
ORIGINAL ARTICLE



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An Affordable Alternative to the High Cost of Digital Fundus Photography

Abstract

Purpose: Digital ophthalmic photography is a desired method of providing instant diagnostic images. However, the "rush" to digital imaging has been delayed in many offices by the high cost of equipment, computers and software necessary to create these images. Although many offices see the advantages of such systems, funding is difficult to obtain when the existing film based systems continue to function adequately.

Methods: This paper describes the purpose, testing, construction and use of the Nikon D-1x digital camera on the Zeiss FF-3, FF-4 and Topcon 50EX fundus cameras. This use of "off the shelf" digital equipment, programs and computers allows virtually any office the opportunity to enter ophthalmic digital imaging with a minimum of investment. Either Macintosh or Windows computer operating systems with Firewire support may be used. Nikon and the manufacturer of the computer system provide service and support. Saved image files (JPEG) are a moderate size making the average angiographic study file size 10MB or less. Images may be archived in a wide selection of file formats, with or without compression.

Results: The photographic images from this self-constructed digital fundus system are more than acceptable for diagnostic fundus photography. The quality of color images and the angiographic studies are excellent. Angiographic results used for diagnosis and treatment are available to the physician within minutes following the conclusion of the study. Images are stored both on compact disk in the patient's chart and

on a central server. Our department will achieve the level of 80% patient digital imaging with the minimum of capital equipment cost.

Conclusions: This home built digital system for the Zeiss FF-3, FF-4 or Topcon 50EX fundus cameras is easy to construct and operate by the average ophthalmic photographer while offering a 90% savings over film based system processing/supply cost per patient. Image quality is acceptable for patient diagnosis and treatment. The time interval from completion of imaging to presenting viewable images to the requesting physician is minimal. Photographic time required per patient remains about the same as with film based systems. Photofinishing time per patient is greatly reduced for this digital imaging system when compared to film systems. The greatest limitation of this system is the loss of a timer for angiographic studies when files are saved in a format other than the Nikon .NEF (Nikon Electronic Image Format) file format. This limitation may be corrected through the use of a third party application.

DIGITAL CAMERA, COMPUTER AND PROGRAMS

Following the introduction of the professional digital camera, ophthalmic photographers have sought a way to combine their fundus camera with an easily replaceable, easy to use digital camera with simple programs. The advent of less expensive computers, CDR (Compact Disk Recording) capabilities, large charge couple device (CCD) chip technology, and recently, the advent of "Firewire" technology, has made the construction of a home built digital imaging system a reality. Now, an ophthalmic photographer may view and edit digital images as they are acquired in color or black and



Figure 1: Portable digital system elements.

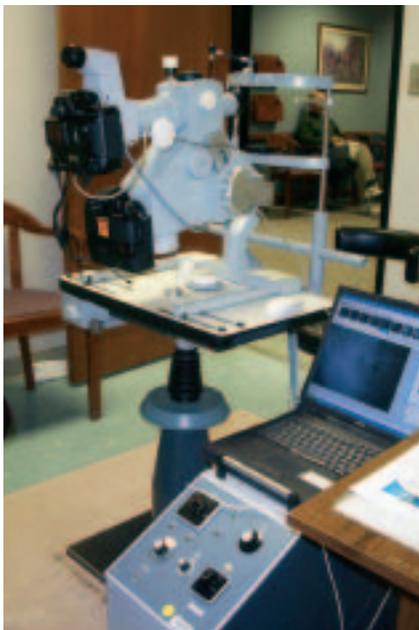


Figure 2: Portable digital system in use.

white, perform fluorescein angiography, and create a compact disc (CD) with the patient's images almost immediately following the angiographic study. In large institutions such as the University of Virginia, medical education is a co-primary mission to the treatment of ophthalmic patients.

Residents may now discuss a

patient's interesting finding around a viewing station and actually point to areas of interest on the screen. Future patients, as well as current ones, benefit from this interaction among the residents and attending physicians.

TIME AND COST

Although the savings in darkroom and processing time provides an immediate "saving" for the patient and physician, the real savings occur when one considers the cost of film and development. At the University of Virginia, the average cost of film, chemistry, outside processing and plastic storage sheets approaches \$10.00 per patient. This cost per patient is based upon the annual cost of photographic supplies, chemistry, outside (color) processing and plastic slide/negative pages divided by the number of patients photographed annually. Utilizing digital photography, the cost per patient for materials (CDR, CD label and plastic storage sheet) is reduced to less than \$1.35 per patient. This supply cost is reduced fur-

ther when a patient returns for a repeat study as the previous CD and filing materials are reused for subsequent studies. The additional study is added to the existing patient CD for a cost of less than \$0.07, or the cost of the photography request sheet. Regardless of the size of patient load, an 86.5-99% per patient saving in materials alone is significant reason to consider use of this digital system for your patient photography. Within our practice, the cost of this equipment is less than \$0.46 per patient, if used over a three year period. With our 5,000+ annual photographic patient volume, the cost of this digital system is recovered in 90 days.

COMMERCIAL VS. HOME BUILT SYSTEMS

There are a number of excellent digital systems available on the market. These systems offer excellent results, image handling software, patient management databases, and peer-to-peer connectivity or central server file access. This level of digital acquisition and management comes at a price but may be exactly what your office requires for "turn key" installation. We would be pleased to have any one of these fine systems in our photography suite. However, with four ophthalmic photography locations to convert to digital photography, we just can't afford to make the large capital investment required while film based systems continue to function adequately. A low cost system that offered portability with "off the shelf" image processing technology was also preferred.

SYSTEM COST

Low total cost makes constructing this system so inviting. The assembly cost is minimal and replacement parts are readily available. The heart of the system is a Nikon D-1x, 5.3 megapixel digital camera (www.nikonusa.com). This is supplemented with the Nikon Capture software, Firewire connection to the computer which may be a laptop, in a portable application (Figures 1 and 2), or desktop in others (Figure 3). The cost for system con-



Figure 3: "Base" system with desktop computer.



Figure 4: Nikon digital camera on Topcon 50EX fundus camera.

struction at publication of this article is USD \$7,000 for the Zeiss FF-3, FF-4 fundus cameras. The overall cost is \$4,000 higher for the connection to the Topcon 50X and Topcon 50EX cameras because of the addition of the Topcon F-mount video adapter and 2x accessory lens (Figure 4).

ZEISS TESTING

The Zeiss FF-3 and FF-4 fundus cameras utilize a solenoid head to remove the viewing mirror from the optical path during the photography sequence. There is a switch at the upper limit of travel for the mirror. This switch closes a circuit, triggering the motor drive on the camera body to fire the camera and activate the flash. The switch circuit may be easily identified as it carries no current and only has a momentary connection of continuity. This switch circuit is identified as Pins #3 and #4 of the Male eight-pin plug that plugs into the fundus camera solenoid head. It is important to determine that this is the correct circuit for your fundus camera prior to attaching an electronic digital camera. Use a multi-tester while tripping the footswitch (fundus camera power on) and testing for this "trigger" circuit. Remember, as it will only pass continuity when the solenoid mirror reaches the top of its travel, there will be NO current on this pair of pins. Test your system before you go to the next step.

PARTS REQUIRED FOR ZEISS CONNECTION

The parts list is simple:

Nikon:

- Nikon D-1x Camera
- Nikon Adapter Cord MC-25
- Nikon Capture Program version 2.0

Zeiss:

- Zeiss/Nikon Dovetail Mount (obsolete, if possible use an old or spare one)
- Zeiss FF-4/Nikon Cord # 30-13-63-0000 (these cost \$535USD, use an old broken one you have)

Computer Store:

- Laptop of at least 800 MHz processor speed (a desktop computer may be used if portability is not an issue)
- PCMCIA Firewire card or IEEE direct connection to laptop or desktop

CONSTRUCTION OF THE ZEISS/NIKON D-1 CONNECTION CORD

This is the part that is so easy. A wiring diagram is included below to make construction even easier (Figure 5).

1. Cut the flash wire and small connector wire off of the Zeiss cord near the solenoid head plug.
2. Cut the trigger plug (the big one) off near where it connects to the Nikon F-3 camera. You now have one cord left with two wires in it, a blue one and a white one. Check these wires with your multi-tester, they should connect to pins #3 and #4 of the solenoid head plug.
3. Open the box on the end of the Nikon MC-25 cord (Figure 6). There are two small circuit boards. Locate the connections on the top board (small one) that relate to the two pins on the outside box connection. Solder the white and blue wires from the Zeiss cord to these connections.
4. Make a notch on the side of the box for the wire to pass through. Reassemble the box and tape the project.

ZEISS EYEPIECE SETTING AND DOVETAIL MOUNT

Since the Nikon F-3 camera body was replaced with another Nikon camera body, the eyepiece setting should have been the same. That is not the case when the Nikon D-1x digital camera body is used. The user must add +2.50 diopter correction to your standard (film based) eyepiece setting. The reason for this change is that the Nikon D-1x body is approximately 0.25 inch thicker from the lens mount to the film plane. If your personal correction will not allow for this ocular adjustment, this

home built system may NOT be for you. What is the best way to set your eyepiece correction? One method is to tape a dollar bill target in front of the fundus camera. Add +2.50 to your current correction, take a test image, then advance or withdraw the focus knob while taking images until

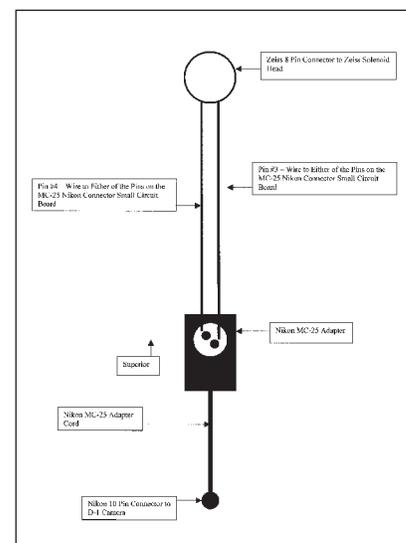


Figure 5: Zeiss adapter cord wiring diagram.



Figure 5: Opened box on Nikon MC-25 cord.



Figure 7: Cardboard washer in dovetail mount.

best sharpness is obtained. Without moving the focus knob, focus the eyepiece image until the dollar bill target is sharp for you. Mark or record your new "digital" eyepiece setting.

The pentaprism on the Nikon D-1 camera is slightly larger (anterior) than that of the Nikon F-3 camera. The Nikon D-1x camera touches the Zeiss solenoid viewing head. This can slightly cant the camera (back superiorly) and prevent proper fit of the camera to the solenoid head. This "touch" is eliminated by cutting a washer out of a thin piece of cardboard that is packaged with Angiolith film. This washer was inserted between the solenoid head and spring side of the dovetail mount (Figure 7). This small adjustment appears to have had little or no effect on the established film based eyepiece setting.

SAFETY FIRST

Considering the repair/replacement cost and availability of the Nikon D-1x camera body, we added a safety strap to the camera that, in turn, is looped over the astigmatism control of the Zeiss fundus camera. We have repaired two Nikon F-3 camera bodies that have suffered the same common fate of the Zeiss dovetail connection failure (operator or spring failure induced). This is a prudent precaution to take in order to avoid future equipment breakage and system downtime.



Figure 5: Nikon Capture program.

USE OF ZEISS/NIKON D-1 DIGITAL SYSTEM

We use both laptop and desktop computers with Firewire connections and the Zeiss/Nikon digital connection. The Firewire connection allows images to be seen on the computer screen as they are acquired by using the Nikon Capture program (Figure 8). Using the Firewire cable, you will also have full access to the Nikon D-1 digital camera controls through the computer. Set digital camera to Manual, 500th sec, set storage to TIFF-RGB (8-bit), Medium image (2000 x 1312), match the ISO to the film you were using (or lowest ISO setting which is 125) and click away. We save images as JPEG "Good Balance" images. The resulting saved JPEG files are about 600K to 1,000K in size for each image. The "Large" image format (3008 x 1960) may be used. This will increase the size of the saved JPEG image file.

Frequently, we find that the color images are a bit light for our preference. This is because we cannot match the film ISO of 100 with the Nikon D-1x digital camera. The color images are adjusted by reducing the brightness of each image by 20 with the Nikon Capture program. This makes an accurate rendition of the view as seen through the eyepiece.

ZEISS ANGIOGRAPHY

There are very few alterations that need to be made to your standard film-based photography plan for digital angiographic studies. We prefer to begin with color photography on the non-transit (fellow) eye, then photograph the transit eye. When color photography is completed on both eyes, the camera settings are changed through the computer to ISO 800 black and white. The barrier filter is inserted into the dovetail mount of the Nikon D-1 digital camera and we prepare for fluorescein injection. Positioning is now in front of the correct eye for fluorescein transit.

Although it may take a few seconds for the large images to appear on the computer screen, the thumbnail images appear almost immediately. If you suspend pho-

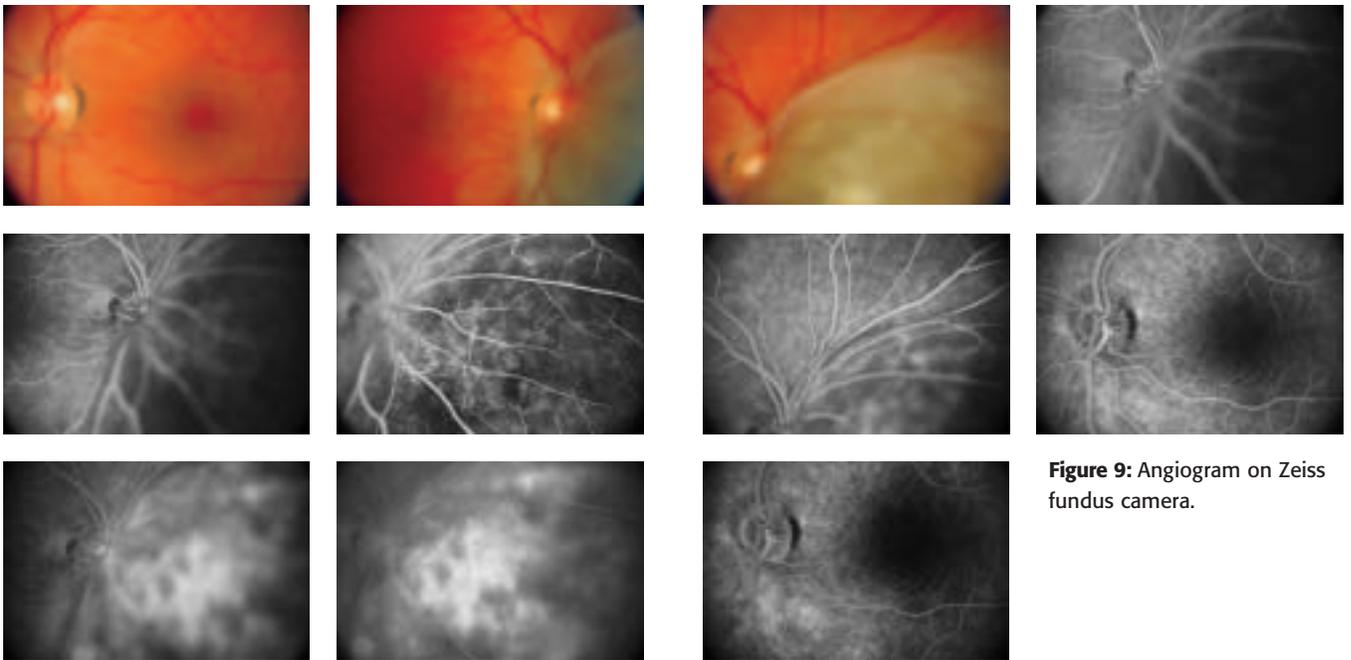


Figure 9: Angiogram on Zeiss fundus camera.

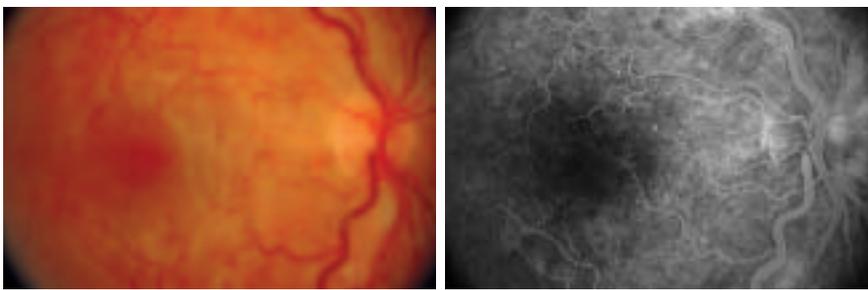


Figure 10: 1.4x Magnification of Zeiss image.

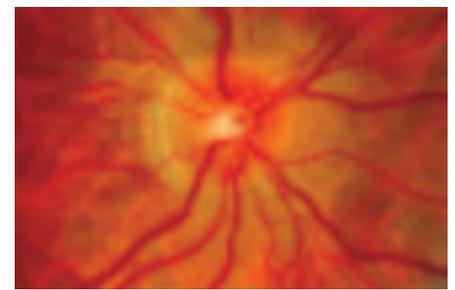


Figure 11: 2.24x Magnification with 1.6x extender

tography for a few seconds, the last image acquired appears on the screen as a large image. Our physicians have been very pleased with the quality of the images obtained (Figure 9).

We continue to photograph the patient's name tag prior to photography and photograph a tag that says "LATES" prior to the late shots to avoid confusion with the mid-phase photographs.

IMAGE MAGNIFICATION

Nikon and other manufacturers utilize a photo sensor that is slightly smaller than a standard 35mm frame resulting in a magnification or "cropping" of the image. Images appear to be 1.4x magnified over film based systems (Figure 10). Some physicians find this magnification objectionable, others do not. Physicians at our facility are divided over this issue.

With film, a Zeiss 2x extender is used to record optic nerve pictures. The use of this adapter results in a 2.8x magnification of the digital image. That magnification is too great for good imaging of the optic nerve. The alternative was to use the Zeiss 1.6x extender (30-16-68) instead of the 2x extender. The resulting magnification is



Figure 12: Topcon 50EX connection for digital cable.

2.24x and provides impressive images of the optic nerve head (Figure 11). The availability of the 1.6x extender through Zeiss is unknown, as many parts for the Zeiss FF-3 and FF-4 fundus cameras are now discontinued.

TOPCON 50EX TESTING

The Topcon 50EX fundus camera is more difficult for the consumer to test, but information and experience has shown that the nine pin "D" connector on the base of the camera (Figure 12) contains the following pin sequence

required to perform photography with the Nikon D-1x digital camera; Pin #1 = Flash, Pin #2 = Flash Ground, Pin #7 = Trigger, Pin #4 = Trigger Ground. This same pin configuration is used for the Topcon 50X and Topcon 50IA fundus cameras. The Topcon 50X/50IA cameras requires a different relay lens (TL-111) than the one listed for the Topcon 50EX. Check with your Topcon supplier for availability of this attachment.

PARTS NEEDED

Topcon:

- Topcon TL 207 1x Relay Lens F Mount #27363 \$3,500

Any Photo Store:

- PC to PC Sync Cord \$17.85

Radio Shack:

- #2600116 6 foot 232 Cable DB-9 Male to DB-9 Male \$12.99

(Pin-out colors for this cable)

1=Black, 2=Brown, 4=Orange, 7=Blue

Nikon:

- Nikon D-1x Camera
- Nikon TC-201 Teleconverter (\$300USD)
- Nikon Adapter Cord MC-25
- Nikon Capture Program

Computer Store:

- Laptop of at least 800 MHz processor speed (a desktop computer may be used if portability is not an issue). PCMCIA Firewire card or IEEE 1394 direct connection to laptop or desktop computer.

ASSEMBLY OF THE TOPCON 50EX/NIKON D-1 CONNECTION CORD

Although a little bit more complicated than the Zeiss connection, it is still very easy to do (Figure 13).

1. Cut 6 foot DB-9 cord in half. Strip back insulation cover 6 inches.
2. Locate Pin #1,2,4,7 wires. Cut off remaining wires.
3. Strip back end of flash PC-PC cord (the one that does not go into camera connection). Use a soldering iron to tin the wire ends. Solder the positive one (center of PC connection) onto the Pin #1 wire and the ground

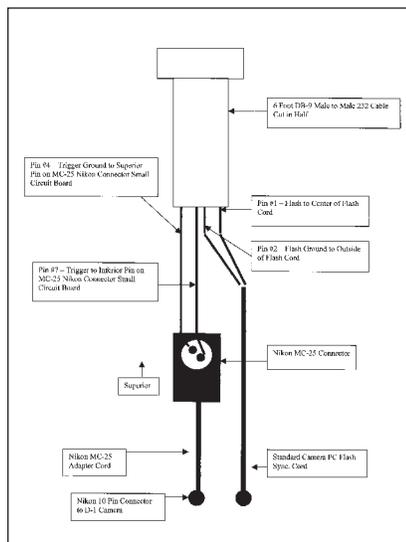


Figure 13: Topcon adapter cord wiring diagram.

one onto the Pin #2 wire of the 9 pin connector.

Tape your connections.

4. Open the box on the end of the Nikon MC-25 cord. There are two small circuit boards. Locate the connections on the top board (small one) that relate to the two pins on the outside box connection. Solder the wires that match Pins #4 and 7 to the two main pins. Polarity is an issue. Pin #4 wire must go to the SUPERIOR pin on the MC-25 adapter. Pin #7 wire must go to the INFERIOR pin on the MC-25 adapter.
5. Make a notch on the side of the box for the wire to pass through. Reassemble the box.
6. Tape the project wires as required.

2X TELECONVERTER

The Topcon TL 207 1x Relay Lens F Mount is really designed for video imaging to a chip that is smaller than the chip used in the Nikon D-1 camera. The resulting image, although good, is one-half the size required to fill the imaging chip of the Nikon D-1 camera. The addition of the Nikon TC-201 Teleconverter corrects this image size problem (Figure 14). However, there



Figure 14: Topcon Relay Lens with 2x Teleconverter, Nikon D-1x camera.

is approximately a four stop loss of illumination through this attachment. For most angiographic photography, this will cause no problem (Figure 15). The Nikon Capture program allows you to reset the ISO of the Nikon D-1 digital camera to "Push" the highest ISO by several f-stops if you wish.

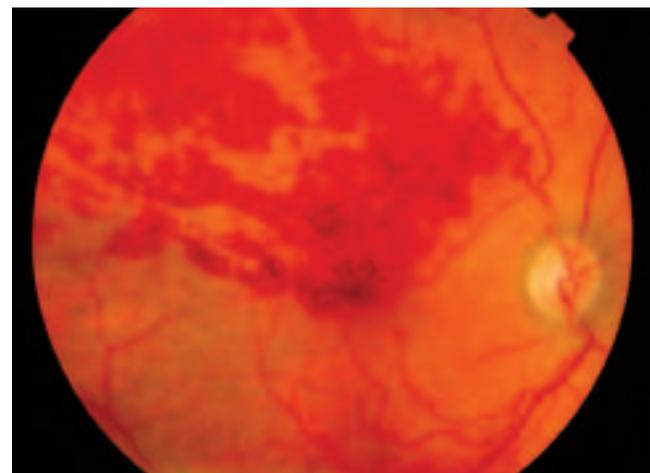


Figure 15: Topcon fundus image 50 degree.

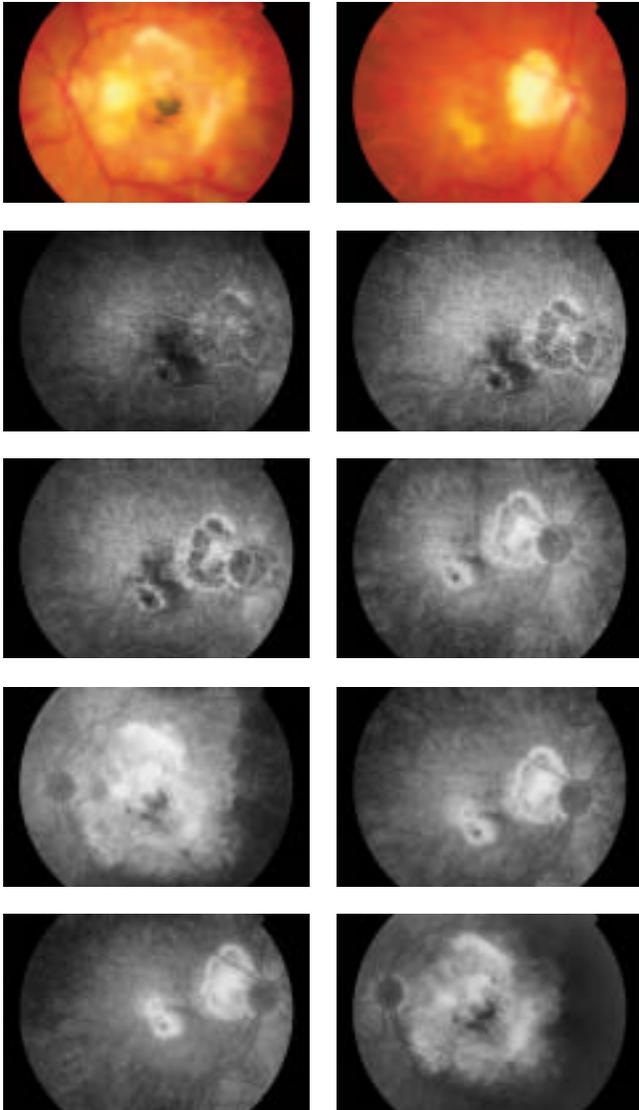


Figure 16: Angiogram on Topcon 50EX fundus camera.

TOPCON EYEPIECE CORRECTION

The Topcon TL 207 1x Relay Lens has a method of adjusting the digital image to make it parfocal with the reticule in the Topcon eyepiece. Due to the additional depth of the digital camera body (0.25 inch), at the full limit of this adjustment we could get close to a parfocal setting, but was still +0.25 diopter off the factory set eyepiece reticule image for the lower Topcon film recording back. Again, a dollar bill was used as a target and followed the same procedures used for the Zeiss fundus camera to obtain the sharpest digital image. This "personal digital correction" was marked on the eyepiece for future reference.

USE OF TOPCON/NIKON D-1 DIGITAL SYSTEM

A laptop with the Firewire connection was used, as this allows the images to be seen as they are acquired. For color photography set the digital camera to "Manual", 1/50 second and ISO 200. For angiography use 1/40

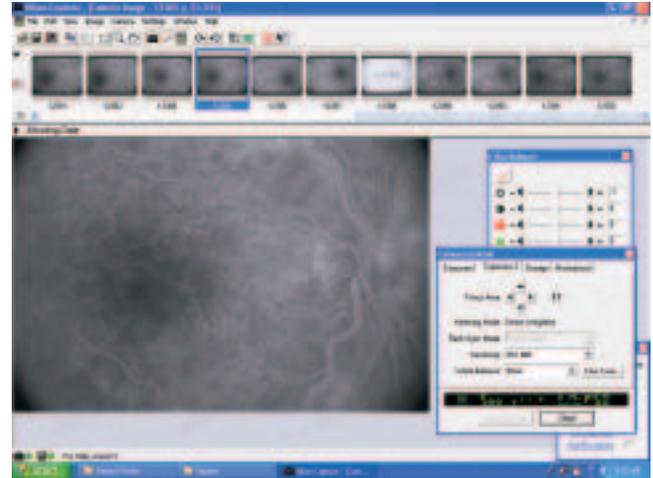


Figure 17: Nikon Capture showing angiogram and camera setting window.

second and ISO 800. Set the image storage quality at TIFF-RGB (8 bit) Medium (2000 x 1312). The JPEG "Good Balance" setting was used to save images. The resulting JPEG files are about 600K to 1,000K in size for each image. The Large image format (3008 x 1960) may be used. This will increase the size of the saved JPEG image file. The slow digital camera shutter speed is required to allow the Topcon fundus camera internal operations to complete prior to flash triggering (Figure 16). Here too we continue to photograph the patient's name tag prior to all photography, and photograph a tag that says "LATES" prior to the late shots on the angiographic studies. The Topcon camera may remain in "AUTO" photography mode. Manual exposure adjustments are made using the flash intensity touchpads.

NIKON CAPTURE VERSION 2.0

You may only need the optional Nikon Capture program for PC or Mac applications for the majority of your fundus imaging (Figure 17). In this program you can change camera settings, contrast, color, rotation and image histogram. Then you can save captured images as a smaller JPEG image file or NEF (Nikon Electronic Format), BMP, or TIFF (RGB or CMYK) file formats. We use the "Good Balance" setting for saving images from the 7.5 MB NEF capture format to JPEG files of about 600K each. Use the Nikon Capture version 2.0 or greater program for best results. Version 2.0 allows you to rotate the first image into proper position. Subsequent images will be captured and will be in proper orientation. Version 1.0 does not allow for this important feature.

All images captured using the Nikon Capture program contain information about time, shutter speed, camera used, f-stop, lens and more. This information is found under the heading Shooting Data. Most of this information does not apply to an ophthalmic fundus application. Time that the image was acquired is useful to know for our angiographic studies. The displayed time

is from the internal clock on the Nikon D-1 camera and reads to one thousandths of a second. This timer function and shooting data information is lost from view when the NEF images are saved into another format such as TIFF or JPEG. Our retina physicians are divided on the real necessity of the timer function, but accept the timer loss when saving to files other than NEF as a minor inconvenience of using the system. The time that is then recognized by the computer is the time that the saved image was created in the new computer file.

BATTERY OR AC POWER?

The Nikon D-1 digital camera is battery powered. There is an AC power supply that is available as a replacement for the rechargeable battery. The connection for this AC power cord is on the left front of the Nikon D-1 camera. This location puts the AC power cord in a bind and makes it difficult to attach or remove the camera from the Zeiss dovetail mount. This difficulty is compounded when the user has to remove the camera frequently in order to insert or remove the barrier filter during the course of a busy day. For that reason, it is recommended to purchase an additional rechargeable battery when using the Nikon D-1 digital camera with a Zeiss fundus camera. Although the length of use for the rechargeable battery is a function of the number of exposures taken, it was found that a depleted battery is fully charged long before the replacement's charge is expended. The Topcon/Nikon D-1 digital camera configuration allows for ready use of the AC power supply. It is recommended to use the AC power supply with the Topcon fundus camera as the location of the digital camera power readout is difficult to view because it is so high above the floor.

VIEWING ONLY PROGRAMS

Nikon Capture has a small flaw when viewing images. If you take images of a patient, save the images to a format other than NEF, you cannot view the saved images with the Nikon Capture program. If you save images to a folder as NEF images, you can only view them one at a time. For these reasons, we use other programs to view and manipulate our images.

IVIEW32 (<http://irfranview.tuwien.ac.at/english.htm>) is a freeware program you can use to view the images and have a slideshow. It is simple and free.

VUEPRINT (www.hamrick.com) is an inexpensive shareware program that many of our physicians prefer to use for image viewing. It allows a large number of image adjustments, dual image viewing and image rotation that they find useful during laser treatment. The cost of this shareware program is about \$40.00USD. VuePrint is available in eleven different languages and will open AVI and MPEG files, as well.

Windows XP and Apple OS X are both suitable image handling operating platforms. No additional programs are needed for viewing and printing of your

angiograms. Windows XP does not allow image adjustments for brightness, contrast and rotation.

IMAGE FILING

Now that we had the images, we needed to determine a method to archive them. One system is to label each image by saving an identifying number or name in the file name. Nikon Capture can do this type of action to all saved images (Smith, John 2002-04-18 001.jpg). All of these "named" images are saved into a folder named with the patient's history number, year, month, date (1234567-2002-04-18). These patient visits (folders) are collected into a large folder (master patient photo file). If there are 1,000 folders, and six visits by John Smith, they will appear in the master folder as:

1234567-2001-04-10
1234567-2001-08-04
1234567-2001-11-21
1234567-2002-02-20
1234567-2002-04-11
1234567-2002-04-18

This makes it easy to find all the visits recorded on John Smith, history number 1234567.

A CD is also burned for each patient. This CD is pre-labeled with the department name, contact information and the words "Confidential Patient Data". The CD is then labeled with each visit date that data is added, patient name, history number, date created and attending physician (Figure 18) and placed into the patient's paper chart.

Backup CDs of patient photography are routinely taken off of all acquisition computers, these image files are then copied onto a central computer, and the transfer CDs are stored elsewhere.

This system is not restricted or private in nature, however, it works for many ophthalmic offices.



Figure 18: Custom CD label.

THIRD PARTY PROGRAMS

If you wish to have a capture system, viewing system, and archiving system all in one, you may want to consider a third party program to add to your home built system. There are several good programs available that can make your home built system look and act like one

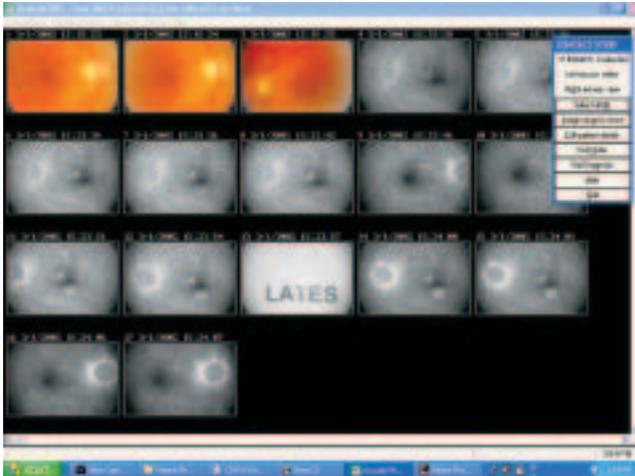


Figure 17: Nikon Capture showing angiogram and camera setting window.

of the large commercial systems on the market (Figure 19). We have only tried one of these “third party programs”, but have seen several. Digital Healthcare’s (www.digital-healthcare.com) Oculab Pro is the product tested at the time of this writing. It is an impressive program and the cost is reasonable. Features include the ability to retain a timer on the images, direct import of images into the program by using Nikon Capture as a “pass through” program, and the ability to import images from previous studies. The time the image was acquired is recorded as the image is captured. This timer addition is a great feature of the Oculab Pro program. Images that were captured earlier and imported into the program retain the time that the image was saved. In order to be accurate on the timing of angiograms, you must use the Oculab Pro program to capture the images.

Digital Healthcare’s Oculab Pro program can also make DICOM (Digital Imaging and Communications in Medicine) images and is HIPAA (Health Insurance Portability and Accountability Act) compliant. These are important future considerations for large institutions such as the University of Virginia Medical Center. The implementation of the EMR (Electronic Medical Record) in our hospital and others will reinforce the need to adhere to both DICOM and HIPAA standards in our future imaging.

DICOM AND HIPAA, IS IT YOUR PROBLEM?

We will only touch briefly on DICOM standards (<http://medical.nema.org>) and HIPAA compliance (www.aha.org/hipaa/hipaa_home.asp) since others are better informed on these topics. Although important considerations, they are beyond the scope of this article. For many ophthalmic photographers, it may never be an issue.

DICOM images are TIFF or JPEG images that are encoded with fields of data such as patient last name, first name, history number, date of birth, date of visit, diagnosis and more. They are tied to a database so that

when you search for images for Smith, John history number 1234567, you will be shown only the visits and images for Mr. John Smith #1234567.

HIPAA compliance is a security and confidentiality issue involving the transfer of patient medical record information. Only authorized users are allowed access to patient records and images. Breaches in confidentiality of the electronic medical record will need to be identified through logon and other electronic means. HIPAA mandates that hospitals have a plan in place by October 16, 2003 to determine Who, When, and from Where a patient’s file was accessed, for How Long and What was viewed in the record. This plan is easier to implement with paper charts than with images in the electronic medical record. These issues only apply to hospitals and large practices in the United States of America.

Neither of these issues is currently of concern to the average solo practice or small group practice.

CONCLUSIONS

This home built digital system for the Zeiss FF-3, FF-4 or Topcon 50EX fundus cameras is easy to construct and operate by the average ophthalmic photographer while offering a 90% savings over film based system processing/supply cost per patient. Image quality is acceptable for patient diagnosis and treatment. The time interval from completion of imaging to presenting viewable images to the requesting physician is minimal. Photographer time required per patient remains about the same as with film based systems. Photo-finishing time per patient for this digital imaging system is greatly reduced over film systems. The greatest limitation of this system is the loss of a timer for angiographic studies when files are saved in a format other than the Nikon .NEF (Nikon Electronic Image Format) file format. This timer function is regained through the use of a third party application. DICOM imaging and HIPAA compliance can be added to this home built system through the addition of a low cost third party program if needed.

ACKNOWLEDGEMENTS

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