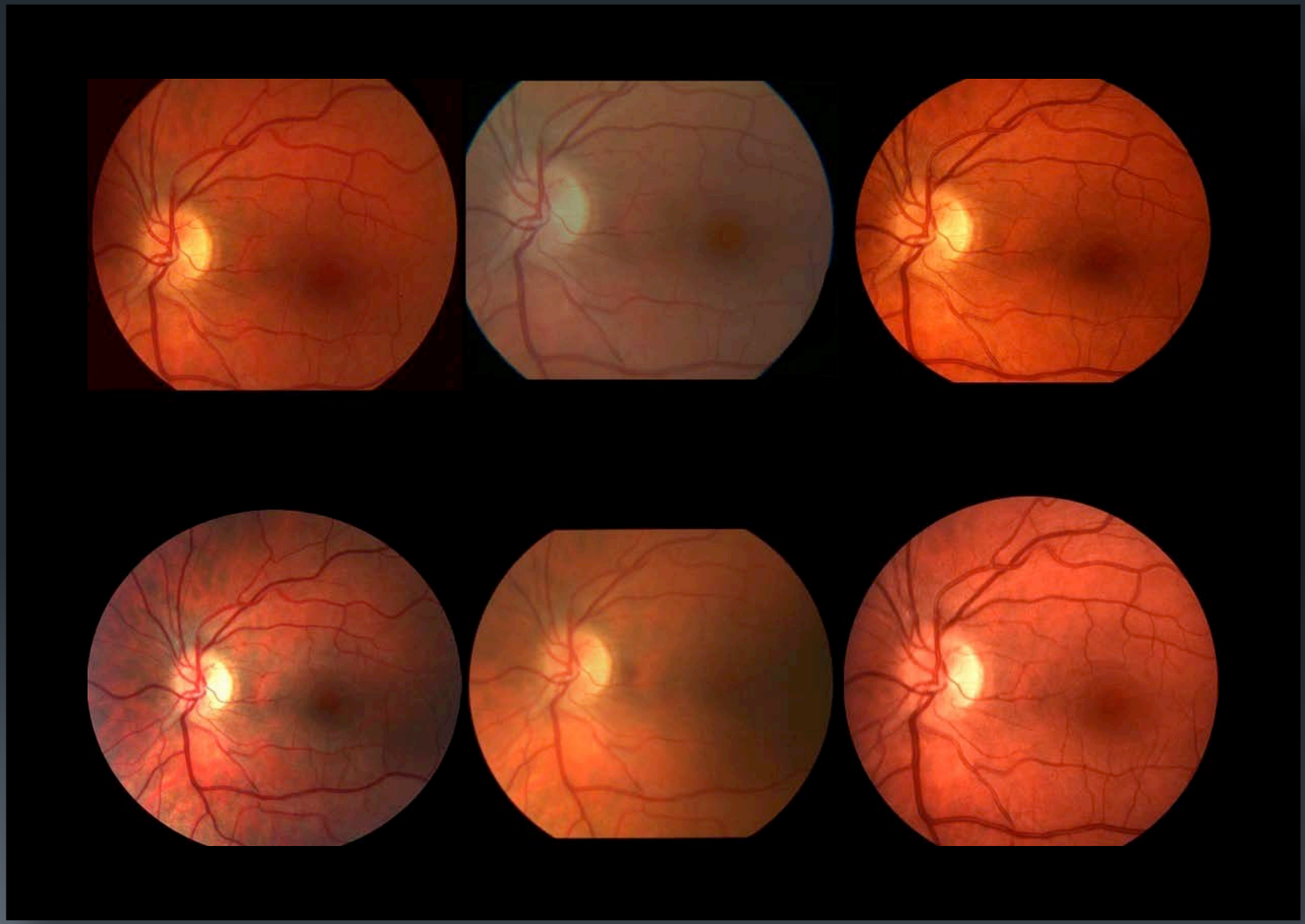
Christye P. Sisson, CRA, MS

Associate Professor

Ronald and Mabel Francis Endowed Chair, Program Chair: Photographic Sciences

School of Photographic Arts and Sciences

Image Variables



Imaging Procedure

- Iris dilated pharmaceutically
- Once dilated, patient aligned in fundus camera headrest
- Photographer adjusts working distance for optimal illumination, focus
- Photograph taken using flash

Image courtesy of National Eye Institute: http://www.stylewiz.com/mnr/nei/photo-gallery.php

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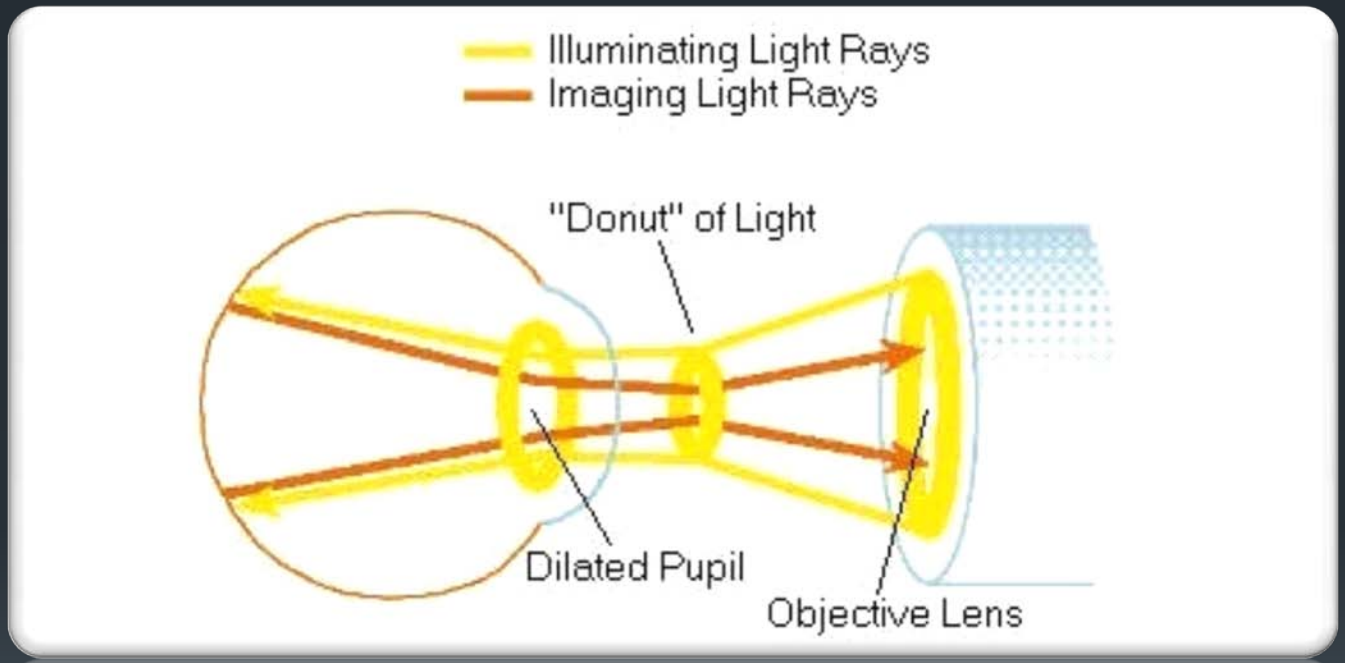
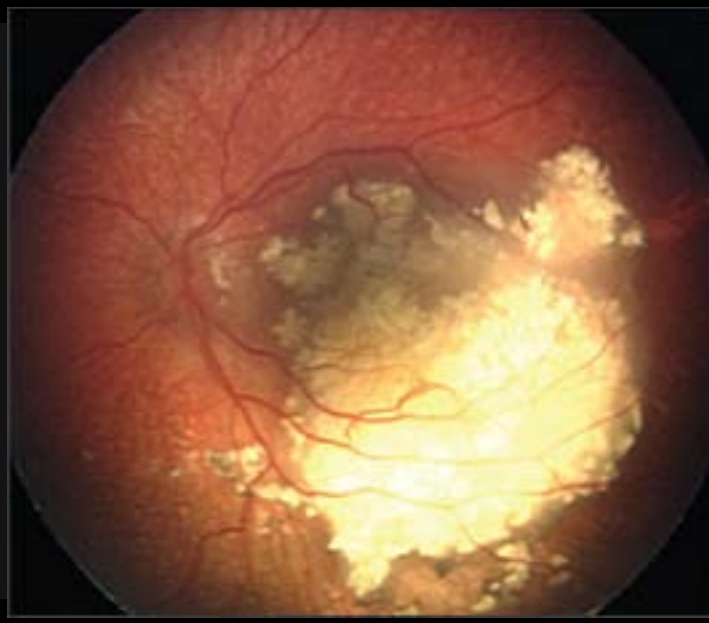
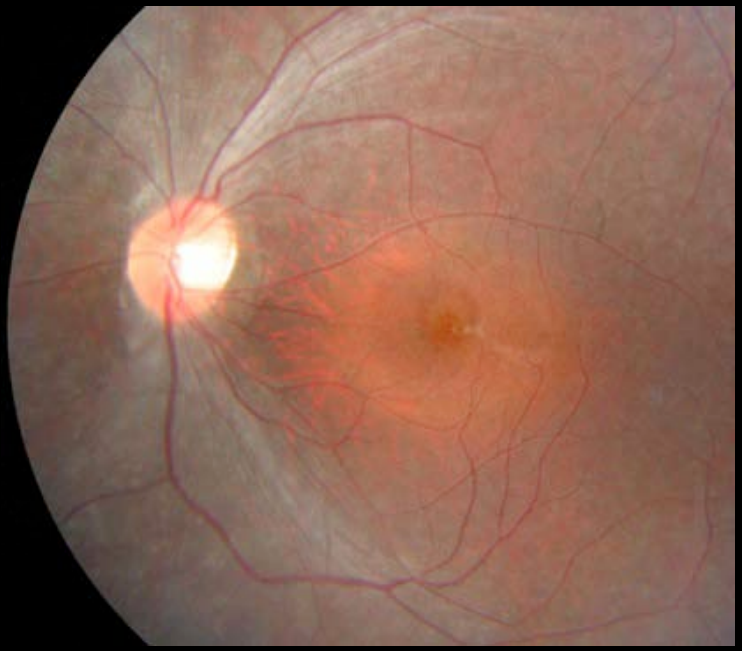
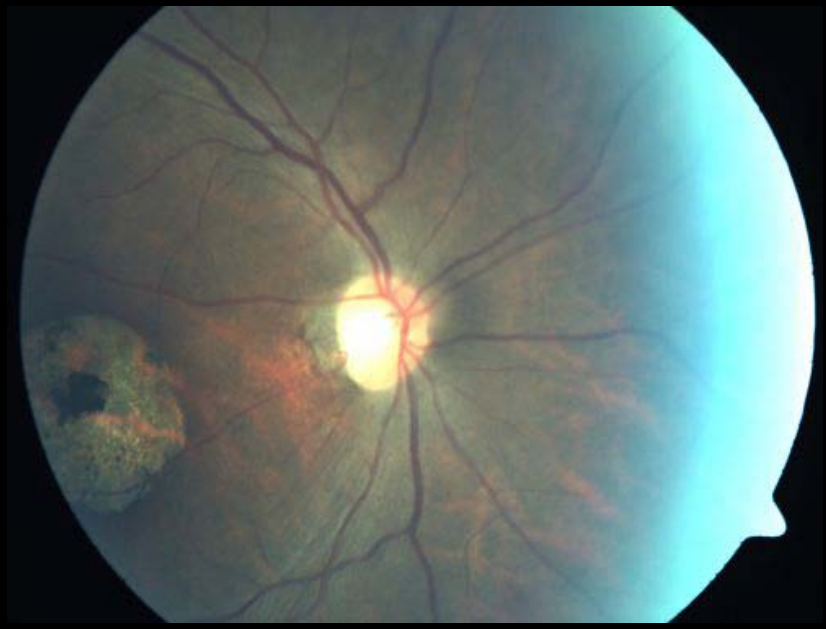
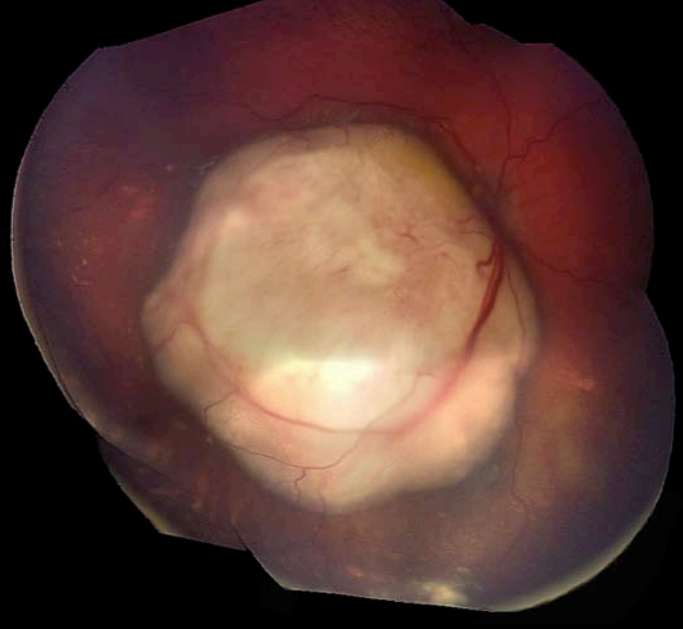
Eye as other half of optical system

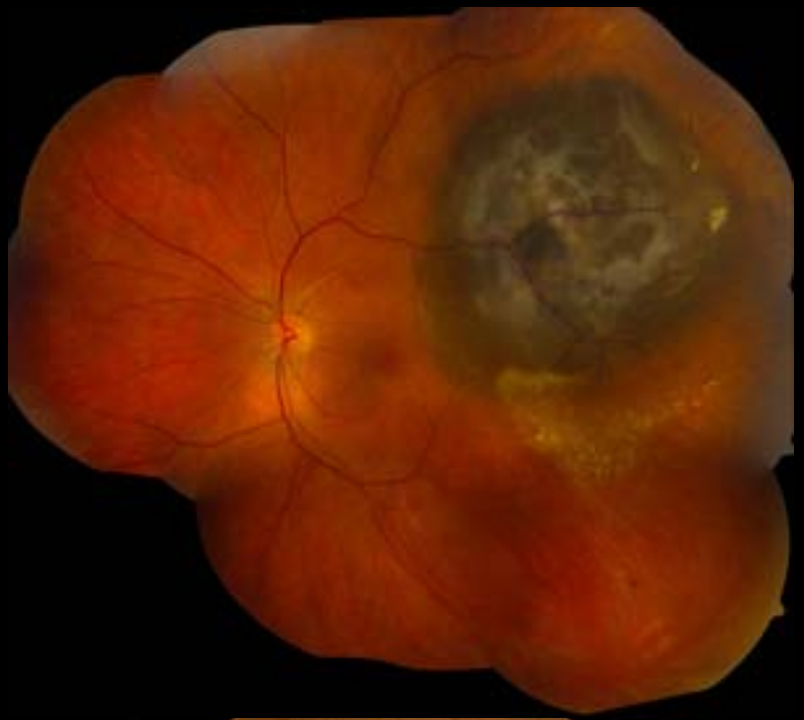


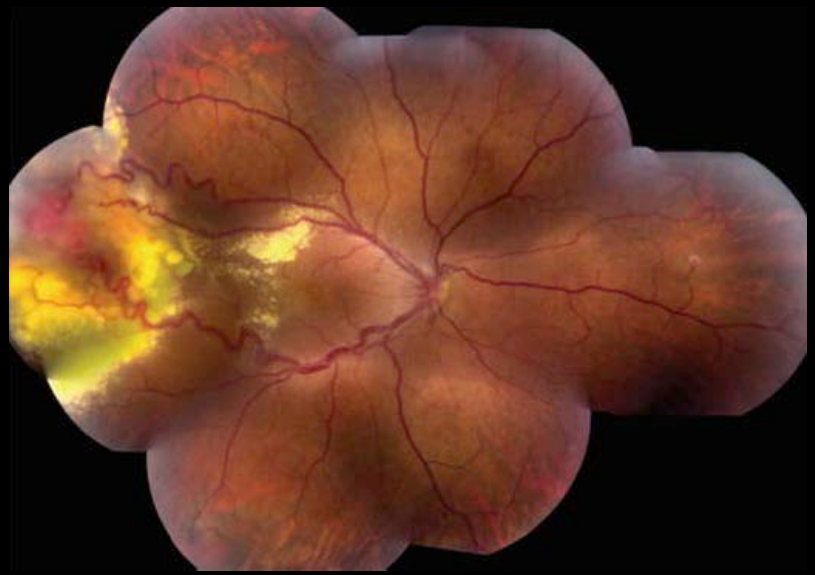
Ophthalmic Photography: Retinal Photography, Angiography, and Electronic Imaging, 2nd Edition Patrick J. Saine and Marshall

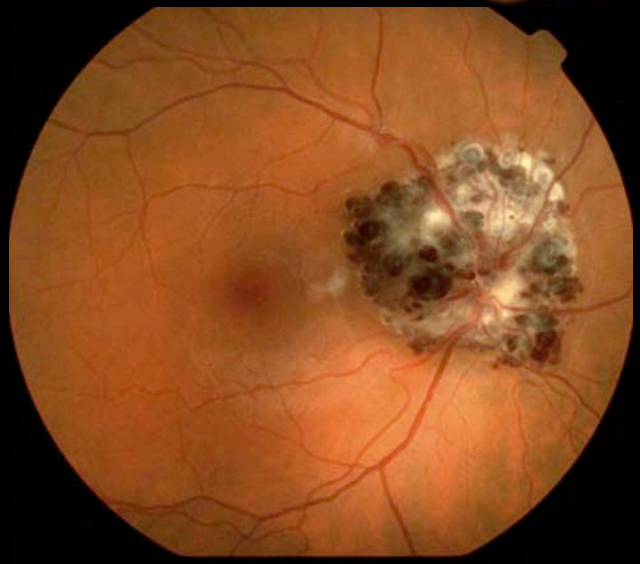


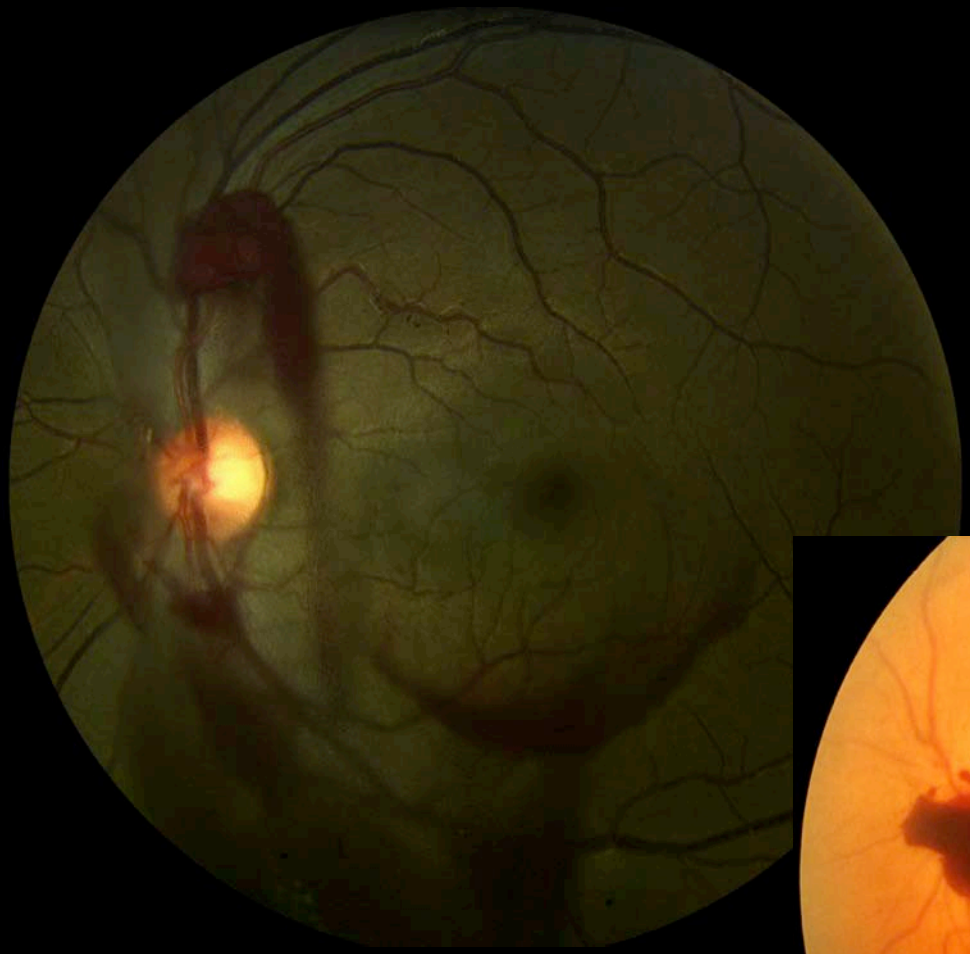




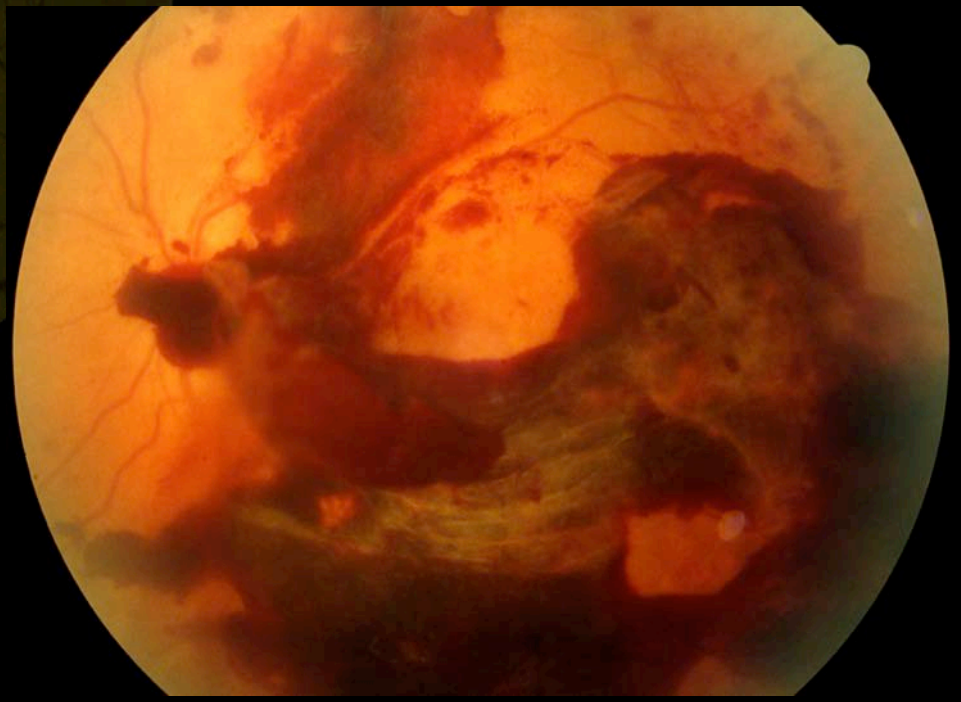


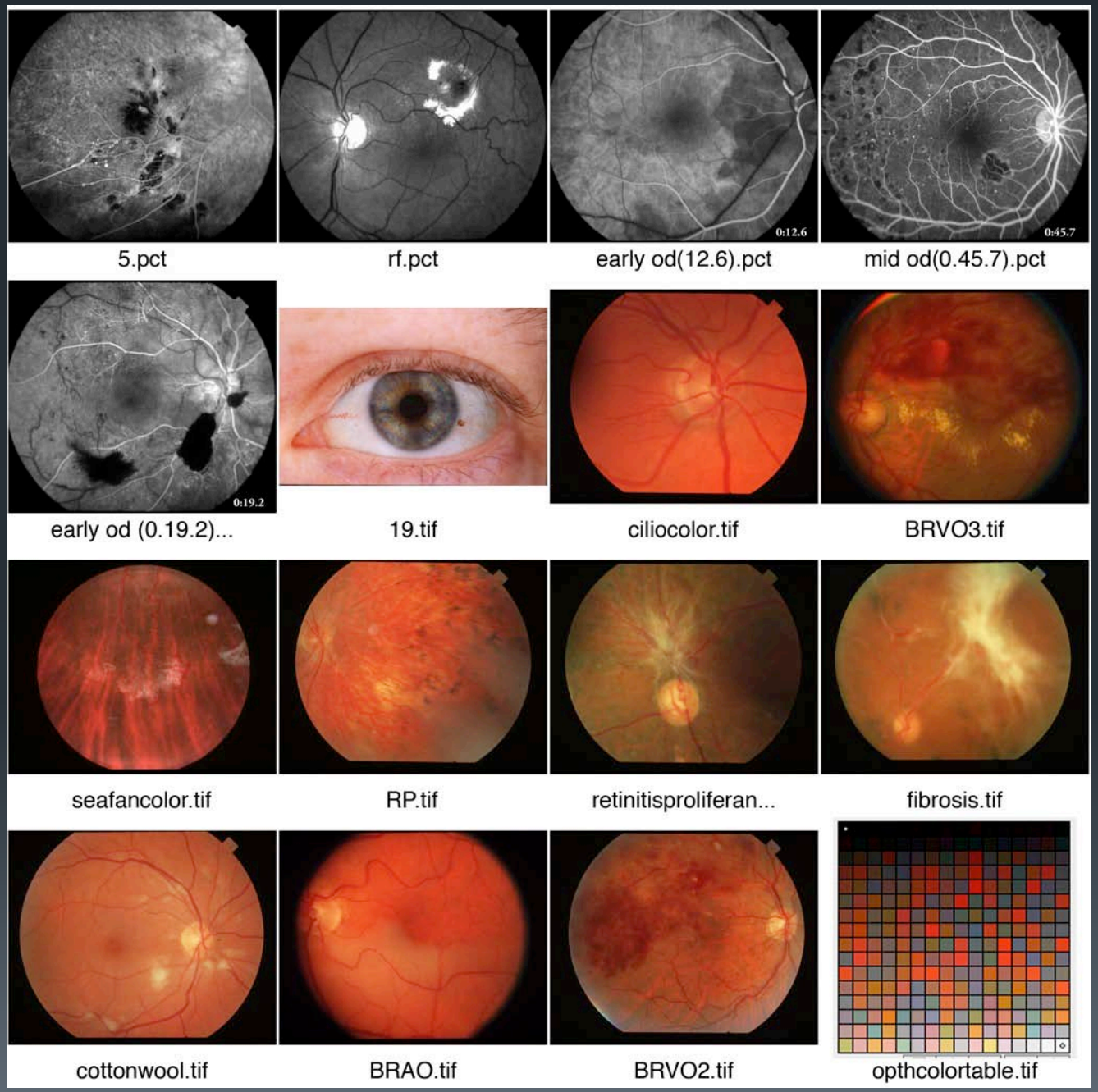








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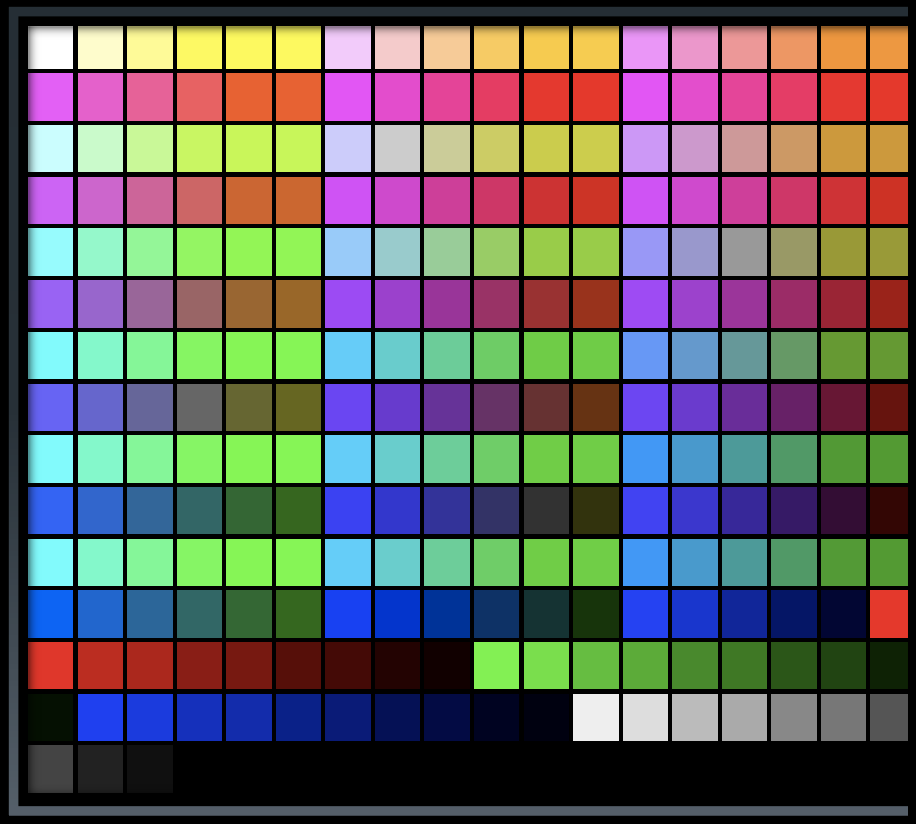
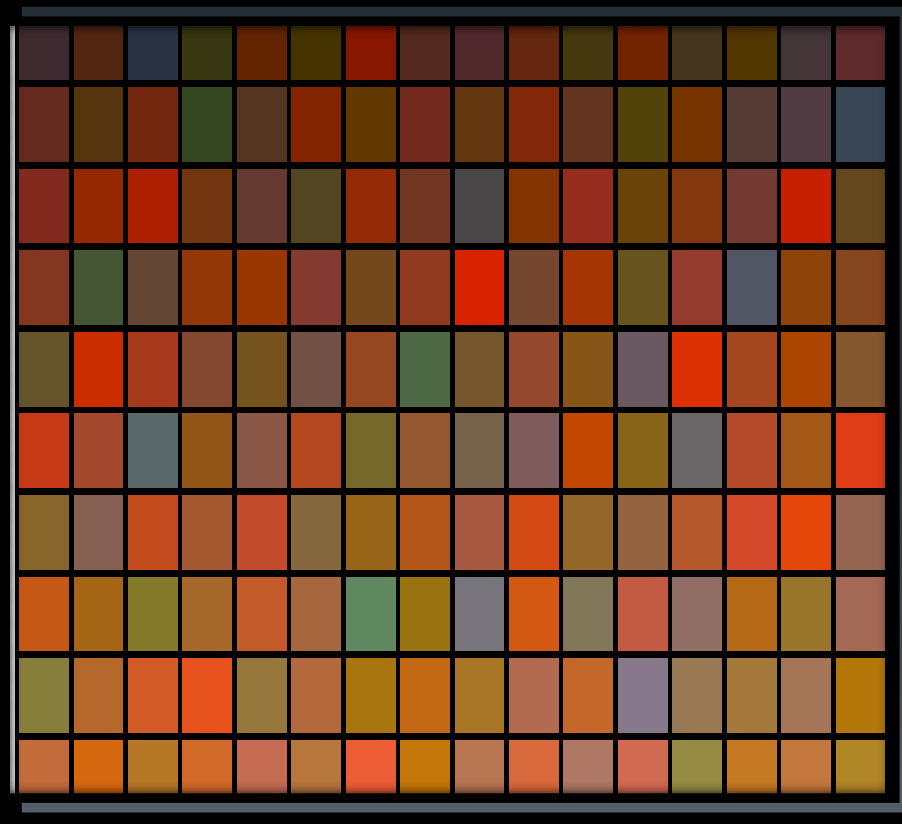
seafancolor.tif
RP.tif
retinitisproliferan...
fibrosis.tif
cottonwool.tif
BRAO.tif
BRVO2.tif
opthcolortable.tif

CCD Color: Normal subject vs. retinal subject

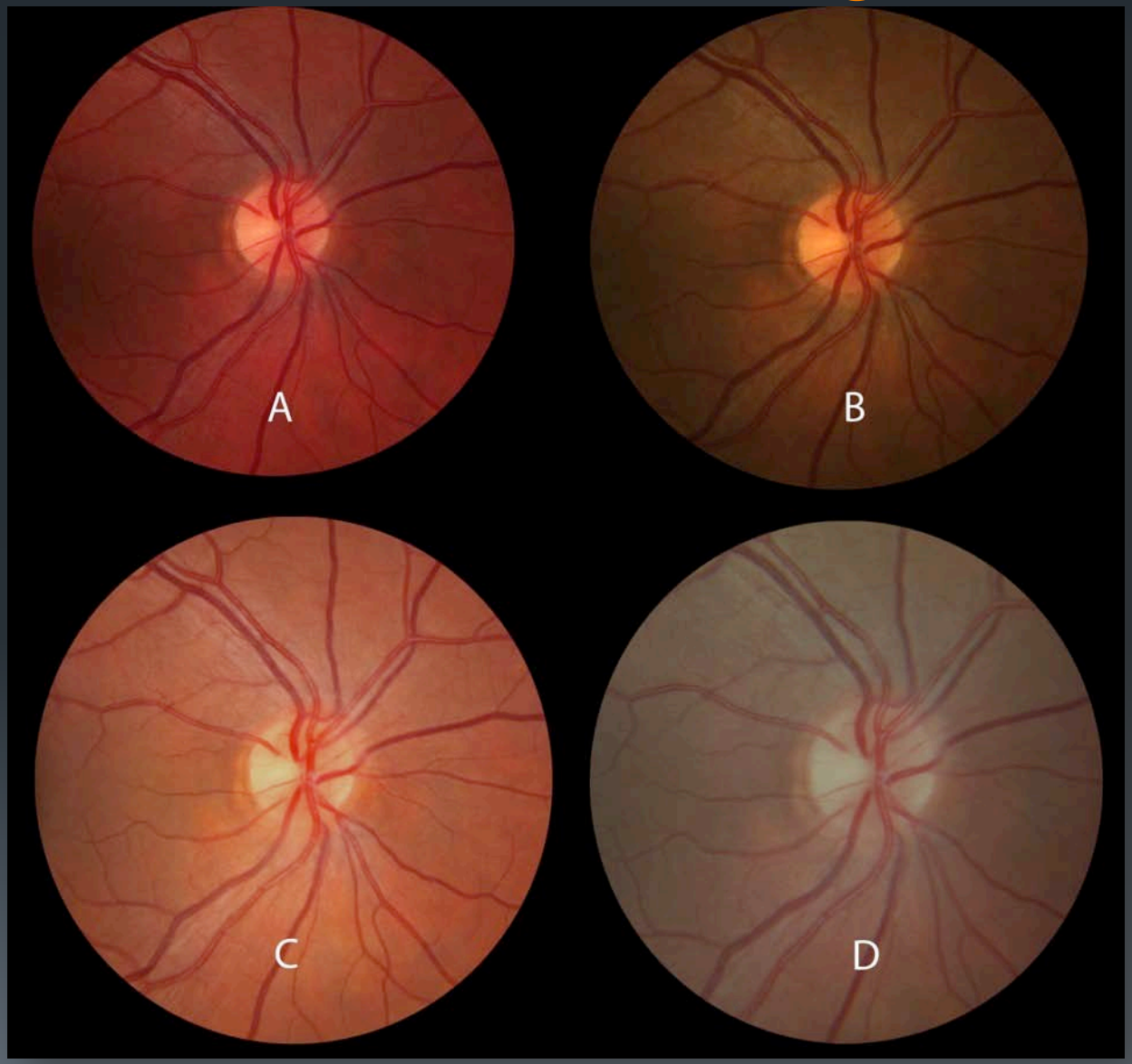
Standard colors



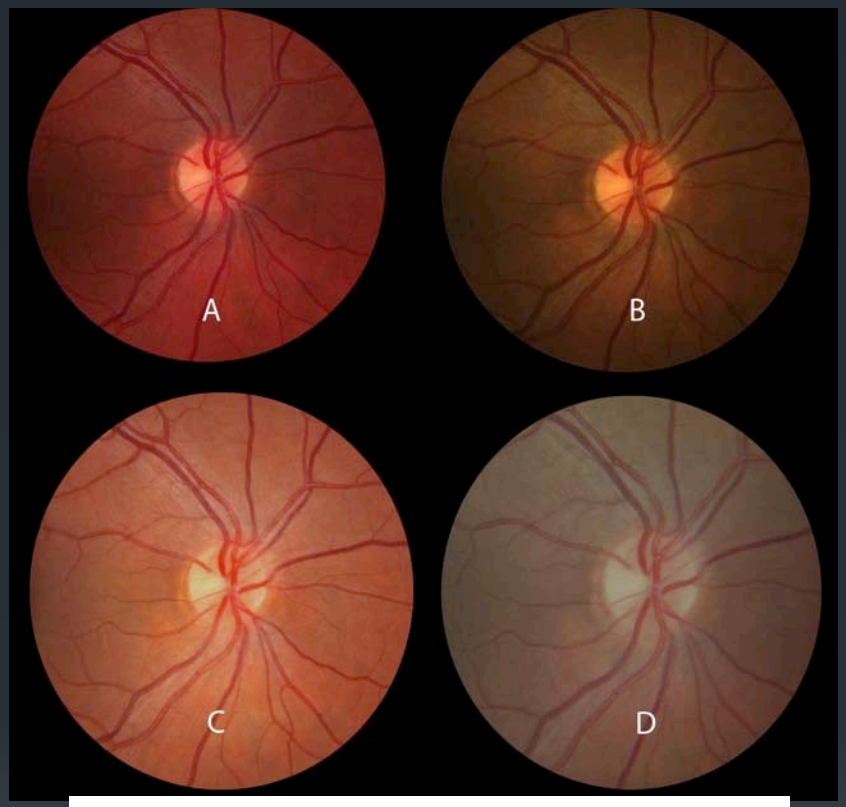
Retinal colors



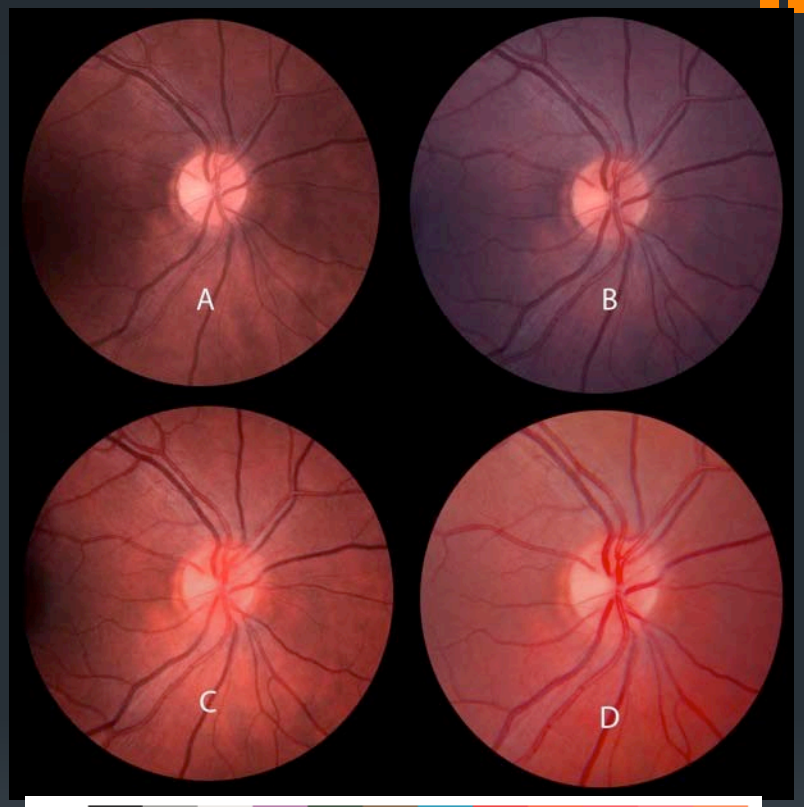
Camera Testing: Phase I

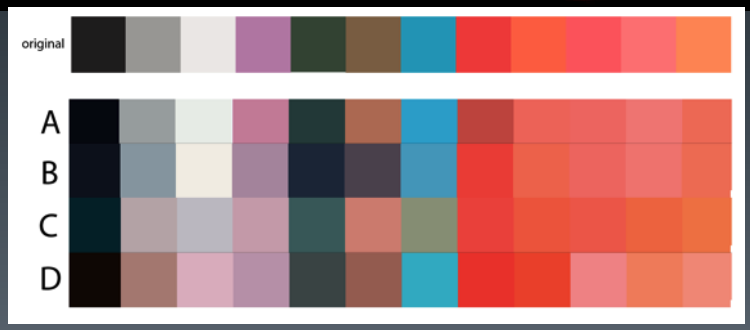


Captured vs. Processed



Before





After

Phase I: Conclusions

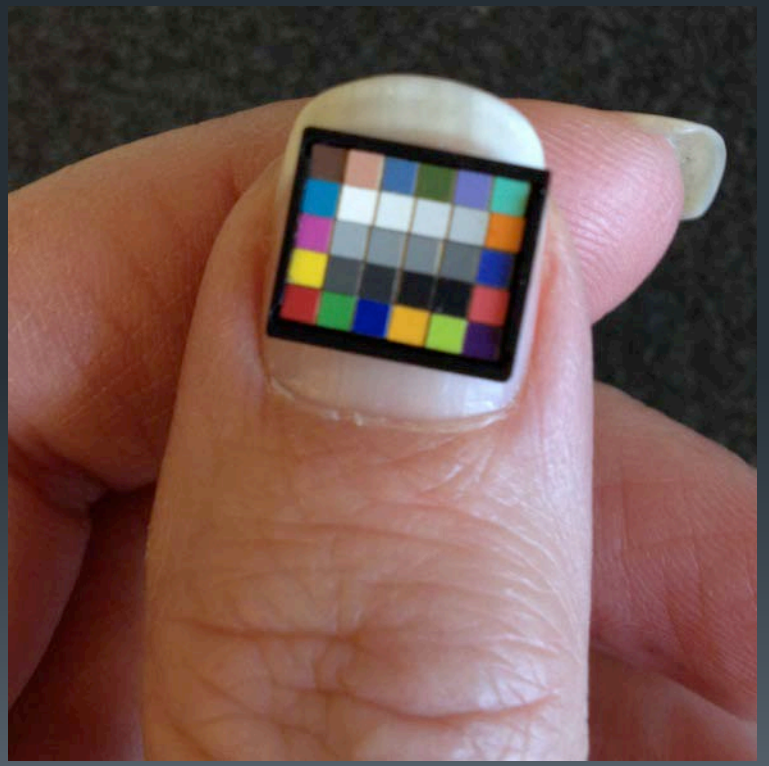
- It is potentially possible to profile a fundus camera, at least individually
  - Applying to RAW image in system would be ideal
- *What we as ophthalmic imagers and practitioners believe to be “correct” retinal color is not correct at all*
- A standard approach to color calibration is needed to mitigate input variables

Color Model Eye Project (MIWG) : Phase II

- Determine minimum color patch size
- Refine testing materials
  - Use of a standard color checker
  - Use of a aspherical model eye
- Determine and refine imaging protocol
- Analyze results on TIFF vs RAW

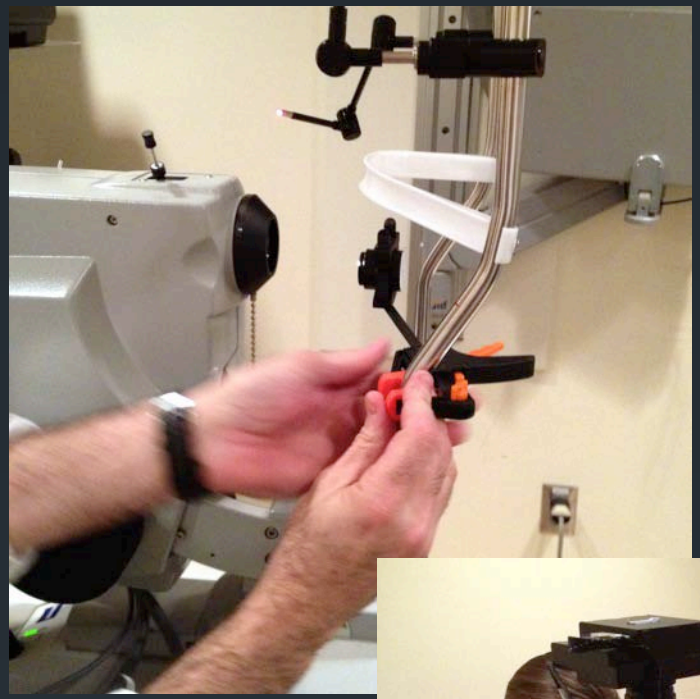
A Better Target (A really, really, really tiny Color Checker)

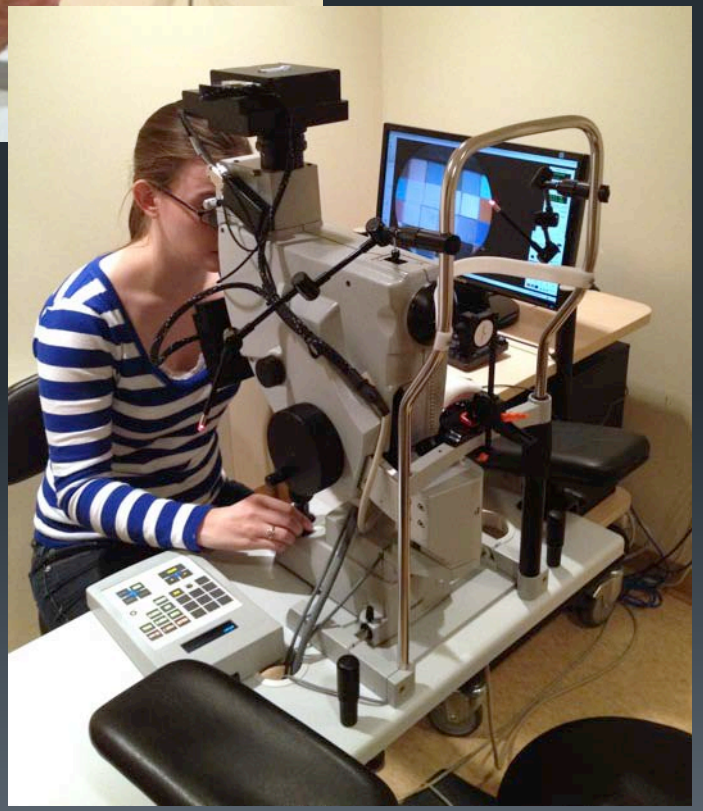
- Identical color patches to GretagMacbeth™ ColorChecker®, 1/12th original size
- Pigmented, painted samples
- Flat field

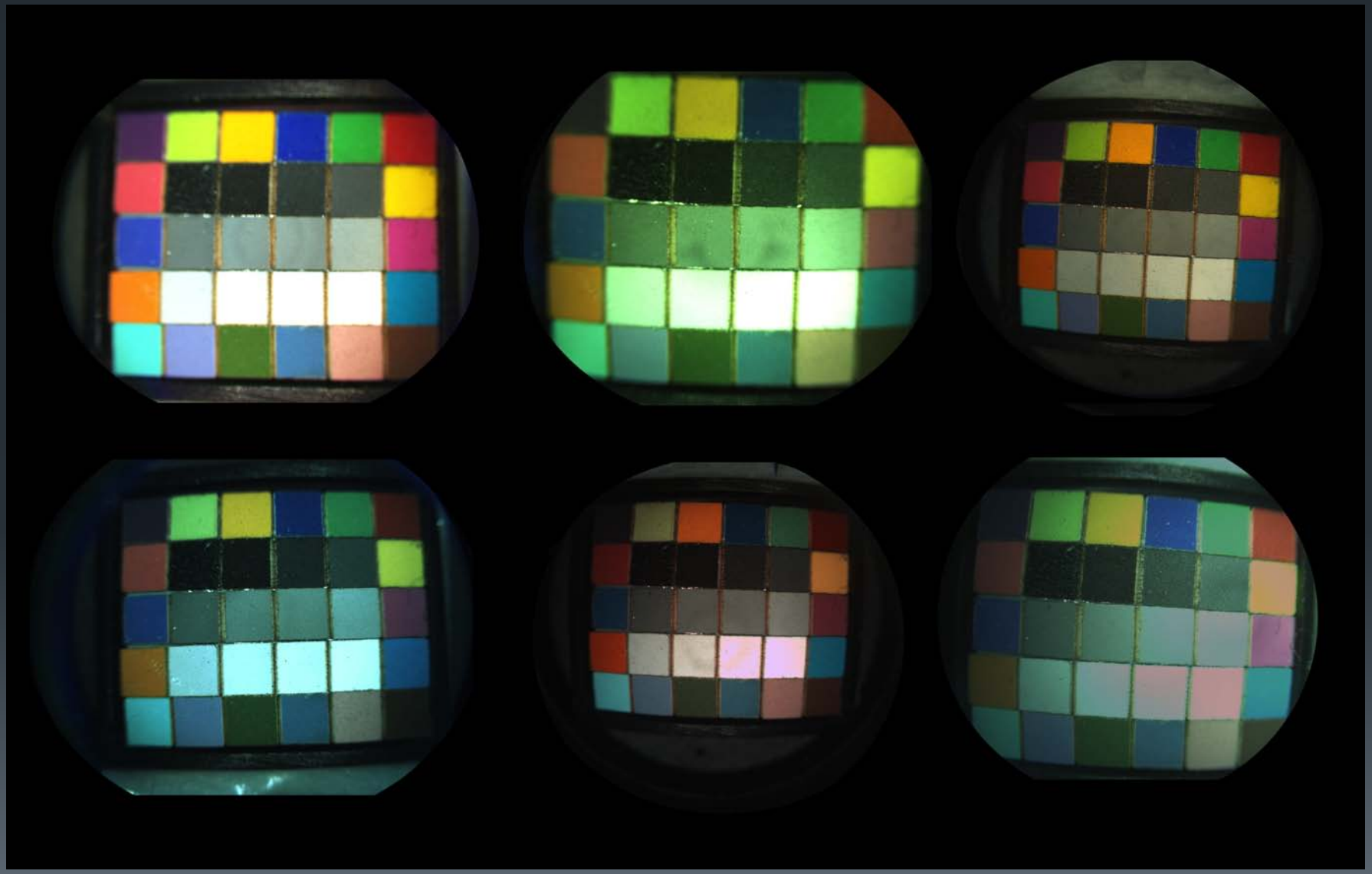


Protocol

- Inserted test target into model eye
- Chose “middle” angle of view
- Established proper alignment/working distance/focus
- Reduced/eliminate viewing illumination
- Captured at “normal” exposure, +/-







Findings and Discussion

- Illumination/exposure ratio issue
- What impact does field of view have? Flat field?
- Colors of target?
- Color of the inside of model eye?
- RAW vs. exported TIFF?
- Implementation?

Illumination/Flash Exposure

- Illumination influences final flash exposure depending on brightness of illumination and flash setting (watt-seconds)
- These variables cannot be standardized, so:
  - Do we include illumination as it exists on average in patient photography OR
  - Do we eliminate illumination as a variable for the purposes of testing

Impact of flat field/angle of view

- Concern on chromatic aberration with field of view lens changes
  - How to determine standard angle of view (clinical vs. testing)
  - Do all the viewing angles need to be tested?
- Concern on flat target
  - Does it need to be curved?

Phase III…

- Modify color patches, model eye if needed
- Extended camera testing at multiple sites
- Software implementation strategies
- Final feasibility report
  - Manufacturer vs. user implementation

Thanks to:

Color Model Eye Group Members

- Bill Fischer *Flaum Eye Institute, University of Rochester Medical Center*
- Jim Strong *Penn State Hershey Eye Center*
- Tim Bennett *Penn State Hershey Eye Center*
- Mark Fairchild *Munsell Color Science Laboratory, Rochester Institute of Technology*
- Susan Farnand *Munsell Color Science Laboratory, Rochester Institute of Technology*
- Matt Carnavale *Sonomed/Escalon*
- Kevin Langton *Carl Zeiss Meditec*
- Rich Amador *Canon*
- Dennis Thayer
- And Katelyn Donovan *RIT Photographic Sciences '14*

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