STUDIES IN PHOTOCOAGULATION

II. THE OBSERVATION SYSTEM*†

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THE photocoagulating beam was studied in the first article of this series. This second article is devoted to the observation system, the essential requirement of which is proper illumination of the fundus. Taking into account that the coagulating beam is already directed towards the patient's eye, it seems obvious that it should also be used for illuminating the fundus. In fact, this has been the system of fundus illumination in all photocoagulators described so far. It should be remembered, however, that an attenuating diaphragm is located on the path of the coagulating beam. It serves to limit the light intensity admitted into the eye below the threshold of coagulation. The attenuated beam is composed of parallel rays focused by the optics of the eye into a small image on the retina. This image is the target at which the coagulating beam is aimed.

Such a system leaves only a little scattered light for illumination of the fundus around the small retinal image of the source. It follows that the observer is obliged to look for the area to be coagulated in the fundus much as if looking for an object in the dark sky with a searchlight. Another possibility is for the observer to look into the fundus with an ophthalmoscope and to memorize the configuration of the fundus. This facilitates the pointing of the coagulating beam in the desired direction, but the technique is tiring and time-consuming, as it often requires repeated switches from a regular ophthalmoscope to the photocoagulator, and *vice versa*. The ideal observation system in the photocoagulator is that which would give a stereoscopic view of the fundus with a wide field.

The conditions to be fulfilled in order to permit such a performance will now be investigated. Since it is impractical to use the coagulating beam for fundus illumination, a second beam, suitably shaped, must be introduced into the patient's eye, for illumination purposes. Instead of being collimated, it must be focused in the pupillary plane of the patient's eye. The illumination of the fundus must cover the area located around the image created by the attenuated coagulating beam. Consequently, the axis of the illuminating beam must coincide with the axis of the coagulating beam, at least at their entrance into the patient's eye.

One solution consists in locating the source of the illuminating beam at a calculated distance behind the source of the coagulating beam. In this case, the two beams will reach the pupil of the patient's eye through the optical system of the coagulating beam. For this purpose, the illuminating source may be formed by a concave

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mirror suitably placed behind the coagulating source. The image of the coagulating source created by the concave mirror is then used as a light source for fundus illumination. This extremely simple solution was utilized in the first pilot model of the photocoagulator constructed at the Retina Foundation (Fig. 1). However, the diaphragm, which controls the image size of the coagulating source in front of the objective, cuts out most of the illuminating beam, because the latter is not focused in the same place as the coagulating beam. In consequence, the area of the fundus illuminated by this method is extremely small (Fig. 1). It is, therefore, necessary to introduce the illuminating beam into the path of the coagulating beam after the latter has passed through the diaphragm and the objective.

FIG. 1.—Diagram of inadequate illumination of the patient's fundus by a secondary source obtained from the coagulating source.

This secondary source is produced by a spherical mirror, which is placed behind the coagulating source. The latter is first imaged by the condenser in the diaphragm. It is then imaged again by the objective and the patient's refractive media on the patient's retina. The secondary source used for fundus illumination is first imaged between the condenser and the diaphragm, then most of the illuminating beam is cut out by the diaphragm. Finally, it is imaged again in the patient's pupil, and it illuminates a small area of the patient's fundus. This illuminated area is an image of the diaphragm.

After the exit from the objective, the coagulating beam is deflected towards the patient's eye by a mirror (M1) at 45° on the axis of the beam (Fig. 2, overleaf). Another mirror (M2) is placed at right-angles to mirror (M1). It has an adequate uncoated aperture in the centre, permitting the passage of the coagulating beam. Mirror (M2) is used for two purposes: to couple the illuminating beam with the coagulating beam, and to reflect the image of the fundus toward the observer. As it is more convenient to observe the fundus from above during photocoagulation, another mirror (M3) is placed parallel to (M2). This third mirror reflects the observation and the illumination axes upward.

An indirect stereoscopic ophthalmoscope with its own illuminating system may now be used for observation. At present the ophthalmoscopic lens is placed between mirrors (M2) and (M3). Such a device has been tried and it performed as expected, giving a stereoscopic view of a wide and well-illuminated area of the patient's fundus. The target for photocoagulation is in the centre of this illuminated field. It is marked by a small bright spot of light created by the attenuated coagulating beam.

FIG. 2.—Diagram of adequate system for fundus illumination by a separate light source obtained from an ordinary indirect stereoscopic ophthalmoscope.

The coagulating beam is deflected by M1 into the patient's eye. During coagulation the perforated sliding mirror is moved aside to let the beam through the uncoated area of M2. At all other times the sliding mirror is in place, and the coagulating beam forms a target spot on the fundus through perforations in the sliding mirror. The ophthalmoscope light is reflected by M3 and M2 into the patient's eye. A bifocal ophthalmoscopic lens permits the observer to see a well-illuminated fundus image framed by the image of the patient's iris and limbus. This gives visual control of the centring of the coagulating beam in the patient's pupil.

There are, however, several problems still to be solved:

(1) Since the mirror (M2) is provided with an uncoated central area to permit the passage of the coagulating beam, this transparent area is a poor reflector for the corresponding portion of the fundus image, which is in the centre of the ophthalmoscopic field. This is where the coagulation is to be produced, and is therefore of the utmost importance to the observer. It was thus found necessary to cover the uncoated area of mirror (M1) with a small sliding mirror. During observation, the sliding mirror covers the central uncoated area of (M1). In so doing, the coagulating beam is completely cut off and there is no target indication in the patient's fundus. To provide a target mark, it was found sufficient to drill several holes in the small sliding mirror. These holes admit a certain number of rays of the coagulating beam into the patient's fundus. Being parallel, these rays are focused

in a single spot on the retina, provided the patient's eye is emmetropic. This spot is brighter than the remainder of the illuminated field because of the greater brightness of the coagulating beam. If there are multiple bright spots in the fundus instead of one bright spot, it means that the patient's fundus is ametropic in the area examined. Correction of the ametropia will cause the multiple spots to fuse into one. The displacement of the sliding mirror is controlled by a push button (p) located on the side of the end-piece of the photocoagulator (Fig. 3).

FIG. 3.—End-piece constructed for indirect stereoscopic viewing of the patient's fundus before and during photocoagulation. (P) is the button controlling the sliding mirror (Fig. 2) and the diaphragm which attenuates the coagulating beam. This end-piece can replace the existing end-piece of the Zeiss photocoagulator.

(2) The second unsolved problem is related to observation with photocoagulators in general. It is essential that the collimated coagulating beam emerging from the instrument, should enter, as completely as possible, into the patient's pupil. This means that the centre of the pupil and the centre of the coagulating beam should coincide. When looking through the ophthalmoscope at the fundus image, the observer does not see the anterior segment of the patient's eye. Therefore, the observer cannot be sure that, at the time of coagulation, the coagulating beam is concentric with the patient's pupil. The reason for this uncertainty is as follows:

The ophthalmoscope forms an image of the observer's pupil in the pupil of the patient's eye. This image is the entrance pupil of the ophthalmoscopic system, and it is small compared to the patient's dilated pupil. As long as the small entrance pupil remains in the patient's dilated pupil, the observer sees the image of the fundus. Therefore, a small displacement of the entrance pupil inside the patient's pupil does not decrease the field of view in the fundus, but simply displaces it. The diameter of the coagulating beam is, on the other hand, at least equal to the diameter of the patient's dilated pupil. Therefore, it must be concentric with it. The only way for the observer to be certain of this is for him

to see the outside of the patient's eye simultaneously with the image of the fundus. This can be achieved if the ophthalmoscope lens is bifocal. The focus of the large central portion of the lens must be calculated for producing the image of the fundus. The small peripheral annular portion of the lens has a focus which forms an image of the patient's anterior segment. The image of the anterior segment must, of course, be in the same plane as the image of the fundus (Fig. 2). Thus, the image of the fundus appears framed by the patient's iris and limbus, and the centring of the coagulating beam can be checked and adjusted under visual control without losing track of the fundus image.

The Zeiss photocoagulator can be adapted to use the observation device described above. For this purpose, it is sufficient to replace the existing end-piece of the instrument by the end-piece represented in Fig. 3. The observer should then use an indirect ophthalmoscope for fundus illumination and for stereoscopic viewing of the fundus.

Summary

The problem of fundus observation during photocoagulation is examined. A concave mirror placed behind the coagulating source cannot be used for adequate illumination of the fundus. A separate source must be used.

A system is described in which the light source of an ordinary indirect stereoscopic ophthalmoscope is used for fundus illumination before and during photocoagulation. The location of the coagulating beam at its entrance into the patient's eye is visually determined through a bifocal ophthalmoscopic lens. Its location and focusing in the fundus is determined by a bright target spot. This apparatus is adaptable to a Zeiss photocoagulator.