Fundus photography and fluorescein angiography

Photography of the external eye, photographic artifacts and the patient

Photography of anterior fundus lesions and the external eye

If the fundus lesion is located anterior to the retina (within the vitreous cavity), or if it is desired to take a picture of the external eye (Figure 19), insertion of a plus-diopter lens into the optical pathway will enable one to bring the object into focus. For this purpose, a selection of lenses of various diopter strengths is available on most fundus cameras. Often, in the case of anterior fundus lesions (Figure 20B), it is not possible to bring the entire object into focus because of the limited depth of field of the fundus camera. In these instances, the photographer must be fairly selective of the plane of focus. If fluorescein angiographic studies are to be performed on a lesion that protrudes out from the plane of the retina towards the camera lens (e.g., "sea-fan," neovascular networks, etc.) [Figure 20], the photographer must work closely with the physician to determine the optimum plane of focus.

To do external eye photography, the camera-to-subject distance must be increased and a plus-diopter lens utilized. Though reasonably good photographs can be obtained with a fundus camera, the photographs often will not demonstrate the pathology well, due to the axial illumination of the camera system. However, this method will at least provide a satisfactory record in the absence of a more suitable external eye camera. Some lens changes may be shown very effectively when the pupil is dilated and external eye photography is done. Have the patient look at the target light and position it so that the patient’s gaze places the optic

Figure 19—An external eye photograph made with the Zeiss fundus camera.
disc in a line directly behind the lens. The disc will then act as a reflector, which enhances the retroillumination of the lens (Figure 21).

**Stereo fundus photography**

Dr. W. Thoner, in 1909, was the first to describe and devise an apparatus designed specifically to do stereo fundus photography. His apparatus was based upon the principle of an indirect ophthalmoscope: The pupillary area is divided into right and left halves and the incident light beam is projected into one half of the pupil while the reflected rays emerge out of the other half of the eye. An ophthalmoscope lens forms the reflected rays into an inverted image which, is then photographed. After the first picture is taken, the entire apparatus is inverted so that the opposite halves of the pupil are used for the incident and reflected rays and a second picture is taken. This apparatus never became popular, since the technique was entirely too cumbersome to become widespread.

In 1927, Nordenson described a method for obtaining stereo fundus photos (Nordenson, 1927), and in 1930 he attempted to build a Zeiss-Nordenson stereo fundus camera. Due to technical difficulties, this apparatus was not very successful and did not go into production. Of a number of physicians claiming to produce stereo fundus photos, apparently only Metzger and Bedell had any reasonable degree of success (Metzger, 1927). Bedell included stereo photos in a paper published in the *New York State Journal of Medicine* in 1927. In this paper, Bedell proposed a lateral shift of the camera by 24 mm, and Mr. Lee Allen in his excellent paper also proposed this same technique of camera shift to obtain stereoscopic pictures by means of cornea-induced parallax (Allen, 1964). In 1953, Norton mounted a 35 mm stereo camera to a Bausch & Lomb binocular ophthalmoscope and made exposures with a xenon-arc lamp (Norton, 1953). In 1964, Dr. Donaldson described his new stereo fundus camera. In 1965, Lee Allen designed an accessory which could be adapted to the Zeiss fundus camera for obtaining stereo photographs. Put into production and currently marketed by the Zeiss Company, the Allen Stereo Separator (Figure 22) plays an important part in all stereo fundus photography done in America today.

Currently three methods of obtaining stereo fundus photographs are available. The Donaldson camera is the ideal method, since the apparatus is designed specifically for this purpose, and the two frames which make up the stereo pair are exposed simultaneously. The most important aspect of this latter feature is that once the photographer has mastered the use of the camera, the depth effect is absolutely reproducible. This gives scientific validity to comparative studies of changes that may take place in the shape and dimensions of fundus lesions over a period of time. Additionally, the use of this camera may yield satisfactory results on patients whose level of cooperation is not good enough for stereo photography requiring successive exposures to make up the pair.

The other two techniques for stereo fundus photography are based upon sequential photography and may be done with any conventional fundus camera. For this latter reason alone, these two techniques will probably remain as the method most commonly used in spite of the fact that the quality of stereoscopic effect may not be as dramatic and as consistent as that obtained with the Donaldson camera. Both of these techniques utilize a lateral shift of the camera’s optical axis to utilize cornea-induced parallax, and thus, to provide the required disparity between the two images for a stereoscopic effect (Figure 23). The only difference between these two techniques is the method employed in achieving this.
Figure 21—Satisfactory pictures of the eye lens may be obtained with the fundus camera. Utilizing external eye photography techniques with the camera, the retina is illuminated by the camera, and the lens can be photographed with retroillumination. Positioning the optic disc directly behind the lens yields better results (A) since the degree of retroillumination used was greater than what was used in B.

lateral shift; the two camera positions may be attained manually, or the shift may be achieved by use of the Allen Stereo Separator. Topcon offers an accessory, the Stereo Adaptor, as an aid in performing stereo fundus photography. Though this adaptor is similar to the Allen Stereo Separator in that it employs a movable glass plate which is positioned over the front lens of the fundus camera, the position of this lens is changed manually.

The Allen Stereo Separator is slipped over the barrel of the Zeiss fundus camera. It consists of a flat, plane-parallel, glass plate that is situated over the front lens of the fundus camera, and a solenoid with its motor, which is connected to the power generator. The glass plate may be activated either manually by a remote-control hand switch or electronically by means of the solenoid through the power generator.

First, position the glass plate into the left-hand position, align the camera and focus the image. Now, with the remote-control hand switch, move the plate into the right-hand position and observe the illumination. By repeatedly moving the glass plate and making fine adjustments with the joystick, determine the joystick position that will yield a well-illuminated field in both left- and right-hand positions. When this is observed, make two exposures in rapid succession.

If the repeated movements of the glass plate with the hand control do not permit both the left and right fields to be well-illuminated, the distance of traverse of the plate must be decreased, since it is

Figure 22—The Allen Stereo Separator is mounted over the front barrel of the Zeiss camera and is powered by the power generator. The Separator consists of a movable glass plate (A) which is activated by the Solenoid motor (B) after each flash. The two positions of the glass plate provide the image disparity needed for the stereo effect.

Figure 23—Stereo photography may be done manually by first positioning the camera centrally (B); next, tilt the joystick to the left until the illumination is entering the dilated pupil at the nine o'clock position (A). This position will yield the left frame of the stereo pair. After the first picture has been made, repeat the procedure for the right frame by tilting the joystick to the right so that the camera illumination is entering the pupil at the three o'clock position (C).
obvious that when the illumination is good for one field and is poor for the second field, the light beam in that second position is no longer passing through the dilated pupil. (It is not unusual, however, for one of the fields to be more dimly illuminated than the other.) Decreasing the distance between the two positions of the camera’s optical axis on the cornea (referred to as the “stereo-base”) diminishes the stereoscopic effect. In other words, the greater the stereo-base, the more dramatic the stereoscopic effect. Too great a stereo-base will result in a hyperstereoscopic effect, and too small a stereo-base will cause too shallow a depth effect. This stereo-base may be adjusted according to the degree of dilatation of the pupil. For good stereoscopic effect, the pupil should be well-dilated.

Stereo pairs may also be obtained manually, utilizing cornea-induced parallax by manipulating the joystick to obtain the left- and right-hand frames. Position the camera in the same manner as for single-frame photography, with the light beam entering the eye centrally through the dilated pupil. Focus the image. To obtain the first (left-hand) frame, tilt the joystick to the left so that the camera illumination is now at the left margin of the dilated pupil. In doing so, you will see in the eyepiece the familiar orange crescent as the leading edges of the incident beam strike the iris. Under ordinary circumstances, the photographer would move the camera back to the right in order to eliminate that artifact, but for this procedure, continue further left. As this is being done, you will see the orange crescent move away from the left margin of the eyepiece and begin to progress across the field of view. At some point near the center of the field, this catoptric, or reflected, image fades and disappears, restoring a full view of the fundus. To obtain optimum camera position, pull the joystick back slightly away from the patient. Recheck the focus in combination with the astigmatic correction control. Note the composition of the field in order to be able to duplicate it in the event the patient moves after the first flash. Make the exposure. Repeat the procedure for the right-hand frame, being certain that the camera does not swing on its axis. For good stereo effect, the camera axes for both pictures must be parallel.

The procedure for stereo photography of the peripheral quadrants is slightly different in that the pupillary area be-

![Figure 24—Procedural Artifacts. A—incident light beam striking the margin of the iris. B—Camera-to-subject distance too short. C—The correct camera-to-subject distance. 0—Camera-to-subject distance too great. Note the loss of fine details as compared to photo C. E—Intrusion of lashes into the light beam. F—Smudge on the front lens of the fundus camera.](image)
comes elliptic, as was previously discussed. The camera displacement used to provide the disparity required between the two images should not be a horizontal one, but rather, a displacement along the longest axis of the ellipse. Critical focus as well as astigmatic correction are very important factors in these procedures.

Artifacts in fundus photography

Because the design of the fundus camera requires a specific working distance to the cornea (Topton = 45 mm, Zeiss = 50 mm), and because the illuminating beam must pass into the eye undisturbed by lids, lashes or iris, any deviation away from these conditions introduces artifacts into the pictures. Additionally, certain equipment malfunctions and alterations found in the optical system may cause photographic artifacts. These artifacts may be divided into three main categories; procedural, optical and mechanical or electrical.

Procedural artifacts

Procedural artifacts are probably the most common artifacts encountered in fundus photography (Figure 24). Generally, they are the result of faulty procedure, e.g., incorrect camera-to-subject distance, or incorrect alignment of the camera to the eye. If the incident light beam is interrupted by the iris margin, a bright orange crescent appears at the margin of the eyepiece and will appear in the resultant picture. This catoptric image may be eliminated by moving the joystick in the opposite direction. If the light beam is interrupted by lids or lashes, an irregular hazy veil will be present over parts of the picture. The solution is to retract the lids and lashes for photography as shown in Figure 23. If the camera-to-subject distance is altered from its critical point and the distance is too short, a whitish-blue highlight will appear; if the distance is too great, a bluish-gray haze will appear over the picture. This latter condition is usually proportional to the degree of alteration in the camera-to-subject distance, and the haze is densest at the picture margin. When the change in distance is very slight, the artifact consists of a blue-gray halo, which is present only at the picture margins. As the distance increases, this haze begins to encroach further into the picture area.
Until, finally, the entire picture area is covered by this haze. Although the image of the fundus may be seen, fine details are obscured. Artifacts resulting from too great a camera-to-subject distance are probably the most common to appear on fundus photographs, especially for the beginner, since the condition is most difficult for the inexperienced photographer to recognize prior to making the exposure.

According to Lee Allen, the appearance of catoptric images and haze is due to the fact that the central lens cortex, posterior lens capsule and anterior vitreous are being illuminated directly in the path of the emerging image of the fundus. In the early Zeiss cameras as well as in the Top con cameras, the range of motion of the camera is fairly limited between the point where a catoptric image appears when the distance is too short and the point where haze is seen when the distance is too great. This range of motion, referred to by Allen as the "free zone," is related to the optics of the patient’s eye as well as to the quality of the intraocular media. The incident beam, consisting of a ring of light surrounding a nonilluminated (shadow) area, passes through the lens at the level of the pupil. Allen describes the "shadow" area as a cone-shaped shadow created by the small black dot etched into one of the condensing lenses of the fundus camera. The reflected rays that form the image occupy an area 2.0 mm in diameter in the central portion of this shadow area at the plane of the pupil, and the haze occurs as a result of dispersion of light off the lens and vitreous surfaces. Lee Allen extended the free region considerably by installing an additional black dot into the optical pathway of the Zeiss fundus camera to mask out a little more of the illuminating beam. This was done by cutting out a circular mask from heavy black paper and installing it in the No. 7 aperture of the recess-disc with thread (Allen, 1964). This mask was later produced by Zeiss, and the ‘Allen Dot’ may now be purchased from Zeiss and installed in any of their cameras. The purpose of the Allen Dot is to lengthen the shadow back through the lens and into the vitreous to prevent illumination of their surfaces (Figure 25).

Since the Allen Dot has extended the range of the "free zone" of the Zeiss camera, it also makes very slight alterations from critical camera position more difficult to recognize in the camera eye-piece. The only way for the photographer to be certain of having optimum camera distance, therefore, is to manipulate the joystick back and forth until the deepest tone of color is seen.

**Optical artifacts**

Dust or finger marks on the front lens will show up on the photograph as bright, diffuse areas. Often, if a patient is blinking and tearing due to sensitivity to the camera light, a tear may actually be thrown off the lashes and onto the fundus camera lens. These foreign particles must, of course, be removed.

The appearance of a half-moon crescent in the center of a picture area (Figure 26A) may be due to misalignment of one of the rear elements in the fundus camera, or in the case of a Zeiss camera, perhaps due to misalignment of the eyepiece mirror. In these cases, an equipment company representative should be called in to make the appropriate correction.

**Mechanical or electrical artifacts**

The (mechanical) mirror cut-off of part of the picture image due to a shift in the position of the white plastic plugs on the arm of the Zeiss camera eyepiece has been discussed in a previous section (Figure 26B). This same artifact may occur with the Zeiss electronically-activated eyepiece, in which a solenoid, activated by means of a remote control foot switch, moves the mirror out of the optical pathway for each exposure. This eyepiece assembly may be found on the Zeiss fundus flash camera. If the image is cut-off by the mirror when the solenoid eyepiece assembly is used, the cut-off may be the result of a premature release of the foot switch. The depression of the foot switch has initiated the series of actions required for exposure, i.e., the eyepiece mirror has been removed from the optical pathway and the shutter of the 35 mm camera body is moving across the film plane. If the foot switch has been released before the shutter completes its traverse of the film plane and the electronic flash is triggered, the relay connection to the eyepiece mirror is broken and the mirror is released to begin its way back into the viewing position. It is at this point in time that the electronic flash is triggered to make the exposure. Thus, if the eyepiece mirror has...
Figure 26—Optical and electrical and mechanical artifacts: A—An artifact caused by misalignment of the camera optics. B—Mirror out-of-the image.

The role played by the patient in fundus photography is a vital one in the determination of the outcome of the photographic session. Since the optics of the subject eye is an integral part of the overall optical system, any severe changes in its transparent quality will prevent obtaining satisfactory results. Additionally, the capability of the patient to cooperate fully and to follow instructions well is a very important factor for the photographer to consider, especially in angiography. Prior to the widespread use of angiography, many patients who might have been photographed were not, simply because they displayed some bit of photophobia or were physically uncomfortable. Single-frame color fundus photography could still be effectively carried out on these patients if the photographer was determined and persistent enough. The ophthalmic photographer today, however, sees a much broader spectrum of patients for fluorescein angiography than before, patients who are probably more severely incapacitated and for whom good retinal circulation studies may be of tantamount importance in their clinical management.

The ability of the photographer to establish a good working rapport with the patient is probably equally important to good camera technique. Often, the eye patient arriving in our laboratory for angiography is not only undergoing great stress related to his eye problem, but may also be laboring under misunderstandings of the angiographic procedure. The photographer should strive to put the patient at ease insofar as the angiography is concerned, before proceeding with the technical work. Often, the patient’s physician has only asked that he report to the laboratory for a “test” or for “an angiogram,” without further explanation. Upon being oriented by photo personnel, these patients expressed great relief upon learning that the dye to be injected is to be injected into the arm, rather than directly into the eye. Conversely, some are equally surprised to learn that they are to receive an injection at all. Since these misunderstandings occur with such frequency, I feel that the photographer should, if he is in a position to do so, request that the doctor or his office staff prepare the patient by explaining exactly how this clinical test is to be performed. In any event, I recommend that the photographer take
a brief moment to orient the patient fully before proceeding.

The patient of normal size and configuration who is ambulatory does not present a problem in being able to achieve a proper position at the camera, but some patients who fall outside of this category should be given some consideration. When a patient is transported to the laboratory from his or her hospital room in a wheelchair and does not have the capability to sit for a long enough time in the regular chair used for angiography, a great deal of manipulation may be necessary to position him properly.

Those wheelchairs on which the legrests are adjustable to a horizontal position are more suited to this purpose than those with fixed legrests. When working with a Zeiss camera, raise the legrests so that they clear the legs of the camera table, and push the chair directly up against the table. Lower the table so that the patient can reach the chinrest. Because the patient will be seated at the edge of the wheelchair, the brakes should be applied to prevent the chair from rolling. Pillows or blankets stuffed behind the patient will give more stability during the photographic session. If the patient is small and cannot reach the chinrest, a means of elevating him must be devised. The degree of success in these situations will be dependent upon the photographer’s ingenuity, as well as his ability at patient management. The presence of an assistant will be required at all times during these sessions to insure the safety of the patient.

The obese patient or the buxom, short-necked female patient will often find it difficult to reach the chinrest of the camera. In these cases, raise the patient’s chair higher than usual, lower the camera and ask the patient to back the chair off slightly away from the camera. This forces the patient to lean forward into the head and chinrest assembly, rather than approaching the camera in an upright position. Frequent reminders to maintain contact in the chinrest may be necessary.

Children should be given more time and effort in order to elicit the greatest amount of cooperation and to make the photographic session less traumatic for them. Positioning may be a bit difficult; two methods of approach may be used. If the child is big enough, use an adjustable stool raised to its maximum height, and lower the fundus camera down. Have the child assume a seated position with the legs spread apart and push the stool directly up against the table. This ought to help the child reach the chinrest (A). An alternative (B) is to have the child stand on a step stool. In both cases, the photographer must spend time with the patient to elicit good cooperation.
to permit the child to reach the chinrest in the proper way. If the child is not quite big enough to sit at the camera, have him stand in place on a small footstool for the photography (Figure 27).

Fundus photography is usually performed with the patient maintaining a steady gaze by looking in the direction indicated by the photographer. In most cases, a small fixation target light is placed before the patient to help steady the gaze. A problem may be encountered if the central visual acuity of the fellow eye is not good enough to see the target light, or to maintain a steady gaze at it. This capability must be determined at an early time, in order for the photographer and patient to work well together. In fact, our laboratory policy is that no patient may have photography performed unless the visual acuity has been measured immediately prior to such work. If the central visual acuity is found to be good, any difficulty encountered therefore, may arise as a result of confusion on the part of the patient regarding the role that he must play, or may be simply due to overconvergence, as was previously discussed.

If the patient has poor visual acuity in the fellow eye, which precludes the use of an external target, the Zeiss camera, as well as the latest model Topcon camera, is equipped with a built-in fixation device which may be used to position the eye for photography. If a built-in fixation device is not available, the photographer will have to seek other ways to achieve proper positioning of the eye. The following are some of the methods that I have used and found successful. The technique chosen must be determined by each individual case.

1) Ask the patient to look straight ahead. Manipulate the camera position to locate the area of interest. If this fails, it is because the movement of the camera distracted the patient, causing the gaze to shift to the camera light.

2) Ask the patient to pretend to look at a clock, and indicate the numeral that he should gaze at, e.g., "3 o'clock," etc. This may be a difficult concept for the patient to follow, as he may not visualize the correct "size" clock, and the gaze may swing too far peripherally.

3) The patient may be able to see a bright penlight that an assistant can hold.

4) For many very far peripheral fields, work out a system with the patient in which he fixes at some point on the wall or ceiling which will bring the area of interest into view. Mark that spot with a large "X" made with black photographic masking tape. These marks can be left on the laboratory walls for many months, knowing that the patient will he returning at regular intervals for fundus photographs. These cases do require some ambient room illumination in order for the patient to be able to see the mark.

5) Another technique is to hold one of the patient's hands, and ask him to fix his gaze at one of his fingertips. Manipulate the position of his hand while looking through the eyepiece until the area of interest can be seen. Upon locating the field, ask the patient to hold that gaze while dropping the hand. Often, these procedures must be repeated before any photography takes place, since many patients will inadvertently follow their hand back to the table. Only when the patient fully understands will he maintain the direction of gaze as the hand is dropped. With a small number of patients, it will be necessary to continue holding the hand in position during photography. In these cases, an assistant will be required to help with lid retraction and patient management.

6) Fundus photography on a patient with nystagmus is, at best, unpredictable and difficult. Nystagmus is an involuntary constant movement of the eyeballs. Most often, the movement is lateral, but sometimes the movement is in a vertical plane, and in rare instances, even in a circular pattern. With patience, it is possible to obtain fairly satisfactory fundus photographs of these patients by positioning the camera in such a fashion that a fundus view may be obtained and a focus achieved. Then attempt to make the exposures when the fundus passes across the camera's field of view.